



HAL
open science

From scientific information on climate change to economic analysis for adaptation of infrastructure: the case study of SNCF

Vivian Dépoues

► **To cite this version:**

Vivian Dépoues. From scientific information on climate change to economic analysis for adaptation of infrastructure: the case study of SNCF. Economics and Finance. Université Paris Saclay (COMUE), 2019. English. NNT: 2019SACLV015 . tel-02083989

HAL Id: tel-02083989

<https://theses.hal.science/tel-02083989v1>

Submitted on 29 Mar 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

From scientific information on climate change to economic analysis for adaptation of infrastructure: the case study of SNCF

Thèse de doctorat de l'Université Paris-Saclay
préparée à l'Université de Versailles Saint-Quentin-en-Yvelines

École doctorale n°578 Sciences de l'Homme et de la Société ED SHS
Spécialité de doctorat : Sciences économiques

Thèse présentée et soutenue à GUYANCOURT, le 05 Février 2019, par

Vivian Dépoues

Composition du Jury :

| | |
|---|-----------------------|
| Ángel Aparicio Professor, Universidad Politécnica de Madrid (Escuela T.S) | Président du jury |
| Anders Blok Associate Professor, University of Copenhagen (Sociologisk Institut) | Rapporteur |
| Arnaud Diemer Maître de Conférences (HDR), Université Clermont Auvergne (CERDI) | Rapporteur |
| Franck Lecocq Professeur, AgroParistech (CIRED) | Examineur |
| Jean-Paul Vanderlinden Professeur, Université Versailles-Saint-Quentin (CEARC), | Co-Directeur de thèse |
| Tommaso Venturini Advance research fellow, ENS Lyon (INRIA/lxxi) | Co-Directeur de thèse |
| Aude Bodiguel Economiste, ADEME | Invitée |
| Benoît Leguet Economiste, Directeur Général, I4CE | Invité |

This thesis describes and analyzes *in situ* how a big company deals with the scientific knowledge on the impacts of climate change. It is the outcome of a joint project between CEARC (laboratory of the University Paris Saclay), I4CE (the Institute for Climate Economics), ADEME (the French environment and energy agency) and SNCF, France's national state-owned railway company. It intends to improve our understanding of how large organizations adapt to multifaceted changes and address wicked environmental problems.

Table of contents

- TABLE OF CONTENTS..... 1**
- RESUME (EN FRANÇAIS) 6**
- LIST OF ACRONYMS..... 8**
- LIST OF FIGURES..... 10**
- LIST OF TABLES..... 11**
- LIST OF BOXES..... 12**
- INTRODUCTION..... 13**
 - I. What is this dissertation about? 13
 - 1. Research objectives 13
 - 2. Initial questioning 15
 - 3. An interdisciplinary qualitative approach 19
 - 4. Our main arguments..... 19
 - II. How to read this manuscript? 20
- CHAPTER 1 - AN EMBEDDED INDUCTIVE RESEARCH-PROCESS..... 24**
 - I. Studying the interaction between climate knowledge and adaptation 24
 - 1. The perspective of science and technology studies 25
 - 2. Methodological choices: an empirical and inductive research 29
 - 3. Reflexivity 36

| | |
|---|-----------|
| II. Research process..... | 37 |
| 1. A “embedded research” setting | 37 |
| 2. Research protocol..... | 41 |
| Conclusion of the chapter: Benefits and limitations of the approach | 45 |
| CHAPTER 2 - FROM SCIENTIFIC KNOWLEDGE ON CLIMATE CHANGE TO ADAPTATION OF RAILWAYS. STATE OF THE ART..... | 49 |
| I. A knowledge base rooted in climate-sciences: strong evidence of a complex phenomenon | 49 |
| 1. A major certainty: we are exiting a window of very stable conditions | 49 |
| 2. Some essential characteristics of climate change | 51 |
| II. from science to decision: a problematic interface..... | 57 |
| 1. A science made to be “policy-relevant” for adaptation | 57 |
| 2. A post normal framework for wicked situations | 59 |
| III. Adaptation of infrastructures to climate change: where are we? focus on transport and railways..... | 64 |
| 1. Active research communities on transports adaptation and resilience | 64 |
| 2. Interaction with institutional and private dynamics | 68 |
| 3. Discussion and take-home messages: emerging and incomplete processes..... | 74 |
| Conclusion of the chapter: an ambiguous representation of the adaptation challenge..... | 75 |
| CHAPTER 3 - STUDYING SNCF CORPORATE ADAPTATION..... | 80 |
| I. Presenting SNCF | 80 |
| 1. Profile and ongoing changes | 80 |
| 2. SNCF as a case study..... | 87 |
| II. History of adaptation at SNCF: the D-RAIL project in 2011 | 88 |
| 1. Objectives and process of a first attempt to address adaptation in the company... .. | 88 |
| 2. Projects’ outcomes and persistence..... | 93 |

| | | |
|---|--|------------|
| III. | Ongoing adaptation initiatives: Adaptation as a corporate policy..... | 95 |
| 1. | Building a corporate response to external expectations | 96 |
| 2. | Towards a “pragmatic” corporate position | 99 |
| IV. | Ongoing adaptation initiatives: Internal initiatives for resilience | 105 |
| 1. | Improving the understanding of the relationship between the weather and railway: a first step towards adaptation? | 105 |
| 2. | An incomplete intersement process | 109 |
| | Conclusion of the chapter: a true concern, not a strategic priority | 111 |
| CHAPTER 4 - OPERATING THE RAILWAY SYSTEM IN A MEDITERRANEAN CLIMATE | | 114 |
| I. | Introducing the case-study..... | 114 |
| 1. | Location and context | 114 |
| 2. | Conducting interviews | 117 |
| II. | Lifecycle of a railway-section: where and when does the climate issue appear? | 118 |
| 1. | Long-term projects: example of a new high-speed line, Montpellier-Perpignan ... | 118 |
| 2. | Daily traffic operations and resilience | 127 |
| III. | Analysis and discussion: limited performativity of scientific discourse on climate change..... | 130 |
| 1. | How does SNCF deal with changes in climate? | 130 |
| 2. | Unasked questions..... | 131 |
| 3. | Climate change as one trend among others | 133 |
| | Conclusion of the chapter and first sequences of the study: adaptation as it is pragmatically done for now and condition to move beyond incremental optimisation..... | 139 |
| CHAPTER 5 - AN EXPERIMENTAL WORKSHOP TO QUESTION THE IMPLICATIONS OF AN INCREASE IN EXTREME WEATHER EVENTS FREQUENCY | | 143 |
| I. | Designing an exploratory workshop for creating deliberation spaces and move adaptation forward..... | 143 |
| 1. | Workshops’ objective and methods | 144 |

| | | |
|------|--|------------|
| 2. | An protocol to focus on variability and extremes despite uncertainties | 146 |
| II. | Discussion outcomes: questioning the status-quo | 148 |
| 1. | Questions raised by the focus on an increased climate variability, seasonal variation and extremes | 148 |
| 2. | Discussing roles distribution, responsibility and governance | 151 |
| 3. | A variety of potential adaptation postures | 156 |
| | Conclusion of the chapter: a successful workshop giving flesh to broader questions | 158 |
| | CHAPTER 6 - ECONOMICS FOR ADAPTATION AS A STRATEGIC INSIGHT | 162 |
| I. | Strategic foresight at sncf: where and when? | 162 |
| 1. | A short history of long term thinking in SNCF | 162 |
| 2. | Climate change: the issue of novelty and speed | 164 |
| II. | Sustainable development for adaptation: a twofold challenge..... | 166 |
| 1. | Picking up the interressement thread | 166 |
| 2. | Demonstrating how adaptation is contributing to current SNCF priorities | 167 |
| 3. | Formulating how and why adaptation is also a specific and challenging issue | 170 |
| III. | Economics to catalyse this process: how?..... | 172 |
| 1. | Economics at SNCF..... | 173 |
| 2. | Economics for adaptation..... | 175 |
| 3. | Conditions to make it happen not just about economics | 179 |
| | Conclusion of the chapter: it is possible to set up the right conditions to move further on adaptation and economics can help..... | 181 |
| | GENERAL CONCLUSION | 184 |
| | Economics is the answer but what is the question?..... | 184 |
| | Summary of the findings | 186 |
| | Outlooks and future researches | 190 |
| | What SNCF tells us about adaptation of infrastructure | 193 |

REFERENCES..... 196

AKNOWLEDGEMENTS - REMERCIEMENTS..... 236

APPENDICES..... 239

Résumé (en français)

Issue d'un partenariat entre des acteurs de l'adaptation au changement climatique (I4CE, ADEME, CEARC) et SNCF, cette thèse se propose de décrire et d'analyser *in situ* ce que cette organisation fait de la connaissance disponible sur les impacts du changement climatique et ce que cette connaissance lui fait. Elle cherche à contribuer à notre compréhension de la manière dont les grandes organisations se transforment face au changement global décrit et annoncé. La thèse s'articule en six chapitres dont trois ont donné lieu à des articles soumis à des revues à comité de lecture.

Le premier chapitre revient sur le montage du projet lui-même, la posture de recherche déployée et ses fondements théoriques (sociologie de la traduction, théorie ancrée) à partir desquels nous avons travaillé pendant trois ans. Il détaille notre intention initiale de tester l'apport de ce type d'approches pour fluidifier l'interface entre production scientifique sur les impacts et l'adaptation au changement climatique et les enjeux opérationnels d'un acteur socioéconomique comme SNCF. Cette posture vise à la fois à prendre pleinement en compte le monde des acteurs connectés entre eux et mobilisant une diversité de savoirs et à dialoguer avec les heuristiques d'adaptation, notamment économiques, proposées dans la littérature.

Le deuxième chapitre caractérise le décalage présent dans la littérature entre des connaissances sur le changement climatique potentiellement très impactantes pour les grands réseaux et la manière dont ces derniers s'adaptent. Il décrit une science pensée pour l'adaptation, la prise de décision, l'anticipation voire la transformation et une adaptation des infrastructures à peine émergente, plus volontiers réactive, progressive et incrémentale. Il interroge l'intérêt, la pertinence et les possibilités de réduire et dépasser ce décalage.

Le troisième chapitre introduit le cas de SNCF, à la fois très particulier et très parlant : SNCF est un acteur économique de plus en plus « comme les autres » et toujours spécifique, acteur de l'aménagement du territoire et reflet de la société française. Ce chapitre analyse les tentatives menées en interne pour permettre à l'organisation de se saisir explicitement de la question de l'adaptation. Il détaille la variété, les motivations et les limites des démarches institutionnelles et des initiatives d'experts tournées vers la résilience. Cette première analyse met en évidence une problématisation – au sens de la sociologie de la traduction – qui

demeure incomplète. Les porteurs de ces démarches ont des difficultés à intéresser et à démontrer le caractère stratégique du sujet pour l'entreprise. Celui-ci paraît trop éloigné des enjeux opérationnels.

C'est pourquoi, nous avons souhaité nous déplacer pour voir comment les acteurs plus en prise avec le terrain percevaient et décrivaient leurs relations au climat et à ses changements perçus ou anticipés. Cela a donné lieu à une étude de cas approfondie sur l'exploitation ferroviaire dans la région de Montpellier dont rend compte le quatrième chapitre. Ce chapitre présente ainsi comment, du temps long de la conception d'une LGV jusqu'à la gestion de la circulation au quotidien, le climat est un réel enjeu pour le ferroviaire qui s'adapte déjà. Bien réel pour les acteurs, le changement climatique est géré sur un mode réactif et incrémental – l'adaptation devant en permanence se négocier avec des héritages lourds et d'autres dynamiques d'évolution. Ces analyses nous ont permis de compléter un portrait de l'adaptation « telle qu'elle se fait » et telle qu'elle s'articule avec les dynamiques structurantes du système ferroviaire et notamment les efforts continus de rationalisation et d'optimisation.

Dans un cinquième chapitre nous partageons les résultats d'un *focus-group* organisé en octobre 2017 à Montpellier pour étudier les questions qui émergent lorsque l'on met l'accent sur des caractéristiques du changement climatique – les extrêmes et la variabilité – qui nous paraissaient moins bien discutées. On voit alors que le sujet a une réelle capacité à interroger les manières de faire, les doctrines et les choix stratégiques. Il pose cependant des questions de gouvernance qui débordent largement SNCF. Cette manière d'amener le sujet révèle la diversité des postures d'adaptation possibles qui peuvent s'avérer différentes d'une entité à l'autre, y compris au sein même du groupe SNCF.

Le chapitre conclusif s'efforce de récolter les fruits de cette approche. En quoi la description *in situ* permet de répondre à l'intention initiale de « mieux » faire prendre en compte la connaissance sur des évolutions futures dans les décisions présentes, de faire exister ce long-terme dans la stratégie d'une organisation. Il discute notamment de la complémentarité des manières de formuler les enjeux de l'adaptation pour ce type d'acteurs, en tenant compte de la diversité des modes de rationalités présentes. L'analyse économique y apparaît alors comme une forme parmi d'autres, intéressante à mobiliser avant tout comme une science de la gouvernance - pour déployer les conséquences possibles du changement climatique, explorer les pistes et ouvrir des espaces où penser l'adaptation.

List of acronyms

| | |
|-------------|--|
| 3D | Direction du Développement durable (SNCF sustainability department) |
| ADEME | Agence Nationale de l'Environnement et de Maîtrise de l'Energie (French environment & energy management agency) |
| ANT | Actor-network Theory |
| Arafer | Autorité de régulation des activités ferroviaires et routières (French rail and road regulatory body) |
| ARCC | Adaptation and Resilience in the Context of Change network (UK) |
| ARISCC | Adaptation of Railway Infrastructure to Climate Change (UIC) |
| CBA | Cost-Benefit Analysis |
| CEARC | Cultures, Environments, Arctic, Representations, Climate |
| CEN-CENELEC | European Committee for Standardization-European Committee for Electrotechnical Standardization |
| CEREMA | Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement |
| CMIP | Coupled model intercomparison project |
| DEDD | Direction de l'environnement et du développement durable (SNCF Réseau Sustainability department) |
| DEFRA | Department for Environment, Food & Rural Affairs (UK) |
| DMDU | Decision-making Under Deep Uncertainty |
| ECCA | European Climate Change Adaptation conference |
| EDF | Electricité de France (French national power utility) |
| EEA | European Environment Agency |
| EPIC | Etablissement public à caractère industriel et commercial (French public service companies with a commercial and industrial mission) |
| EU | European Union |
| FNAUT | Fédération nationale des associations d'usagers des transports (National Federation of Transport User Associations) |
| GHG | GreenHouse Gases |
| I&P | Ingénierie & Projets (SNCF Réseau engineering department) |
| I4CE | Institute For Climate Economics |
| IGT | Iterative Grounded Theory |
| IM(s) | Infrastructure Manager(s) |
| IPCC | Intergovernmental Panel on Climate Change |
| IPSL | Institut Pierre Simon Laplace |
| ITF | International Transport Forum (OECD) |
| LNMP | Ligne Nouvelle Montpellier-Perpignan (high-speed line project between the cities of Montpellier and Perpignan) |
| M&T | Maintenance & Travaux (SNCF Réseau maintenance department) |
| MCA | Multicriteria Analysis |
| MTES | French Ministry of Ecology (previously MEEDDM and MEDDTL) |
| NOAA | National Oceanic and Atmospheric Administration (US) |
| OECD | Organisation for Economic Co-operation and Development |

| | |
|--------|--|
| ONERC | Observatoire National des Effets du Changement climatique (French national observatory of the effects of climate Change) |
| PDF | Probability Density Function |
| PNACC | Plan National d'Adaptation au Changement Climatique (French national adaptation plan) |
| RFF | Réseau Ferré de France (former French Rail Network, most of RFF activities are now at SNCF Réseau) |
| RSSB | Rail Safety and Standards Board (UK) |
| SNCF | Société Nationale des Chemins de fer Français (French national railway company) |
| STS | Science and Technology Studies (Science, Technology and Society) |
| TER | Train Express Régional (SNCF Regional trains) |
| TGV | Train à Grande Vitesse (SNCF high-speed trains) |
| TRaCCA | Tomorrow's Railway and Climate Change Adaptation (RSSB-UK) |
| UIC | International union of railways |
| WMO | World Meteorological Organization |

List of figures

| | |
|--|-----|
| Figure 1-1 - Rationale for a empirical, inductive approach..... | 29 |
| Figure 1-2 - Mobilization of two major methodological traditions..... | 32 |
| Figure 1-3 - Examples of items on the agenda of the steering committee discussions | 40 |
| Figure 1-4 - A research setting to implement our methodological choices..... | 41 |
| Figure 1-5 - Three stages of material collection..... | 42 |
| Figure 1-6 - Screenshot of a the working interface while analyzing a transcript on Atlas.ti ... | 45 |
| Figure 2-1 - Changing the weather probability density function: means, shape & variance .. | 51 |
| Figure 2-2 - Relative importance of each source of uncertainty in decadal mean surface temperature projections | 54 |
| Figure 2-3 - Map of observed impacts attributed to climate change in the world..... | 55 |
| Figure 2-4 – Screenshot of the CLIMATE-ADAPT European Platform | 67 |
| Figure 2-5 - Slide from a presentation by Alstom Market and Product Strategy officer | 73 |
| Figure 3-1 - Simplified map of the French railway network..... | 83 |
| Figure 3-2 - Timeline of the D-RAIL project..... | 94 |
| Figure 3-3 - Materiality matrix of sustainability issues for SNCF Réseau, 2016..... | 99 |
| Figure 3-4 - Major components of Network Rail Adaptation & Resilience Strategy | 104 |
| Figure 3-5 - Screenshot from the weather-data portal provided to SNCF by Météo-France | 106 |
| Figure 4-1 - The region studied on the simplified map of the French railway network | 115 |
| Figure 4-2 - Zoom on the region studied on a detailed map of the French railway network | 116 |
| Figure 4-3 - Emergence of the climate issue through preliminary studies | 119 |
| Figure 4-4 - Map of the preliminary outline of the LNMP endorsed by the Government..... | 120 |
| Figure 4-5 - Diagram of the main climate hazards in this region affecting railways..... | 127 |
| Figure 4-6 - Photos of major incidents: often mentioned during interviews | 128 |
| Figure 4-7 - 10+1 regional priorities from the Etats généraux du rail et de l’intermodalité . | 136 |
| Figure 4-8 – Example of diagram produced to support user’s associations’ argument | 138 |
| Figure 5-1 - 3 stages of the workshop as it was built and items on the discussion agenda .. | 146 |
| Figure 5-2 - Wrap-up slide on climate science presented during the workshop..... | 147 |
| Figure 5-3 - Key parameters to build adaptation scenarios..... | 154 |
| Figure 6-1 - Screenshot of an incident record in BREHAT | 168 |

List of tables

| | |
|--|-----|
| Table 1-1 - Partnering organizations working on climate change, doing research, providing tools, expertise and support | 38 |
| Table 2-1 - Hierarchy of simple, complicated & complex risks in the IPCC report | 63 |
| Table 2-2 - Assessment of adaptation actions recorded on CLIMATE-ADAPT..... | 68 |
| Table 2-3 - Examples of adaptation focus in different countries..... | 73 |
| Table 2-4 - Criteria used to distinguish incremental and transformational adaptation | 77 |
| Table 3-1 - Major entities of the group SNCF..... | 81 |
| Table 3-2 - Synthesis of the 4 workshops organized or planned through the D-RAIL project. | 91 |
| Table 3-3 - Description of the sample for the exploratory interviews conducted between March and September 2016..... | 95 |
| Table 4-1 - Description of the sample for the interviews conducted between December 2016 and January 2017 | 117 |
| Table 4-2 - Characteristic time of railway system components – horizons of decision..... | 118 |
| Table 4-3 - Synthesis of the 4 scenarios (modernization of the existing line + 3 options for a new line) proposed during the Public debate | 123 |
| Table 5-1 - SNCF participants to the workshop..... | 145 |
| Table 5-2 - Two contrasted regional mobility policy options for adaptation | 153 |
| Table 5-3 - Different adaptation interests of transport stakeholders | 155 |
| Table 5-4 - Synthetic mapping of adaptation issues as expressed during the workshop..... | 160 |

List of boxes

| | |
|--|-----|
| Box 2-1 - Some key findings among climate change impacts & vulnerability in Europe | 56 |
| Box 2-2 - Resources and toolboxes for making decision under deep climate uncertainty | 62 |
| Box 2-3 - Objectives and main outputs of the ARISCC project (Adaptation of Railway Infrastructure to Climate Change), 2011 | 72 |
| Box 3-1 - The ongoing 2018 SNCF Reform | 82 |
| Box 3-2 - A dedicated Mission to address flood-risks | 98 |
| Box 5-1 - Adaptation governance an issue previously identified at SNCF | 154 |

Introduction

This dissertation describes and analyses in situ how a complex organization - SNCF, the French national railway company - deals with scientific knowledge on climate change. The underlying intention is to propose an inductive approach to elucidate the role played by this knowledge in such an organization: how does it find its way to strategic and management decisions? How does it interact with existing habits, convergent or divergent trends? How does this knowledge affect actors' worldviews¹?

I. WHAT IS THIS DISSERTATION ABOUT?

1. *Research objectives*

As any other passenger, when we step in a train, we just want to go from one place to another. Sometimes we briefly look out the window; sometimes we sleep, read a PhD dissertation or browse the internet on our smartphone. The heating or cooling system is on. Most often, we forget about the external environment and the weather on the way. However, railway lines go through landscapes. To connect big and small cities, they have deeply changed the countrysides since the 19th century. Mobility services rely on hard infrastructure which are deeply grounded in their physical environment. Tracks, catenaries and bridges are exposed to the weather, everywhere in the country, day after day, for decades. In addition, trains depend upon other networks – for power supply² and telecommunication – sometimes even more exposed to the weather. These relationships between the railway system and climate are “black-boxed” in the design of the infrastructure.

As researches in science and technology studies (STS) have often shown, there are particular moments like major incidents or technological shifts that reopen this black-box. The French railway system was designed and has been operated for more than 150 years in a stable climate. With climate change we enter one of these rare moments. Actors of the railway system rediscover overlooked interactions while new ones emerge. They hear about changes

¹ As explained in the first chapter, an actor (or an actant when it cannot speak for itself and has no spokesperson) is any entity which makes a difference in the course of action. As the action is “dislocated”, “distributed”, an actor can actually do something (has agency) because it is connected to other actors, it is “made of many others” (Latour, 2006, p. 46). We will meet a great diversity of actors with their own interests, rationalities and connections.

² SNCF is also one of the major electricity consumer of the country.

in their environment, they read about them and they experience them. It is precisely this situation which is fascinating: studying a historical and contemporary company at a moment in which this stability window is progressively vanishing, and in which even deciding what normal climate conditions are becomes difficult.

In this dissertation we portray actors in such situations: top-managers reporting about their risk management practices to authorities; executives who have to justify bad performance caused by summer fires; engineers considering climate in their design choices; associations worried about flood risks; thirsty train users when the TGV bar is closed or elected officials who do not understand how falling leaves can affect regional traffic. We talk about great projects and small maintenance, about major incidents and little annoyances. We see how engineers, maintainers and all of those who take part to this system have stakes in issues connected with changes in climate, from a small rail-segment near Montpellier to offices at the SNCF's headquarter in Paris.

We have reached a point in which talking about climate change as one homogeneous and distant phenomenon does not make sense anymore. Actors experience multiple and diffuse consequences of climate change every day. For an organization like SNCF, it is not a matter of global temperature and average trends anymore but an accumulation of very specific implications. We want to grasp those specific implications and understand where, when and why they do become a problem and how scientific projections can help to tackle this problem.

Our objective is to unfold these issues without denying their complexity. We intend to test how helpful an inductive social inquiry framework can be to propose new representations that welcomes what climate scientists have to tell and how actors in businesses or administrations actually react to this information. We aim at contributing to the emergence of new questions and to the definition of new spaces for exploration and discussion. These challenges exceed the scope of a specific organization such as SNCF³. They raise broader societal questions regarding for example the collective governance of risks or mobility preferences (speed,

³ As we start this research SNCF appears as a homogeneous and stable entity with a well-defined goal and identity (cf. Chapter 3), internal processes, decision-making procedures and relationships to external stakeholders. However, we will quickly see why this apparent stability and homogeneity are never guaranteed. SNCF is actually "composite", gathering multiple rationalities, being at the same time an industrial organization focusing on efficiency, a utility aiming at producing a public service, a business targeting market-performance (Amblard et al., 2005; Boltanski & Thévenot, 1991). It has to hold together divergent priorities and interests (for instance the concerns of the asset manager and these of the mobility services provider). We will therefore work with networks of actors that sometimes cross apparent boundaries of the organization to involve local authorities, users, government officials or even competitors.

comfort, etc.). Choices will need to be taken, actors will have to adopt new attitudes regarding ongoing changes. Our work has the modest ambition to contribute to the elucidation of the issues at stake and to the recomposition of what really counts for such organizations.

2. Initial questioning

Where it comes from: questions about the performativity of scientific knowledge

This research derives from a series of personal questions that I encountered during my first professional experiences in the field of environmental and climate policies. Those questions were related to the potential performativity of scientific results on socioeconomic activities and the influence of science in organizations and especially in businesses. I was wondering what the role of science could be to deal with complex issues such as the consequences of climate change without reducing them to a single social, technical or economic dimension.

Back then, I observed that scientific teams, all over the world (IPCC, 2014b), were releasing results with very significant implications on our representations of our collective existence. Indeed, researches on global changes deeply question models of developments and political systems (Jacquet, Pachauri, & Tubiana, 2009; Latour, 1995, 1999; Paugam, Pachauri, & Tubiana, 2015). They reveal forgotten interdependencies, they show that human actions actually affect natural equilibriums and create new major risks (Amilton, Bonneuil, & Gemenne, 2015; Beau & Larrère, 2015; Beck & Latour, 2004). They also provide us with an increasing understanding of these relationships and the mechanisms at work. To some extent, we can now anticipate future changes and modify the current course of action. This original situation shakes up how we should organize our relationships with what we have been calling for so long our “environment” (Callon, Lascoumes, & Barthe, 2001; Fitoussi & Laurent, 2008; Jonas, 1992; Latour, 2015; Rumpala, 2010; Soubeyran & Lolive, 2007).

Among global transformations, the consequences of climate change are a major issue. Conclusions on this topic are both very clear and multifaceted. For many activities up to now, weather conditions were not an issue because they fell into well-known statistical distributions. The associated risks could be assessed and managed through ordinary actuarial practices. As a result, these sectors tended to forget about climate. Recent scientific results

on the impacts of climate change remind them about the importance of weather conditions and spell the end of such an actuarial approach to climate risk mitigation.

However, we collectively struggle to move from these theoretical implications to actual changes in the socioeconomic world. The conclusions from research hardly translate in public policies and businesses strategies. Recently, many research projects – such as projects conducted through the EU Research and Innovation funding program⁴ – dedicated important resources to bridge this apparent gap between research and society. Innovation oriented research, toolboxes, methodological frameworks have become a priority.

A potential role for economics to mainstream climate adaptation

In a context of increasingly dominant economic rationality, the perspective of economics appears as a particularly promising approach to represent the interactions between decision-making and the climate in commensurable terms. The mainspring of environmental economics is to make environmental “externalities” accountable in the same system of reference as other important issues. With economics we can hope to be able to talk with the language of organizations (speaking of investments, risks, performance metrics, costs and benefits, etc.). Many “decision-making tools” have been developed to make it possible in the specific case of climate impacts despite its long and uncertain time-horizons (Dittrich, Wreford, & Moran, 2016; Econadapt Consortium, 2015; Hallegatte, 2009; Watkiss & Hunt, 2013). Still, political and economic decision-makers barely take ownership of this material (e.g. (Nassopoulos, Salagnac, Leseur, & Meunier, 2014)). We found very few feedbacks or actual use cases of these tools.

These observations led us to assume that there was more than an information gap, a knowledge accessibility or understanding issue. Obstacles might include other dimensions such as cognitive barriers, incompatibility of time-horizons, conflicts in priorities, shared worldviews which need renegotiation. The concerns that appear essential for those who worked on environmental global challenges, are still peripheral for most people. At that moment, the socialization of scientific conclusions, “interessement”⁵ (Callon, 1996) to the consequences of global changes, “mainstreaming” of those concerns became to us, the very

⁴ Cf. <https://ec.europa.eu/research/fp7/> - last accessed July 2018

⁵ All what a specific actor or entity does to bolster his or her perspective and stabilize the discussion around his or her own framing of the issue

first challenge to tackle. We needed to elucidate current representations and interdependencies, to describe successive translations of information, to unfold interests and implications chains, to find entry points in existing organizational processes to catch decision-makers attention.

Unfolding complexity first

In this thesis, we defend that making the complexity visible, traceable and being able to monitor and account for it, is not just an optional or a trivial step but a necessary and critical process. We make the hypothesis that methods of social inquiry can efficiently participate to perform this task. Those approaches, inspired by pragmatism (Dewey, 1940; Lippmann & Latour, 2008; Zask, 2015), seminal researches in STS (e.g. (Latour & Woolgar, 1988; Tollis, Créton-Cazanave, & Aublet, 2014)) and learning experiments (European Commission : CORDIS, 2010; Venturini, 2010) precisely intend to identify and follow connections between actors and concerns. They aim at understanding and reporting about a variety of perspectives. Beyond their educational value, we wanted to test on an actual case how such approaches can contribute to provide a new perspective on a situation and possibly unlock further action. We indeed thought that they can operationally be mobilized to better deal with current uncertainties and take full consideration of existing tensions.

Our statement is that social inquiry and economics heuristics can be complementary drivers for a better uptake of climate adaptation challenges. Economics work with well-defined questions through a deductive and normative process. However, and especially when dealing with social problems as concrete as infrastructure development (Armatte, 2011; Vatin, 2008), economists know when they need to enrich their representation of the reality to better consider friction and complexity (Diemer, 2004; Steiner, 2011). As Guesnerie puts it, understanding the social dimensions of economic issues requires the "cross examination of all human sciences [in order to] resist both to esoteric thinking on imaginary worlds and to a reckless computation of data" (Guesnerie, 2001). The approach we use in this research works with what actors themselves have to say through an inductive and exploratory process but it shares the same intention to enrich or renew our collective understanding of a situation:

"We suggest that what is seen as 'economic', and what as 'social', may consist of different ways of describing the same sets of processes. MacKenzie has argued that although the economics of technological change and the sociology of scientific knowledge make

different presumptions (for example, where sociology of scientific knowledge and actor-network analyses of technology find it difficult to account for 'closure' and the stabilization of technological artefacts, economic analyses start from the presumption that technologies have stable characteristics that can be subject to a rational economic calculus), they are approaching essentially the same topic (the creation of stable networks) from directly opposite points of view (MacKenzie, 1992).” (Williams & Edge, 1996)

We wager that it might be very fruitful to articulate both approaches, to anchor economic heuristics in real-life complexity and to propose relevant and diverse ways to deal with this complexity. A “thick description” (Geertz, 1994) of the economy – its diversity of actors’ behaviors, limited resources and unlimited desires, institutional constraints, etc. - is a crucial component of economic sciences.

Working on the actual case of infrastructures

These initial interrogations gave rise to discussions with the future partners of this project. With them we identified real-cases where these issues were becoming salient. Working with climate change and economics experts we met the specific context of infrastructure managers and operators.

Infrastructures, such as transport-networks – understood as sociotechnical systems⁶ – are among the first components of our societies concerned by the impact of climate change:

“Transport is today a critical support system for the smooth operation of our societies and economies. At the European level, the political relevance of transport is high as a necessary instrument for the facilitation of trans-boundary relationships and the physical and economic integration within the EU. Changes in climate could compromise the smooth operation of our societies and the economy.” (European Environment Agency, 2014)

They are essential to contemporary globalized interconnected economies. They provide the material condition for movements and transactions through space and time and perform a certain vision of development made of speed, division and distribution of work. They are also deeply rooted in representations inherited from the times they emerged (Edwards, 2003). We decided to carry out our investigation on SNCF. Indeed, as we will see in the next chapters, the case of the railways in France is both very specific and insightful to understand contemporary challenges.

⁶ i.e. complex of social and technical relationships between heterogeneous actors, including people but also technological entities (humans and non-humans), cf. Chapter 1.

We have begun with scientific knowledge on climate change, economics for decision making and transport infrastructures as three ingredients of our topic. Our work has then been to rearrange them into a meaningful network of heterogeneous components and interactions. In this dissertation, we are less interested by each element taken separately than by their interactions, their entanglement, the complex they form.

3. *An interdisciplinary qualitative approach*

To handle these heterogeneous ingredients we had to rely on an interdisciplinary perspective: we needed to understand climate science and directly engage with climate-scientists, we read from environmental science, sociology, engineering science and economics literatures. We worked daily within a team of economists and had a great number of discussions with railway engineers. To conduct our work, we went on the field and talked with people at any step of the research.

“The great thing about a standpoint is that you can stand on it and modify it! Why would I be ‘stuck with’ it? [...] All of the sciences have been inventing ways to move from one standpoint to the next, from one frame of reference to the next” (Latour, 2005, pp. 145–146)

Through this thesis, we have tried to build a device enabling displacements, able to propose complementary standpoints and possibly reveal perspective effects. We started with our personal background in environmental studies and science and technology studies (STS) and we have intended to provide relevant inputs for a robust economic analysis. Therefore, we took all the time needed to clarify what is behind the question we have briefly introduced, to make the implicit explicit, to formulate relevant research questions.

4. *Our main arguments*

We defend two lines of arguments. The first one is about the adaptation of organizations, seen as composite assemblages (Amblard, Bernoux, Herreros, & Livian, 2005), to climate change. After three years of inquiry, we confirm *adaptation is best described as a long iterative learning process, intrinsically constructivist*. According to us, adaptation challenge in a company such as SNCF is a governance challenge more than a technical one. The issue at stake is to create the necessary conditions to unfold the implications of climate change for the organization. It is more about creating room for exploration and discussion

than to design *ex ante* comprehensive adaptation pathways. These discussions should enable a full consideration of possible consequences and responses, including radical transformations. Governance frameworks have to enable political negotiations of the acceptable level of risk and of the repartition of responsibility.

The second argument of our thesis is about the method itself. We defend that *the type of inductive social inquiry we tried to implement might be an efficient first contribution to create this room*. Things are complex, but it is possible to provide representations of this complexity in order to deal with it, without reducing it. Our inductive approach has worked quite well to identify key issues, propose alternative focuses, raise and give flesh to critical questions.

II. HOW TO READ THIS MANUSCRIPT?

The dissertation is divided in six autonomous, but strongly related chapters completed by this introduction and a general conclusion. It starts (Chapter 1) with the method section in order to stay as close as possible to the process we actually followed. We wanted to give access to the reader to our intellectual pathway. This pathway was influenced "along the way" by our observation and our partners. By sticking, inasmuch as possible, to the chronology we followed we feel that the intricacies that we faced and the iterative learning process adaptation we discovered are best served.

Three of the chapters are based on articles we published (#3) or submitted to peer-reviewed journals (#4 and #5):

- Dépoues, V. (2017). Organisational uptake of scientific information about climate change by infrastructure managers: the case of adaptation of the French railway company. *Climatic Change*, 143(3-4), 473-486.
- Dépoues, V., Vanderlinden, JP., Venturini, T. (under review in *Vertigo* January 2019). Entre dire et faire : discours scientifique sur le changement climatique et adaptation du système ferroviaire français.
- Dépoues, V., Vanderlinden, JP., Venturini, T., Jézéquel, A. (Submitted in January 2019). An experimental workshop to question the implications of an increase in extreme weather events frequency on the organization of French railways system.

The first chapter introduces the project's design, the research protocol and theoretical background rooted in qualitative analysis and STS. A key goal of this project was to experiment how social investigation could be carried out in very close collaboration with the subject of

the observation. In this research setting, we alternated periods where we were 'embedded' in the studied organization and periods of reflexive *distanciation*.

The second chapter presents a review of the literature on climate impacts and how they can affect infrastructures. It describes an apparent gap between a science that is meant to encourage large-scale actions and an adaptation that remains limited and incremental. It questions the relevance and saliency of frameworks which seek to bridge this gap and proposes an inductive inquiry as a form of reality-check. Scientific literature is the very first site we surveyed in our inquiry.

The third chapter introduces the case-study of SNCF and reports about existing adaptation initiatives in the company. It describes the drivers and limits of both corporate processes and R&D projects. According to actors interviewed in the first part of the research, adaptation is often perceived as a marginal topic, distant from strategic and operational concerns. This is why we have decided for our fourth chapter to conduct an in-depth analysis closer to the operational concerns of the railway system. This leads to the investigation of a local sub-case study. In the region of Montpellier, climate change is a major issue for the railway system, affecting long-life projects like the design of a new line as well as the current traffic management. This system is already adapting, but in an incremental and reactive mode.

These various SNCF sites portray adaptation as it is done for now as the negotiated outcomes of many interrelated trends and legacy pathways. The fifth chapter exposes the results of a workshop organized in Montpellier in October 2017 aiming at going beyond this first observation. Presenting climate change as a potential rapid game-changer and focusing on variability and extreme weather events, we encouraged participants to question SNCF procedures, doctrines and even strategic choices. The focus group has revealed the intrinsic variety of SNCF attitudes towards adaptation that depend both on the activity segment (i.e., infrastructure management, high-speed, regional or commuter trains operations) and on the market structure (i.e. State run monopoly, open access markets or regulated competition).

The concluding chapter attempts to take stock of what we described and to contribute to the organizational uptake of scientific information about climate impacts. It discusses the complementarity between various approaches, including those derived from economics to enable more anticipation. Building on the history of long-term thinking at SNCF, we defend

that economic analysis might be powerful not as device for optimization or objectivation but as a tool for exploration. Adaptation economics, we believe, is a science of governance that should help unfolding and pondering the consequences of climate change, exploring possible pathways and creating room for nurturing adaptive capacity.



"Inquiring is not thinking in a chair." John Dewey

Chapter 1 - An embedded inductive research-process

This chapter is about the theoretical framework and the methodology of this research. It first presents the background and essence of our inquiry rooted in STS (I), then the approach we used to conduct our work (II). In the first section, we explain why we chose to implement an empirical and inductive method. We introduce how Actor network theory (ANT) and Iterative-grounded theory (IGT) are relevant approaches to provide an operative understanding of the climate adaptation challenges for a large organization. In the second part of the chapter, we present the project partners', its governance and how we have actually been working over three years to collect and analyze material in order to be in position to write "risky accounts" (Latour, 2005, p. 133). We explain how this "embedded research" setting has allowed us, both to access the relevant material to perform an original empirical research and to create the conditions of interaction with the actors to test the value of the social inquiry to provide alternative understanding of a complex situation.

I. STUDYING THE INTERACTION BETWEEN CLIMATE KNOWLEDGE AND ADAPTATION

In the next chapter we will begin our investigation by looking at scientific knowledge on the impacts of climate change (IPCC, 2014c). Scholars and practitioners make recommendations to move from science to action and defending a "policy relevant" science. Indeed, conclusions from research *a priori* have the potential to seriously challenge current socio-economic choices and models. However, a growing number of experts note that there is a gap between these conclusions and implementation of adaptation of organizations directly impacted, such as infrastructure managers (cf. Chapter 2).

This problematic interactions between a science-based knowledge, changes in the climate system, infrastructure as a sociotechnical system and a large organization are our main research interest in this thesis. This interest is rooted in science and technology studies (STS). We use the term STS here to refer to a diverse research tradition, i.e. "not only a field, but also an intellectual community sharing, if not a paradigm, at least a common epistemological repository" (Latzko-Toth, 2009). As noted by (Bowden, 1995) "STS is a multidisciplinary field.

The key factor holding the various STS research agendas together is a topical interest in science and technology". In this research, we focus on how an issue produced by science meets the economic world as studied and performed by economics.

1. *The perspective of science and technology studies*

Because of its plural and multidisciplinary nature, STS research uses notions that are rich and polysemic and that need to be clarified for the use of this thesis.

Scientific knowledge. STS developed a rich critical thinking about classical representations of science as a domain detached from society and linear models going from "pure" scientific research to political or economic decisions. Instead, STS began to analyze the social production of scientific facts and innovations as collective processes focusing on science "in the making". In these processes, social facts are involved in science. Science is made by people who are also citizens and economic agents, who work in companies or administrations and actually do things (Felt, Fouché, Miller, & Smith-Doerr, 2016; Hackett, Amsterdamska, Lynch, & Wacjman, 2008). As Pestre writes, science it is "an institution and not just a knowledge":

"Scientists are in constant interaction with the material world. [...] Scientists are engaged in a continuous debate and interact with each other. [...] Scientists, taken individually, are not pure rationalities at work. [...] Scientists come from different institutional and social backgrounds. [...] Scientists are constantly trying to unify their proposals". (Pestre, 2006, pp. 1–28)

Conversely, science produces new entities which need to be socialized and sometimes change the socioeconomic world. It enacts the social (Law & Urry, 2004).

Climate change. Studied from this perspective, the current consensus on climate change had to be patiently built. As described by Edwards, this involved a large community of researchers, "political and scientific institutions, observation networks, and scientific practice [which] evolved together over several centuries to culminate in the global knowledge infrastructure we have today":

"Our climate knowledge is provisional and imperfect. Yet it is real, and it is strong, because it is supported by a global infrastructure built on old, robust observing systems and refined predictive models, on extensive simulation experiments and model inter comparisons" (Edwards, 2010, p. 439)

Numerical circulation models have played a major role, first to build this consensus on the causes of climate change (Guillemot, 2007) and now to provide inputs regarding the consequences of the phenomena. STS are concerned with these scientific conclusions on the way we see, and we live in the contemporary world. They defend the hypothesis that results on climate change may have huge consequences and should induce a renewal of our representations and actions (e.g. (Amilton et al., 2015; Beau & Larrère, 2015; Dahan & Guillemot, 2015)).

Infrastructures. Infrastructures, as systems, have been a privileged research topic for STS⁷ for a long time (Blok, Nakazora, & Winthereik, 2016; Coutard, 2002; Hughes, 1993; Mayntz & Hughes, 1988; Mumford & Winner, 2010). Making visible what is usually only “part of the background”, revealing critical connections (large systems in the making or consequences of incidents), STS see infrastructure as a “fundamentally relational concept” (Star, 1999). Edwards, after Castells, defines infrastructures as “those systems without which contemporary societies cannot function” (Castells, 1996; Edwards, 2003). Indeed, infrastructures are at the intersection of multiple relationships that structure a collective. They are the wires, tracks, pipes, which physically “binds us together” (Latour, 2005, p. 189). Infrastructures are made out of “hard” components – of steel and concrete – but also of softer elements among which energy, information and human-relationships. We are describing them, following the STS tradition, as complex sociotechnical systems (Gueguen, Jarrige, Le Courant, & Paloque-Berges, 2017):

“The word “infrastructure” itself very often refers to the physical aspect (the hardware) whereas critical infrastructures are complex sociotechnical. [...] As historians, sociologists, and anthropologists of technology increasingly recognize, all infrastructures are in fact socio-technical in nature. Not only hardware but organizations, socially-communicated background knowledge, general acceptance and reliance, and near-ubiquitous accessibility are required for a system to be an infrastructure.” (Edwards, 2003).

Studying infrastructure, we question the relationships to the technology they rely on; to the areas they serve; to the social and economic interactions they enable; to power balance they reflect, the standards they embody, the conventions they rely on, etc. (Star, 1999; Winner,

⁷ Among the most famous works on infrastructures, we find researches on “large technical systems” (LTS), initiated by Hugues (Coutard, 2002; Hughes, 1993; Mayntz & Hughes, 1988). Alain Gras translated this notion in France with the term “macro-système technique” (Gras, 1993). “The idea of large technical systems focuses attention on growth around a technological core. By contrast, infrastructures are not merely large systems, but sociotechnical institutions”(Edwards, 2003). LTS tend to develop along a certain pattern, following a pathway visible “only on historical scales” and their development relies on key actors named “system-builders” who, at a certain point, “organize existing possibilities into a complete system with a vision that must be simultaneously social and technical”.

1986). Infrastructures are simultaneously the outcomes and the flagships of a certain vision of a collective horizon often called progress or innovation. They both contribute to shape and are shaped development pathways (der Vleuten, 2004; Edwards, 2003).

Infrastructures are at the crossroads of spatiotemporal scales, economic, political and social issues, following pathways and enabling possible futures⁸. They have lifetime expectancies of several decades: decision made today regarding for instance new development or retrofitting programs will determine infrastructure adaptation to climate change over the long run (Ribeill, 2011). They are both the very first of our assets exposed to climate hazards and they embody our strategies to protect against and control those hazards. They propagate the consequences of local disruption across regions⁹ and they guarantee, through connectivity, a certain form a large-scale resilience of economies:

“Increasingly, modern societies are confronted with the forgotten relationship between built infrastructures and the assumed background of natural forces and structures upon which the former rely. Long considered essentially static, this background is now regarded not only as naturally variable, but also as subject to alteration by human activity. Global climate change, for example, is changing the parameters within which built infrastructures function” (Edwards, 2003).

Large organizations and the climate system. STS look at all those specific objects as at hybrid systems, made of technical and social (human and non-human) components. In this perspective, we are more interested in the process of organizing¹⁰ than in the organization as a stable homogeneous entity. However, we keep the term, thinking with Ménard that “studies of organizations [...] constitutes a privileged topic for intersection between economics, management and social sciences” (Ménard, 2018). Similarly, there is no autonomous climate that could be apprehended as a whole, exogenous, factor. Those terms are conveniently used to describe complex weavings of interactions between thousands of components as heterogeneous as the ambition of a regional politician, the experience of a railway worker, the resistance of continuous welded rail, the diameter of a drainage nozzle, the water sprays

⁸ [...] I have argued that studying infrastructures on different scales of force, time, and social organization produces different pictures of how they develop, as well as of their constraining and enabling effects on social and individual life. Different scalar views also lead to different pictures of the solidity of the “modernist settlement” that separates nature, society, and technology”. (Edwards, 2003)

⁹ e.g. “The complexity of the current transport system has an amplifying effect on [climate] impacts: if disruptions affect critical sections of the network, transport flows may be delayed or stopped many kilometers away from the area originally affected. Multi-modal, complex transport chains and their associated production and logistics activities could be halted, and the daily routines of millions of citizens could be altered; and if vulnerable infrastructures are serving regions with already limited accessibility alternatives, they could compromise their development prospects (European Environment Agency, 2014)

¹⁰ Holding together, keeping a collective, managing the tension between available resources and a goal.

of Saint-Roch station, holidays preferences of French families, the risk aversion of green bond holders, the curiosity of a transport journalist, the nonchalance of a smoker who throws his butt by the track, the interest of a water-bottle street vendor, the invasiveness of Ambrosia, the warming potential of CO₂ molecules emitted in Beijing or in the Parisian suburbs, the Cevennes massif blocking storm clouds from the Mediterranean or the degree of soil moisture.

Many studies within the field of STS have focused on moments when entities and collectives are not yet or not anymore stabilized; those moments when contours of a priori well-defined groups of categories become uncertain. The production of new scientific facts, the socialization of an innovation or accidents are among these particular situations in which “solid” relationships become magmatic¹¹:

“According to the definition of the Encyclopedia Britannica, magma is a flow of ‘partially molten rock’, a configuration in which rock is both liquid and solid at the same time, exactly as social is in controversies. But there’s more to this metaphor: what is most interesting in magma is that solid and liquid states exist in a ceaseless mutual transformation. On the one hand, the solid rock touched by the heat of the flow melts and becomes part of the stream. On the other hand, at the margins of the flow, the lava cools down and crystallizes. [...] Through this dynamic the social is unremittingly constructed, deconstructed and reconstructed. This is the social in action and that’s why we have no other choice than diving in magma. (Venturini, 2010)

These situations raised governmentality issues, the social being destabilized by the outcome of science and technology, we need to recompose, reorganize, integrate the new elements, find an adapted and always temporary *modus vivendi* (Lippmann & Latour, 2008, p. 105).

Socializing climate knowledge falls into this problematic category (Hulme, 2009). When immersed in a particular organization, it is a source of disagreement: top-priority for some actors, secondary for others, major challenge for the structure of the system itself or simple peripheral perturbation, urgent or easily postponed. Multiple representations live together, convergent or incompatible: for some people, climate change is the image of global changes and has a symbolic, paradigmatic, substance; for others it is a very specific problem that can only be addressed in each local context by first describing the actual effect on the system. Heterogeneous, “not yet stabilized, closed or back-boxed”, the interaction between

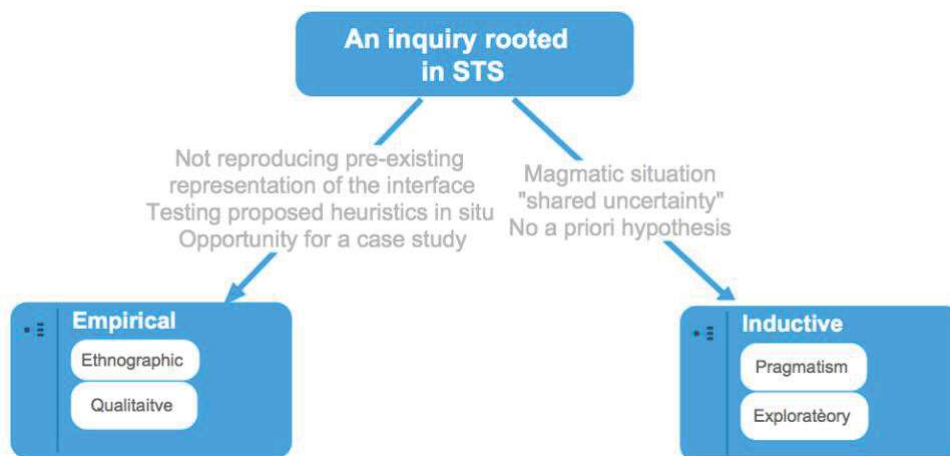
¹¹ Those moments of shared uncertainty are called “controversies” in this literature— this term is therefore used with a broader meaning than what we are used to in everyday language: “Every bit of science and technology which is not yet stabilized, closed or black-boxed” (Macospol, 2007)

knowledge on future changes and a socioeconomic organization such as the French railway system carry the seeds of potential controversies.

2. Methodological choices: an empirical and inductive research

This situation led us to make two structuring choices when framing our research: we decided to use a pragmatic empirical (i) and inductive (ii) approach (Figure 1-1).

Figure 1-1 - Rationale for a empirical, inductive approach



Source: Author

i. "The name of the game is to get back to empiricism" (Latour, 2005, p. 146)

Adaptation raises general questions but is always context-dependent. Our interest for this topic progressively grew while interacting on climate-related issues with large organizations and observing how some specific companies were tackling this complex challenge¹². We were especially interested by infrastructure managers and environmental services providers we had previously the occasion to work with. Indeed, these actors are at the frontline of adaptation, both directly exposed to climate hazards and able to think in the long term. However, as often with complex objects like these organizations, there are lots of *a priori* representations on how they work, what are their priorities, what they should, or they could do, etc. Working with the climate research and expert's community we tend to assume – sited in conference rooms in Paris or Brussels – that the situation for such organizations is rather simple: they have a vested interest to adapt and to anticipate the coming impacts of climate change. However, these organizations are far from being homogeneous entities, they have to deal with a variety of complex issues. Reasoning from the outside we take the risk to just reproduce

¹² For instance, around events such as <http://www.forumeteoclimat.com/> - last accessed June 2018

preexisting or outdated representations and categories. This is why we wanted to go closer, to understand how such an organization works, who (or what) is actually acting behind this overarching concept, how these actors access, process, interact with knowledge.

We had the opportunity to do so with one particular company – namely SNCF – introduced in the next section and presented in further details in chapter 3. We decided to take this opportunity to conduct an in-depth work with this organization. The work presented in the next chapters is therefore first and foremost an empirical work. Our intention has been to collect original material, to observe what was going on, to design tests and to experiment in situ. In short, we chose to carry out a pragmatic investigation regarding what knowledge on climate change is actually doing to such an organization and what people within this organization are doing with this knowledge.

As Lorino noticed, an inquiry refers to the work of both scientists and detectives (Lorino, 2014). It combines creative thinking – creating plausible stories – and logical thinking to draw all the implications and consequences of hypothetical scenarios and test them: “Sherlock Holmes is doing much more than deduction, he thinks, he imagines, he does”. An inquiry starts with a case, an unexplained fact; the detective collects clues, follows intuitions, develops and test theories. It is a rigorous and demanding method, following traces, imagining devices to invite actors to express their views, opening black boxes (de Sardan, 1995). It is an invitation to suspend judgment, to refuse the traffic of clichés, to empirically test everything:

“We are in the business of description. Everyone else is trading on clichés. Enquiries, survey, fieldwork, archives, polls, whatever— we go, we listen, we learn, we practice, we become competent, we change our views. Very simple really: it’s called inquiries. Good inquiries always produce a lot of new descriptions”. (Latour, 2005, p. 157)

ii. An inductive approach: when there is no clear hypothesis to test

In a magmatic situation, it is very hard to assume a priori that one perspective is more relevant than another one. It is difficult to assume that one specific economic model will meet actors’ expectations and be able to answer their questions. This project is particularly interested in economics as a possibly relevant “translation” able to bridge the apparent “knowledge uptake gap” between climate science and adaptation. The rationale behind this idea lies on the assumption that the language of costs, benefits or risks might be more audible for companies or other economic actors. However, there are many implicit hypotheses in such a proposition,

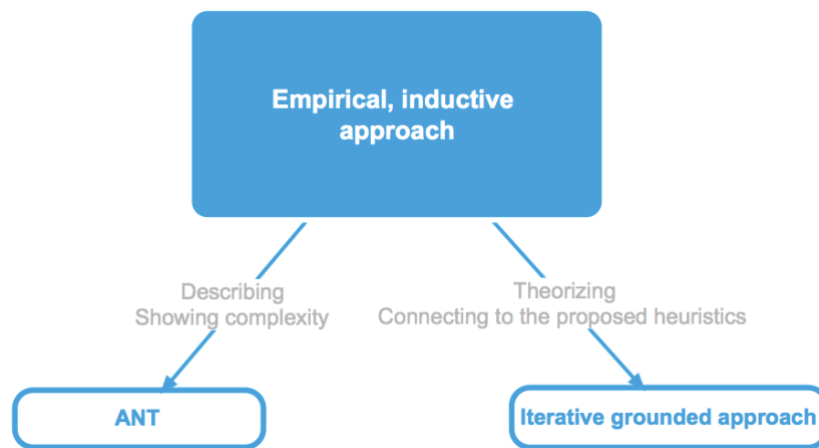
regarding for instance the relevance of scientific information or the decision-making process. Those are complex processes in which we can hardly test each specific premise in a deductive way. This is why we chose an inductive approach. We wanted to describe first, before assuming that any form of “translation” could be the most relevant. Such an inductive perspective is not the most common in sciences of adaptation. With this thesis, we want to propose it as an interesting alternative to move forward in adaptation implementation.

We tried both to elucidate the specific situation of SNCF and to test what this type of research methods can produce. We wanted to experiment how efficient it could be to take the time it needs for a qualitative social enquiry to propose a better framing of the question of the impact of climate change on the system and so to improve the governance of adaptation. Can a precise description of the situation contribute to coin and select relevant heuristics, approaches and tools for adaptation (Swart, Biesbroek, & Lourenço, 2014)? Can it help, both to generate a more credible, salient and legitimate knowledge (Cash et al., 2003) and to improve how we collectively take profit of what we already know? Far from denying the interest of the deductive frameworks available in the literature, we intend to provide a complementary perspective to help reconnecting those to actual and grounded situations.

Conceptual background for such an approach

We based our work on two of the dominant empirical inductive approaches that exist in social sciences: Actor Network Theory (ANT) - also called translation sociology - and the Iterative Grounded Theory (IGT) (Figure 1-2). Related, these research methods have also evolved according to different research streams with their own specificities.

Figure 1-2 - Mobilization of two major methodological traditions



Source: Author

i. Actor-network theory – “we are in the business of description [...] describe – write – describe – write” (Latour, 2005, p. 146)

For the ANT, stability is what has to be explained. Initially developed to study the success of innovations (Akrich, Callon, & Latour, 1988), ANT is an attempt to understand the processes of creation and socialization of science and technology by focusing on the capacity of heterogeneous actors to do things through their connections: “knowledge is a social product which [...] may be seen as a product or an effect of a network of heterogeneous material” (Law, 1992). It is relevant in our case when considering adaptation as a process of stabilization, an attempt to recompose our common world, questioned by the scientific work on impacts of climate change and vulnerability of societies¹³. ANT suits well this moment of shared uncertainty.

With ANT, the investigation starts “in the middle of things” (Latour, 2005, p. 27), then, it patiently follows actants’ traces (Latour, 1987). Actants or actors are any things - human or non-human - that do “modify a state of affairs by making a difference”. Actors do not just transport information but operate displacements, transformations, translations. Those transformations leave footprints, and the researcher looks for them. He produces devices, propose tests to actors, to record them. Following the topography of the investigation field, he moves from one viewpoint to another, multiplying perspectives on the action. He draws

¹³ Studying adaptation through the lens of ANT, we find great similarities between innovation and adaptation: both are an outcome from science and a process that might be able to transform social arrangement. We talk about technical or organizational innovation as well as technical or organizational adaptation; incremental or transformative innovations and adaptation. Both are sources of «interpretative flexibility» or «uncertainty». In this research we understand that adaptation requires the construction of an actor-network as well as innovations.

the networks of connections than enable the actors – through space and time – to actually do something. Actors have agency because they are networks. The researcher describes how multiples sites are connected, not in theory but by actual, observable links.

“To understand how social phenomena are built it’s not enough to observe actors alone not it’s enough to observe social networks once they are stabilized. What should be observed are the actors-network that is to say the fleeting configuration where actors are negotiating the ties of old networks and the emergence of new networks is redefining the identity of actors.” (Venturini, 2010)

More than a theory, ANT first describes a research attitude to adopt when conducting such a field work. Callon proposes three principles to characterize this attitude: “agnosticism (impartiality between actors); generalized symmetry (the commitment to explain conflicting viewpoints in the same terms) and free association (the abandonment of all a priori distinctions between the natural and the social)” (Callon, 1996). Based on this attitude, Venturini enumerates four requirements to “dive in magma”: perplexity (“not simplifying the number of propositions”), consultation (“not short-cutting actor’s voices”), hierarchization (“discussing compatibility of propositions”) and institution: (“once proposition instituted, not questioning their legitimacy”). We have decided to adopt this attitude and follow these principles.

We especially built our research on the developments of ANT made to study magmatic moments through “cartography of controversies” (European Commission : CORDIS, 2010; Venturini et al., 2014; Venturini, Ricci, Mauri, Kimbell, & Meunier, 2015). Mapping controversies is the “exercise of crafting devices to observe and describe social debate especially, but not exclusively, around techno scientific issues” (Venturini, 2010). It aims at exploring and visualizing the complexity of contemporary debates, not at reducing it or trying to provide definitive arbitration between actors’ positions.

These approach come with a form of minimalism in the method: “Just-look and tell what you see” (Venturini, 2010), keeping an “Infra-language”:

“[ANT] main tenet is that actors themselves make everything, including their own frames, their own theories, their own contexts, their own metaphysics, even their own ontologies. So the direction to follow would be more descriptions I am afraid”. (Latour, 2005, p. 157)

Consistently with STS tradition, the researcher does not try to explain what he is observing by referring to any “context” or preexisting “groups”, nor to propose additional categories or

assume action of invisible forces. He just reports about contextualization and generalization proposed by actors, making trackable chains of relations and regroupings visible.

“Follow the connections, ‘follow the actors themselves’. No cold objectification has taken place there, no superior reason is being unfolded. Everywhere, blind termites are busy cranking out data. Just keep sniffing through their galleries, no matter how far this takes you. The same change of topography occurs every time you replace some mysterious structure by fully visible and empirically traceable sites. An organization is certainly not ‘bigger’ than those it organizes.” (Latour, 2005, p. 190)

However, this minimalism is far not unproductive. Social inquiry “makes realities and social worlds. They do not simply describe the world as it is, but also enact it” (Law & Urry, 2004).

ii. Theorization and iterative grounded theory

Contrary to other grounded approaches, ANT usually does not try to go beyond description, to create concepts, propose categories. Actors do that by themselves:

“They, too, compare; they, too, produce typologies; them, too, design standards; them, too, spread their machines as well as their organizations, their ideologies, their states of mind. Why would you be the one doing the intelligent stuff while they would act like a bunch of morons? What they do to expand, to relate, to compare, to organize is what you have to describe as well. It’s not another layer that you would have to add to the ‘mere description’. Don’t try to shift from description to explanation: simply go on with the description. What your own ideas are about your company is of no interest whatsoever compared to how this bit of the company itself has managed to spread”. (Latour, 2005, p. 149).

This reflects a classical debate among STS scholars between descriptive only and analytical perspectives (Bowden, 1995; Hess, 2001; Latzko-Toth, 2009; Yin, 2003). We endorse the position according to which this is no discontinuity between a “thick” description (Geertz, 1994) and interpretation.

This project also intends to contribute to bridge the gap between science of adaptation (Swart et al., 2014), adaptation heuristics proposed and what happens in an organization such as SNCF. In order to do so, we try to connect the descriptions we propose to concepts, heuristics and methods available in the literature on adaptation.

“It is important to acknowledge the underlying heuristics that are being used to guide adaptation processes and continually question their legitimacy. This form of reflexive or double loop learning is necessary to ensure both researchers and practitioners have appropriately framed their

adaptation problems and are relying upon robust heuristics to guide their decision-making. [...] In order to adequately evaluate whether particular heuristics are useful and robust, there is an increasing need for critical mutual reflection between scientists and practitioners as to which assumptions, heuristics, and adaptation principles enable successful adaptation in practice. (Preston, Mustelin, & Maloney, 2015)).

We especially focus on the approaches, models and tools proposed by economists who commonly work of assessing the costs and benefits to compare strategies for an efficient adaptation; investigate the role of markets and regulations and discuss about the most relevant instruments and incentives for adaptation (Econadapt Consortium, 2015; Oberlack & Neumärker, 2013; OECD, 2015).

Our work go both ways: from observation to formal categories, and from scientific corpus to the field, proposing heuristics to actors. We practiced this back and forth between description and conceptualization based on the iterative grounded theory (Charmaz, 2006; Kane, Vanderlinden, Baztan, Touili, & Claus, 2014; Strauss & Corbin, 1997). Grounded theory was developed and formalized by Glaser et Strauss at the end of the 60s (Glaser & Strauss, 1967). It is currently used in many research-fields including spatial planning, organization theory (Touili & Vanderlinden, 2017) and adaptation-studies (Kane et al., 2014; Simonet, 2011; Touili & Vanderlinden, 2017) . The general principle of grounded theory is to produce concepts out of qualitative empirical data. It shades light on the production of meaning by actors themselves (Couture, 2003).

Through the analysis process - protocol described below - we progressively identified categories that we could bridge with concepts existing in adaptation literature. In order to do so, we successively read on various aspects of the contemporary science, including but not limited to the following topics: incremental – transformative adaptation, transition management; exploratory and predict-then-act adaptation approaches and climate services; engineering and socio ecological systems; resilience, risk, vulnerability, adaptive capacity; decision theory, expertise, uncertainty, decision making under deep uncertainty; governance of adaptation; adaptation and planning; foresights and adaptation economics; institutional economics. Iterations between our empirical corpus and these theoretical corpuses progressively allowed us to identify key properties of relevant categories and major relationships between them.

3. Reflexivity

A critical dimension of these approaches is the reflexivity of the investigator. It was particularly important in our research since we were also active stakeholders of several communities involved in the project (cf. section II). Firstly, we work as and with adaptation experts. Secondly, we tend to share the perspective that STS have on climate adaptation as a wicked problem. Being active at the interface between science and decision-making, we take the risk at “becoming arrogant in our attempts at describing and prescribing the shape” this interface should have (Blanchard, 2011, p. 26). We have striven to mitigate this risk through a sustained dialogue between the actors involved in the project and continuous displacements, from one perspective to another, in order to vary viewpoints:

“If I want to be a scientist and reach objectivity, I have to be able to travel from one frame of reference to the next, from one standpoint to the next. Without those displacements, I would be limited to my own narrow point of view for good. [...] (Latour, 2005, p. 146)

“Observing a controversy is like setting up a scientific lab: the quality of observation depends on the capacity to multiply the number and increase the sensitivity of monitoring devices”. (Venturini, 2010)

This attitude is common to approaches grounded in constructivist epistemologies (Andreewsky et al., 2006; Bachelard, 2013; Le Moigne, 2007; Valéry, 1992; Vico, 2001). These regards how knowledge is produced and question what a “valid knowledge” is. They focus on the interaction between the ones who observe and what is observed, “reincorporating the subject into knowledge, a knowledge he produces and which produces her” (Morin, 1967). They attempt to describe the action in its context, focusing on connections, conjunctions, and associations instead of breaking down and atomization. They aim at understanding how things hold together. A direct consequence is to acknowledge that things which are always constructed can be well or badly constructed and might be deconstructed and recomposed (Latour, 2010).

This background defines our guiding principles all along the research to frame the questions but also to design a robust and rigorous research protocol and conduct operationally the inquiry, as presented in the next section.

II. RESEARCH PROCESS

We have been able to conduct this work through the original design of an “embedded research”. We needed to ensure we could both access to the case we intended to study and interact with actors in order to test the approach we were proposing. The necessary condition was therefore to find complementary partners both interested by the topic and open to our method. Indeed, the epistemic foundations and methodological choices we have introduced are more than just the initial posture or an ex-post rationalization of what we did. We have tried to embody them at each step of our research, from our dive in the literature to the reports we wrote, from data collection (especially interviews) to the test of actors’ reactions to our results. This section presents the design the project then the operational protocol we collectively set up to enable this research to happen.

1. A “embedded research” setting

Project’s Partners

This research project involved four organizations and their representatives in addition to the PhD candidate, its supervisors and laboratory. On one side, there are specialists of the climate issues: ADEME – The French Environment and Energy Agency and I4CE – The Institute for climate economics (Table 1-1). On the other side, there is the socioeconomic actor potentially very affected by climate change and key player of the studied system: SNCF.

We present SNCF in more detail in Chapter 3, section I. During our research we have more directly worked with two specific departments of the company: The Sustainability department (3D) of the “Group SNCF” and the Sustainability and environment (DEDD) of SNCF Réseau¹⁴. Those departments are officially in charge of climate change related-issues, both mitigation and adaptation. They are respectively reporting to the General Secretary of SNCF in charge of public affairs and to the Deputy CEO of SNCF Réseau. According to SNCF sustainability director, the critical challenge for adaptation is to achieve mainstreaming long-term issues is short term decision-making (Dubost, 2017): “How are our current practices designed to self-replicate and how does climate change question them?”.

¹⁴ <https://www.sncf-reseau.fr/fr/a-propos/developpement-durable/gouvernance/organisation-interne> - last accessed May 2018

Table 1-1 - Partnering organizations working on climate change, doing research, providing tools, expertise and support

| | |
|---|--|
| <p>ADEME: The French national environment and energy agency.</p>  <p>www.ademe.fr</p> | <p>“ADEME is active in the implementation of public policy in the areas of the environment, energy and sustainable development. It provides expertise and advisory services to businesses, local authorities and communities, government bodies and the public at large, to enable them to establish and consolidate their environmental action. As part of this work the agency helps financing projects, from research to implementation, in its areas of action”. It especially runs a PhD program¹⁵ to “foster the production of new scientific and technological knowledge, with a desire to use the results”. This thesis is part of this program and intends to contribute to the “axis 5” dealing with socio-economic aspects of a transition to a low carbon resilient economy (behavior foresight, modelling, innovation, governance, monitoring and evaluation of adaptation, etc.) (ADEME, 2015). As written in our initial proposal, this project sought to improve our understanding of local decision-making situations to improve adaptation governance and allow better informed and better equipped choices. We had regular interactions with ADEME experts on issues related to buildings and sub-national adaptation.</p> <p>For more on ADEME works on adaptation and adaptive management see: (ADEME, 2013a, 2013b; ADEME & Météo-France, 2011)¹⁶.</p> |
| <p>I4CE – Institute for Climate Economics</p>  <p>www.i4ce.org</p> | <p>“I4CE is a think tank that provides public and private decision makers with expertise on economic and financial issues related to energy and ecological transition”. I4CE has been working on adaptation since 2008 with recent development on barriers to adaptation in France (Simonet & Leseur, 2015) and adaptation finance (Leseur, 2015). In 2012-14, the think tank contributed to a research project called ADAPTATIO (Nassopoulos et al., 2014) which proposed decision-making tools to take climate changes into account in urban-planning operations. This experience raised questions about the relevance and usability of economics to mainstream adaptation in such complex projects. These experience and similar questions being raised in the literature (Watkiss & Hunt, 2013) fostered I4CE’s interest for these issues. For I4CE, this thesis helped to develop an internal expertise on adaptation and to take position on this topic. It contributed to identify actual research-actions gaps and to propose options to bridge them.</p> |

¹⁵ <http://www.ademe.fr/en/the-thesis-programme> - last accessed May 2018

¹⁶ www.ademe.fr/expertises/changement-climatique-energie/passer-a-laction/comment-sadapter-changement-climatique/publications-outils-collectivites-territoriales - last accessed July 2018

CEARC – University Versailles

Saint-Quentin en Yvelines



www.cearc.fr

The CEARC is a research lab working on Cultures, Environments, Arctic, Representations, and Climate. The team working on adaptation focuses on “the study of the interactions between human societies and their changing environment within the various conceivable sustainability paths”. Its research is “based first of all on a postulate: repeated, invasive, global crises and the accumulation of pernicious problems are not attributable to practices that are would be able to reform gradually and marginally, but to a deficit of sustainability of our policies, or even the socio-political system itself. In this sense, the transition to sustainability is a radical transformation, taking place over a long period of time, by paths that are far from being straight and for which we can observe accelerations, slowdowns and even backtrack”. This thesis offers a particular case, studying a specific “corporate”/organizational culture.

Source: Author






Steering committee: a room for actual discussion.

A steering committee, involving representatives of all these partners, has followed the project since the beginning. Its members were an ADEME engineer, the head and a project manager of SNCF 3D, the head and a project manager of SNCF Réseau DEDD, I4CE’s director and the two academic supervisors of this PhD.

We hold five meetings of about two hours each between November 2015 and April 2018, either at I4CE, SNCF or SNCF Réseau. Each meeting gave rise to minutes sent to participants and sometimes to further reactions by emails. This steering committee rapidly became a moment of living discussion between partners, who have progressively learnt to know each other. Every meeting had its specific agenda but, generally speaking, the steering committee helped to frame the project objectives and process, it monitored progresses, provided solutions to unlock situations and move forwards (e.g. contact details, official requests, etc.), discussed preliminary results and validated each step (Figure 1-3). We for instance talked about the relevant framing of the research (“we can’t choose only one component of the infrastructure, we need a systemic understanding” - minutes of the 1st meeting), the right scoping for the case-study or the complementary dimensions to test (“economic decision-making tools are interesting but we also need narratives, stories” - minutes of the 4th meeting).

The committee experienced a small turnover with four persons being successively replaced during the project. This turnover, common in the corporate world recalls that adaptation can only be an iterative subject with necessary repetitions.

Figure 1-3 - Examples of items on the agenda of the steering committee discussions

| | | |
|----------------------------------|---|---|
| <p>Meeting #1 02-09-2016</p> |  | <p>Mutual self-introduction: learning to know each other's Project's design, agenda Research method</p> |
| <p>Meeting #2 06-09-2016</p> |  | <p>Preparation of fieldwork: first persons to contact Framing the case study: objectives and scope Communicating about the first steps</p> |
| <p>Meeting #3 12-05-2016</p> |  | <p>Sharing key messages from the review of the literature First outcomes of the exploratory interviews News from partners, what's going on on adaptation Take home messages of first articles</p> |
| <p>Meeting #4 07-11-2017</p> |  | <p>Designing an experimental device and organizing a workshop Feedback and first outcomes from the workshop Final steps and last questions Communicating on the results</p> |
| <p>Meeting #5 12-20-2017</p> |  | |

Source: Author

Everyday work: from one site to another.

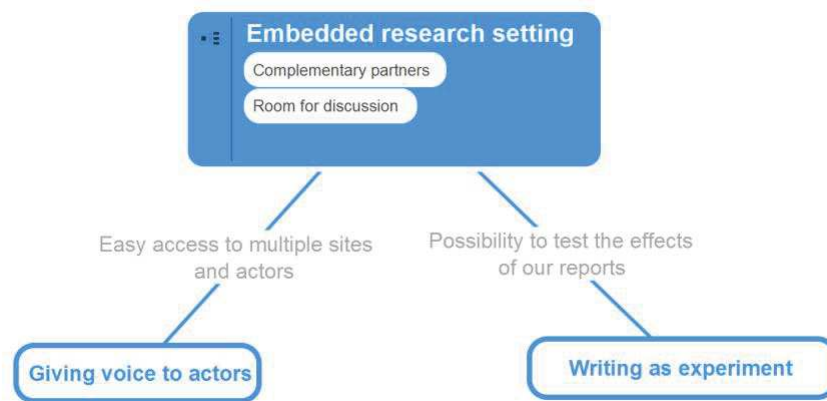
Day-to-day work took place at I4CE, immersed into the universe of adaptation research and expertise, interacting with ongoing action-research projects or training activities. We contributed to side projects on adaptation with local authorities or private companies (e.g. Consortium Projet RISC, 2017; Dépoues, Granger, & Leguet, 2018; Dépoues & Hainaut, 2018; Leguet & Dépoues, 2018)); we represented I4CE to working groups (e.g. concertation for the renewal of the French National Adaptation Plan (ONERC, 2018), OECD expert panels, ADEME jury, etc.); we attended and participated to major meetings on adaptation in France (e.g. 14th International Weather and Climate Forum, (Daudier, 2017; Dépoues, 2017a)) and Europe (Adaptation Future 2016, ECCA 2017 (Dépoues, 2017b)) and we wrote notes and policies briefs on those topics (e.g. (Cochran, Dépoues, Hubert, & Nicol, 2017; Dépoues, 2016; I4CE, 2018)).

We had regular communications with our SNCF focal points. This sustained relationship was very helpful to understand and navigate the SNCF context; access news, material and relevant contacts within the company¹⁷.

2. Research protocol

This original research design provided us with the necessary conditions to implement the methodological choices described above (Figure 1-4). We could collect material and obtain data (Latour, 1993) on several sites with an easy access to actors. We could write our reports and test their effect on actors.

Figure 1-4 - A research setting to implement our methodological choices



Source: Author

Collecting data

For the purpose of our enquiry we surveyed several sites both within SNCF and in the world of research and expertise on adaptation to climate change (conference, meetings, literature). We collected information through interviews; reading of the scientific literature; studying material provided by actors and attending or organizing meetings and workshops.

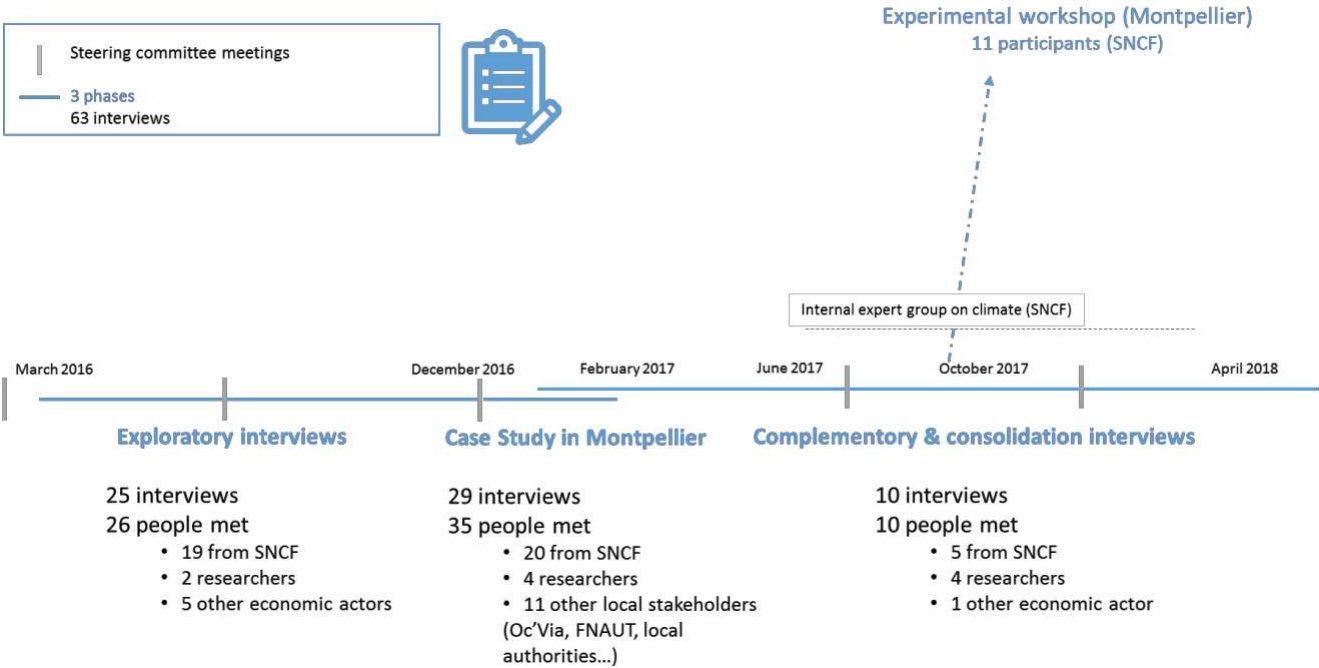
A key strength of this project was to be able to access very easily original and first-hand material from SNCF. This material included emails, notes, internal procedures and standards (e.g. “référentiels IN), presentations, minutes of meetings, maps, studies reports, feedback forms, extracts of databases, and photos. Moreover, we did not analyze this material disconnected from its context but in direct interaction with the contextualization proposed by

¹⁷ Apart from steering-committee meetings, punctual interactions existed with ADEME regarding the project through reporting and contingent conversations.

those who produced, used or exchanged it. This immersion within SNCF universe has been a key factor of success of this research. It took many forms, from direct and sometimes sustained conversations with people working on several sites and departments of the company to a facilitated access to the news and updates about ongoing studies or projects and direct involvement into internal experts' working-groups on adaptation to climate change¹⁸.

Our enquiry was structured around three successive rounds of interviews, complemented by continuous bibliographical work. We first conducted 25 exploratory interviews mostly in the region of Paris, then a detailed regional study in the region of Montpellier with 29 interviews (35 persons met), the organization of a focus group and, eventually, a consolidation phase with 10 additional interviews¹⁹(Figure 1-5).

Figure 1-5 - Three stages of material collection



Source: Author

¹⁸ As described in Chapter 3 we attended and contributed – similarly to other experts in the company – to three meetings of the « Synapse » group on climate and related workflow.
¹⁹ Details on the methodology are provided in each corresponding chapter.

Interviews

Those interviews were all semi-directed and spread between people working at SNCF (n=44) and external experts (n=27). Each interview lasted in average 50-60 minutes with the shortest being 32' and the longest 95'.

We followed a common procedure from request by email to analysis. Our initial introduction included a description of the project, partners and objectives of the interview. It also refers to a written ethical procedure the project coped with (cf. appendices). We recorded most of the interviews.

Questions asked evolved depending on the research step but generally dealt with relationship to weather and climate; knowledge on climate change, adaptation and resilience; relationship to researchers and science and processes of decision making – role of economics; risks and uncertainty management processes; relationships to the future.

We identified people to interview first through recommendation of the steering committee (in particular to identify SNCF experts) then by snowball sampling and contingently.

Most of the interviews took place on interviewees' working sites. Some of them could then be complemented by demonstrations (e.g. used software or databases) and visits (e.g. of the *Centre National des Opérations Ferroviaires*, a *technicentre*, or *railway installations on coastline*).

Analysis and writing: "writing does not freeze, it makes possible to manipulate the material".
(Lejeune, 2014, p. 31)

We have been analyzing this material as we went along (Becker & Richards, 2007; Venturini et al., 2015). As introduced in the first section of this chapter, we associated two complementary moves rooted in ANT (i) and IGT (ii):

i. Writing risky accounts

As advised by Latour, we kept virtual notebooks "to keep track of all our moves" (Latour, 2005, pp. 133–135), considering that "everything is data": interviews, but also telephone calls, meetings, coffee-discussion with colleagues, side-projects, etc. We had a first inquiry log to register all the details about what we did, a notebook to gather information chronologically and dispatched in categories that evolved all along the process, files for

“ad libitum” writing trials and eventually records of the effects of what we wrote on the actors themselves. With them we have been writing and rewriting descriptions at almost any step of the process. Texts under several forms, have been our labs:

“The text, in our discipline, is not a story, not a nice story. Rather, it’s the functional equivalent of a laboratory. It’s a place for trials, experiments, and simulations. Depending on what happens in it, there is or there is not an actor and there is or there is not a network being traced. And that depends entirely on the precise ways in which it is written and every single new topic requires a new way to be handled by a text. Most texts are just plain dead. Nothing happens in them.” (Latour, 2005, p. 149)

Notes proposed to some of the people we met, steering-committee presentations, intermediary reports helped us to check what our descriptions produced on the actors. A scientific paper formalized a version of our results for each stage of the research (Dépoues, 2017c; Dépoues, Vanderlinden, & Venturini, 2018; Dépoues, Vanderlinden, Venturini, & Jézéquel, 2018). Analysis and writing have thus grown up together in an “organic” way. Through writing we could identify the implicit jump with no evidence or trace, so we could go back to the field and try to find where we lost the track and look for the missing pieces.

ii. Formal categorization

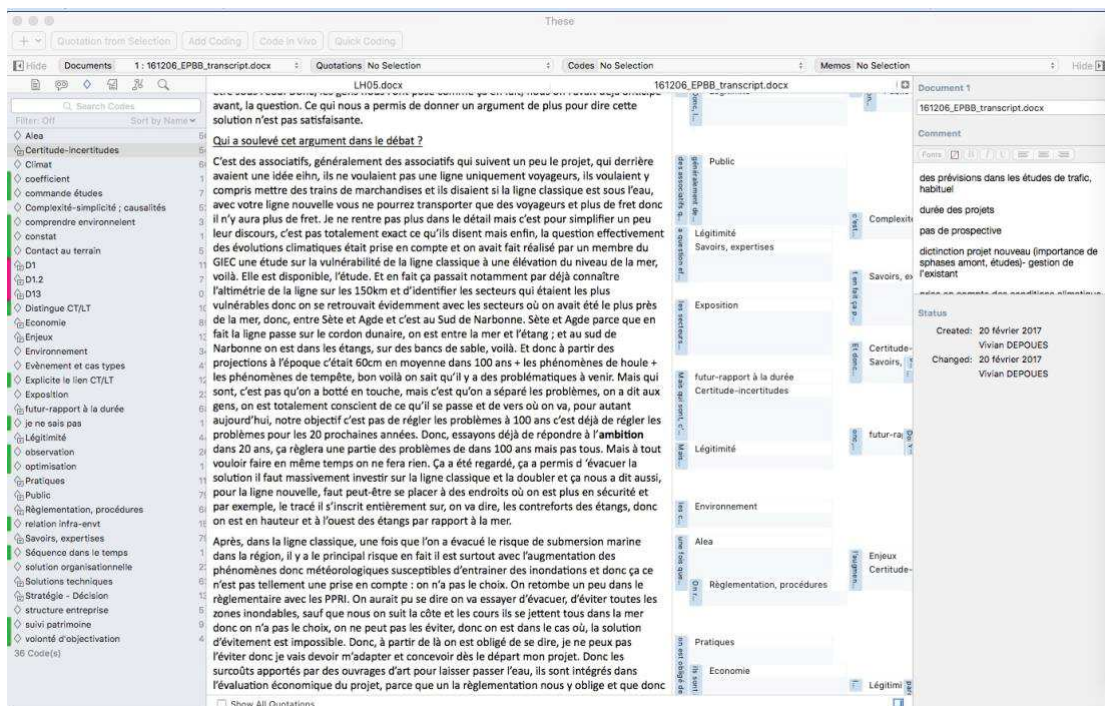
The second move, based on the set of formalized rules proposed by the grounded approach, conducted us, at three moments of the research to step back, put aside what we had read and written until then to take a different look at our corpuses. These moments allowed us to connect the empirical material to adaptation heuristics by looking for relevant articulations between properties emerging from the material (but without forcing any element to fit with preexisting categories).

In order to do so, we taped and anonymized all the interviews, then we organized these transcriptions with a software designed for qualitative research called Atlas.ti (Frieze, 2015; Lejeune, 2014)(Figure 1-6). Starting with samples of this material we examined it to identify and label (code) salient categories. Coding is a three steps process: at the beginning we open many analyses tracks out of all the properties visible in the corpuses (open coding), then, we look for articulation between those properties (axial coding) and eventually, we select the most relevant relationships to build integrated analytical systems (selective coding). By progressing in this coding-process we managed to groups labels in

broader categories and to select representative quotations (Ryghaug & Solli, 2012). Then we tried to bridge those emergent categories with concepts existing in adaptation literature.

This is still a qualitative and iterative process, going back and forth from the corpuses (two sets of interviews and record of a focus group) to the literature. It led us to discover and read more on various aspects of the contemporary science (Lejeune, 2014, pp. 19–39).

Figure 1-6 - Screenshot of the working interface while analyzing a transcript on Atlas.ti



Source: Author

CONCLUSION OF THE CHAPTER: BENEFITS AND LIMITATIONS OF THE APPROACH

As explained above, the design of this project and the approach we used allowed us to propose an original and grounded perspective on adaptation to climate change of a complex sociotechnical system. Research on adaptation is rapidly growing but very often focusing on a few types of accessible systems such as cities. The role and internal processes of companies and utilities is barely documented beyond what they voluntarily report or answer to official consultations (Berkhout, 2012; European Environment Agency, 2014; Stecker et al., 2011) Being able to analyze the French railway system, “from the inside” thanks to the access we got to SNCF staff and material is probably a key strength of our research.

The right location for the right balance between research and operationalization

Designing the project and gathering on paper the conditions to access this fieldwork was only the first step. What has guaranteed the success of this approach is the total freedom of movement and independent writing we experienced through the whole process. Every partner has fully played the game. SNCF representatives were convinced by the potential added value of such a project²⁰ and gave their opinion about the results but always accepted to listen to the conclusions and never attempted to intervene on what was published.

Working with I4CE and SNCF, we were strategically located at the interface between climate and railway expertise, between research and operational services. We had everything we needed to become familiar with the frame of reference, habits, concerns and jargon of different groups of actors. This was a critical condition to be able to test *in situ* how social inquiry can operationally be mobilized and what it can bring to ongoing debates.

Applying the principle of social inquiry to identify solid traces takes time. Three years is a relatively short period for a qualitative research starting from scratch, while it is rather long for a company (for instance if we compare to studies commissioned to consultancy firms which usually deliver in less than a year). Through continuous interactions – rather than relying only on a final report – we found the right balance to provide meaningful elements to partners²¹ and be able to perform a deep analysis of the situation. Some of our focal points also appreciated this extended format and noticed that our regular interactions enabled them to progressively become familiar with the topic and build their own understanding of the issues at stake: “when we take time to understand each other, we manage to do things, to change our own perspective”. This thesis managed to open a modest space for collective deliberation and learning on climate impacts: being during interviews or meetings.

Symmetrically, we encountered the inherent drawbacks to such an embedded approach.

First, it has not always been easy to stick to a strict research posture. We regularly had to argue – especially during meetings of the steering-committee – to stick to observation when some demanded more proactive propositions:

²⁰ Which was actually multiple, including this of having something to report to demonstrate they were doing something about adaptation (SNCF, 2017c)

²¹ We presented for instance our fieldwork as a way to talk about adaptation within the company and so to raise awareness on this topic.

“The purpose of this PhD is to provide elements of understanding on why/how the scientific information is or is not used, not to use it.” Quote of the minutes of the 3rd steering-committee meeting

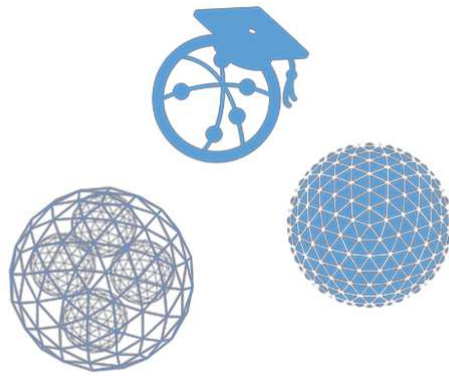
Description only, is indeed something quite unusual for a company which has an operational focus. The balance we mentioned above had to be continuously renegotiated for every partner to get useful insights from this research and for the research to meet the rigor and precision of an actual scientific work.

This was also a question of how we organized our planning to both go deep enough in every aspect and address the variety of questions raised by the partners. Once again it has been a matter of balance between providing a satisfying overview of adaptation as a problem and choose the most relevant aspect for an in-depth analysis. At several points on the road, this PhD could have chosen more specific paths to study²² but favored the transversal landscape.

As this description took time, we could not go as far as we would have liked on experimenting alternative decision framings or tools. This was indeed one of the initial objectives of this project. However, just applying a form of economic calculation or building a specific visualization of an adaptation decision, without integrating it to an existing process did not appear so relevant. The main outcome of the dissertation is therefore to propose key elements to formulate the relevant economic questions and to refer to possible existing methods to handle those questions.

We discuss in the conclusion what this research can tell about adaptation of other organizations beyond SNCF. We did not realize at the beginning how specific SNCF was, because of its organization, history and the role it plays in France. Facing the complexity of this organization, our work progressively focused on this company. We decided to study the French railway system through the lens of this main actor. Where we started at SNCF 3D and the complexity of this organization maybe prevented us from giving the rightful place to other major players such as other mobility companies of Regional councils. This is a choice we assume and which introduced limits in interpretation that we have to keep in mind.

²² For instance: doing an ethnography of the standardization process at SNCF – how weather variables were defined and redefined; comparing how cost-benefit analysis is used as a decision-making tool in SNCF and other contexts; proposing a deeper analysis of the management tools we observed – ex. Weather services of incidents-database.



"Ce monde est ce que la science lui fait."
Isabelle Stengers

Chapter 2 - From scientific knowledge on climate change to adaptation of railways.

State of the art

Our inquiry begins in the library, or more accurately on the online databases of our library, looking at how climate change is pictured and addressed in the literature. We start with the scientific literature synthesized in IPCC assessment reports, in order to understand the multiple perspectives on climate change and adaptation that coexist behind the general consensus on the reality of the challenge. Then, we look at the grey literature - institutional and sectoral reports and strategies - to get an appreciation of how administrations and businesses take these issues and how they have been responding until now, through public or private policies.

I. A KNOWLEDGE BASE ROOTED IN CLIMATE-SCIENCES: STRONG EVIDENCE OF A COMPLEX PHENOMENON

1. *A major certainty: we are exiting a window of very stable conditions*

“The literature available for assessing climate change impacts, adaptation, and vulnerability more than doubled between 2005 and 2010, allowing for a more robust assessment that supports policymaking” [...] Rapidly advancing climate science provides policy-relevant information that creates opportunities for decision making that can lead to climate-resilient development pathways [...]” (IPCC, 2014c, p. 171)

These two sentences are the “Point of Departure” of the contribution of Working Group II - dealing with Impacts, Adaptation and Vulnerability - of the Intergovernmental Panel on Climate Change to its Fifth Assessment Report. This scientific knowledge periodically assessed by the IPCC provides the basis for most discussions and responses regarding climate change.

It gives a clear overview of a rich and diverse science (IPCC, 2014, Chapter 1). Literature published on the topic of climate change between 1970 and 1990 focused primarily on changes in the physical climate system and how these changes affected other aspects of the Earth’s physical environment. It now encompasses studies on many socioecological and

economic systems and covers issues of ethics, equity, and sustainable development. Climate change sciences deal with all spatial and temporal scales: from global to local mechanisms; from paleoclimatology to climate projections for 2100. It is a living and very productive research-field.

In spite of the richness and complexity of climate science, a strong consensus about the main aspects of the situation has emerged and has been described in the IPCC reports. Our climate is changing and human activities are the main driver of this change: “It is extremely likely [i.e. > 95% probability] that human influence has been the dominant cause of the observed warming since the mid-20th century” (IPCC, 2014b, p. 4).

Scientists first report about observed and projected changes in averages, regarding key climate variables such as temperature, or sea level:

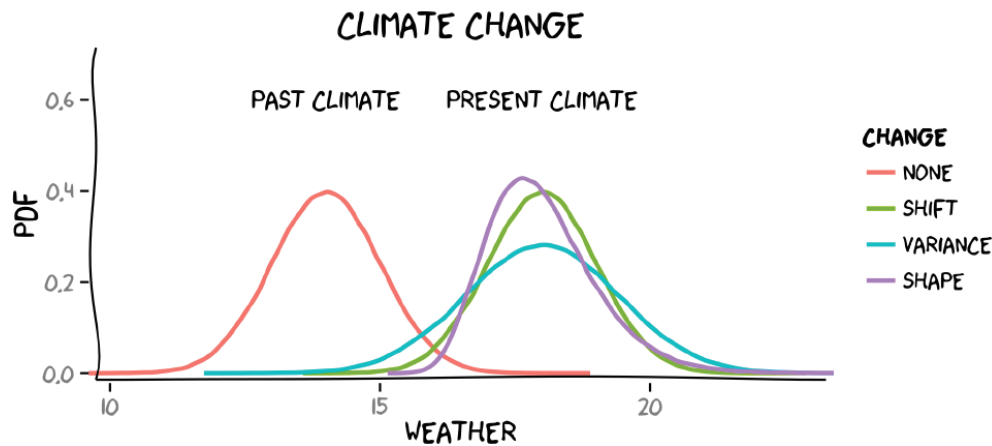
“The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 [0.65 to 1.06] °C over the period 1880 to 2012” (IPCC, 2014b, p. 2)

“Relative to 1850–1900, global surface temperature change for the end of the 21st century (2081–2100) is projected to likely exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (high confidence). Warming is likely to exceed 2°C for RCP6.0 and RCP8.5 (high confidence), more likely than not to exceed 2°C for RCP4.5 (medium confidence), but unlikely to exceed 2°C for RCP2.6 (medium confidence). The increase of global mean surface temperature by the end of the 21st century (2081–2100) relative to 1986–2005 is likely to be 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0 and 2.6°C to 4.8°C under RCP8.5. The Arctic region will continue to warm more rapidly than the global mean.” (IPCC, 2014b, p. 10)

Beyond these averages, there are many specific evolutions of climate processes. Talking about climate is talking about all possible weather situations in one particular place. Climate is defined as the "average weather [...] or as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description,

of the climate system” (WMO²³). Climate change is also the modification of the probability density function (PDF) of possible weather situations (Figure 2-1).

Figure 2-1 - Changing the weather probability density function: means, shape & variance



Source: (Thao, Ribes, & Cattiaux, 2016)

We have a growing understanding of changes in variability - for instance regarding extreme summer temperature (Schär et al., 2004) or seasonality (Cassou & Cattiaux, 2016; Fischer & Schär, 2009). Studies of extremes frequencies and intensity - for instance of heatwaves, hurricane or floods - is another very active research field (Herring et al., 2018; Jézéquel et al., 2018; Ouzeau, Soubeyroux, Schneider, Vautard, & Planton, 2016; Soubeyroux, Schneider, & Ouzeau, 2015; Vautard et al., 2016; Yiou, Cattiaux, Ribes, Vautard, & Vrac, 2018). As Yiou writes, "the average climate changes inexorably while extreme weather events happen randomly but with a law that depends on this average climate" (Yiou & Jouzel, 2015, p. 104).

All this evidence portrays climate change as a phenomenon that questions climate stability experienced in recent centuries. We are exiting a window of very stable conditions and entering an unprecedented world. In any scenario, we have now emitted enough GHG to know that future climate will not be similar to past climate (IPCC, 2014a).

2. Some essential characteristics of climate change

It is very hard to predict what climate change will exactly look like but we have a precise description of some of its major characteristics:

²³ http://www.wmo.int/pages/prog/wcp/ccl/faq/faq_doc_en.html - last accessed June 2018

Multiscalar. Climate change is a global phenomenon with both local drivers and consequences. Beyond global average, it affects each region in a specific way. For instance, when the temperature anomaly in summer in the northern hemisphere was +0.84°C in average over 2017 it was +1.31°C on land (NOAA, 2018). This is even more salient regarding variability. Many weather patterns result from local drivers like specific interactions between atmospheric circulations and the area topography. For example in the south of France, so called Mediterranean episodes (or “episode cevenols”) are particular weather situations in which the influence of the relief is preponderant²⁴ (Jacques, 2016; Vautard et al., 2015). The study of precipitations, in this context, remains a major challenge for climatologists. Current studies show, however, that Mediterranean episodes may be more frequent and potentially more intense at the end of the 21st century.

In addition to global conclusions, the IPCC provides results for nine world-regions. There are also regional reports providing details about more specific contexts. In Europe, the European Environment Agency published every four years a report on *Climate change, impacts and vulnerability in Europe*. “This report is an indicator-based assessment of past and projected climate change and its impacts on ecosystems and society. It also looks at society’s vulnerability to these impacts and at the development of adaptation policies and the underlying knowledge base.” It builds upon a system of indicators updated with information from IPCC as well as “Coupled Model Intercomparison Project Phase 5 (CMIP5) and Coordinated Downscaling Experiment — European Domain (EURO-CORDEX)” (European Environment Agency, 2017a). At a national scale, in France, a series of reports on “the climate of France in the 21st century” commissioned to French scientists by the government, presents the future climate changes across France until 2100 with a 12 km resolution (Jouzel et al., 2014, 2015). Downscaling to reach this precision is one of the main challenges climate scientists face today. They use different methodologies to improve the resolution of projections using statistical techniques or building regional models.

Rapid. The speed is another essential property of ongoing changes. In geologic time scale, the Earth has already experienced climate changes but spread over thousands of years. We

²⁴ “Cevennes storms” or “Mediterranean episodes” are a particular type of rain which mainly affects the Cevennes region, in the south of France and often causes severe flooding. They result from hot, humid and unstable air coming from the Mediterranean, which can generate violent and sometimes stationary storms. They occur mainly in autumn, when the sea is the warmest and evaporation strong. <http://www.meteofrance.fr/actualites/28475438-dossier-episode-mediterraneen> - last accessed February 2018

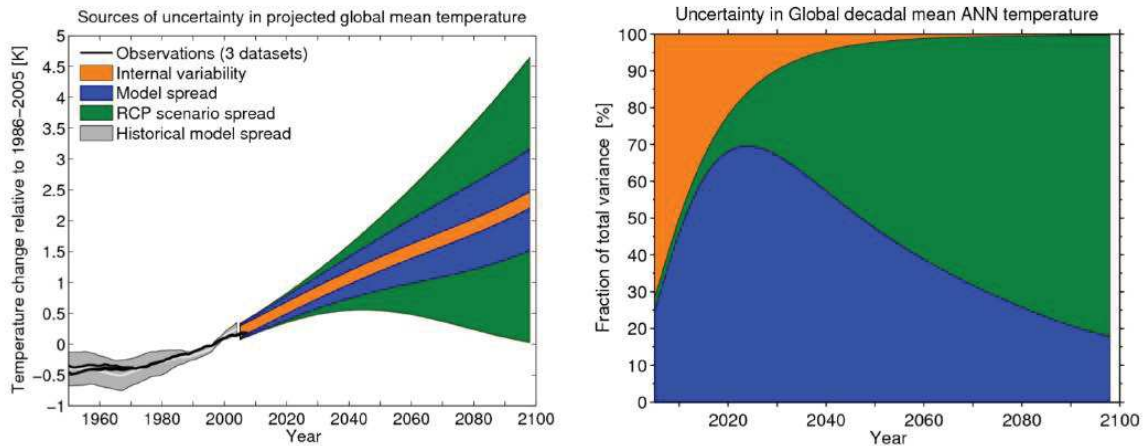
experience climate change today over a human lifetime. We just cannot predict all the possible consequences of such an unprecedented and rapid event. Ruptures, unexpected equilibrium shifts, tipping points are among the possibilities (Cai, Lenton, & Lontzek, 2016; David Tàbara et al., 2018; McNeall, Halloran, Good, & Betts, 2011; Russill, 2015; Steffen et al., 2018; Werners et al., 2013). These are critical issues as we are talking about possibly irreversible effects. The timing and tempo of changes will considerably affect the adaptation capacity of ecological and humans systems (Chavaillaz, 2016; Sippel, Zscheischler, & Reichstein, 2016).

Uncertain and complex. Uncertainties appear to be a critical issue addressed in the literature (Dessai & Van der Sluijs, 2007; Henry, 2013; IPCC, 2014c; Lempert, Nakicenovic, Sarewitz, & Schesinger, 2004; Van Bree & Van der Sluijs, 2014). Reporting on uncertainty ranges around results is part of scientific work. However, communicating uncertainties and how they propagate to various publics can be a tricky challenge (Vanderlinden, 2015; Wardekker, Kloprogge, Petersen, Janssen, & van der Sluijs, 2013). In order to make discussions clearer, scholars often suggest a simple typology of uncertainties:

- Socioeconomic uncertainties (or decision, reflexive or volition uncertainties) depending on how much GHG we will emit in the coming decades (depending on which socioeconomic pathway we will follow);
- Scientific uncertainties (or epistemic) related to our limited capacity to understand and represent the climate complexity;
- Natural variability (or stochastic or ontological uncertainties) related to the nature of the climate system which is chaotic and which behavior at any moment has a strong dependence on initial conditions that are never perfectly known.

Depending on the timescale, each source of uncertainty has not the same importance on future climate projections (Hawkins & Sutton, 2009)(Figure 2-2).

Figure 2-2 - Relative importance of each source of uncertainty in decadal mean surface temperature projections



Source: (Hawkins & Sutton, 2009)

Part of this uncertainty is a deficit of knowledge (i.e. a form of ignorance), which further research might fill (Dessai & Van der Sluijs, 2007; Van Bree & Van der Sluijs, 2014; Van der Sluijs, 1997, 2010, 2012). For some aspects, improving knowledge is just a matter of time or computing power, for others it is about innovation and actual progress in our intellectual capacity to understand and represent physical phenomena (i.e. clarify ambiguities in models²⁵) which is not a linear or predictive process. Another part of the uncertainties will naturally be reduced as we will collectively move forward and make political and economic decisions (e.g. implementing an energy transition or remaining on a business as usual emission pathway).

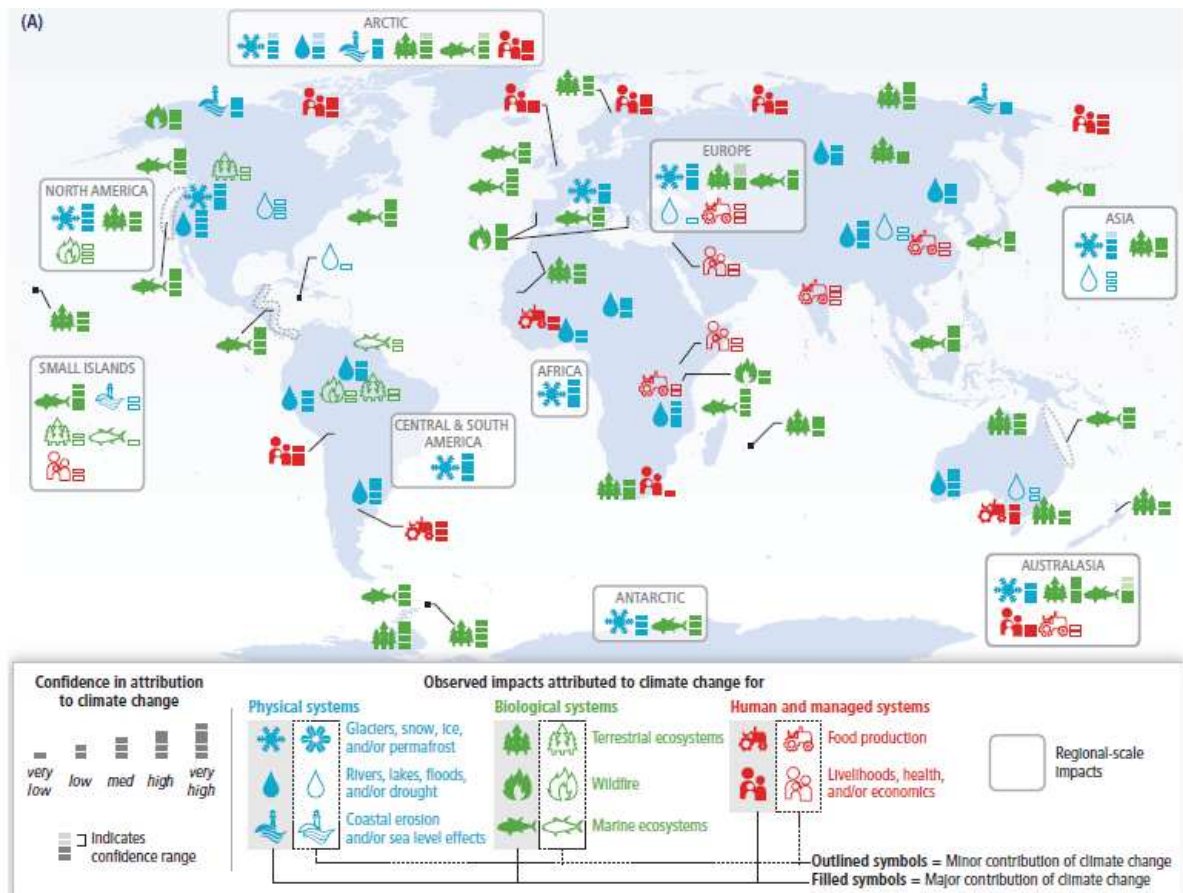
But there is also a final component of uncertainties which is more radical or deep (Guivarch, 2017; Hallegatte, 2009; IPCC, 2014c; Walker, Haasnoot, & Kwakkel, 2013). It is the consequences of the nature of the climate system itself as we usually represent it. This system indeed results of the interaction between multiple components (e.g. the ocean, the atmosphere, the earth-surface but also vegetation, clouds, etc.) involving tens of physical, chemical and biological processes ranging from solar radiations, albedo effect, black-body radiations to living organisms' respiration or geological activity such as volcanoes. As a result, it presents a high level of complexity with all the attributes of complex systems: feedbacks, non-linearities, multiscale, involving very heterogeneous physical processes with highly

²⁵ Being able to model feedbacks for instance is critical to make projections accurate enough. Some processes such as the effect of clouds (Ceppi, Brient, Zelinka, & Hartmann, 2017; Zelinka, Randall, Webb, & Klein, 2017) or melting of the permafrost (Hollesen, Matthiesen, Møller, & Elberling, 2015) are still very difficult to understand and represent for scientists.

different time constants, self-organization and emergent patterns, etc. (Rial et al., 2004). Our modelling capacity is therefore fundamentally limited by a strong dependence on initial conditions with very short predictive horizons. The complexity is even higher when integrating socio-economic processes into the system modelled. Researchers identify some of these radical uncertainties we can call “known unknown” but it is reasonable to assume there are also “unknown unknown” (Carmen Lemos & Rood, 2010; Dessai & Van der Sluijs, 2007; Rayner, 2012; Van Bree & Van der Sluijs, 2014).

With high stakes and impacts. A few years ago, reports on climate change were mainly warning about coming changes. Nowadays they are first reporting about already observed changes and their consequences (Figure 2-3).

Figure 2-3 - Map of observed impacts attributed to climate change in the world



Source: (IPCC, 2014c, p. 7)

Annual reviews from major weather organizations such as the WMO or the NOAA have confirmed that we have recently been experiencing unprecedented weather conditions. For example, 2016 and 2017 were among the hottest years in records (American Meteorological

Society, 2016; NOAA, 2018; World Meteorological Organization, 2018). It affects and will continue to affect all regions and economic sectors. Climate change is investigated as a potential major driver of many problematic situations around the globe: droughts, famines and decreases in harvest, migrations, biodiversity losses, health issues, natural catastrophes or even economic downturns (IPCC, 2014c). In the economic world, climate change has become one of the major identified risks along with extreme weather events and natural disasters and before cyberattacks of terrorist attacks (World Economic Forum, 2018).

Indicators monitored in Europe and in France are consistent with these global trends (Box 2-1):

Box 2-1 - Some key findings among climate change impacts & vulnerability in Europe

- “Climate change is continuing globally and in Europe. Land and sea temperatures are increasing; precipitation patterns are changing, generally making wet regions in Europe wetter, particularly in winter, and dry regions drier, particularly in summer; sea ice extent, glacier volume and snow cover are decreasing; sea levels are rising; and climate-related extremes such as heat waves, heavy precipitation and droughts are increasing in frequency and intensity in many regions.
- New record levels of some climatic variables have been established in recent years, notably global and European temperature in 2014 and again in 2015, global sea level in 2015 and winter Arctic sea ice extent in 2016. Some climatic changes have accelerated in recent decades, such as global sea level rise and the decline of the polar ice sheets.
- Global climate change has substantially increased the probability of various recent extreme weather and climate events in Europe. The reliability of this finding has been strengthened by recent progress in extreme weather attribution techniques.
- Climate change will continue for many decades to come. Improved climate projections provide further evidence that future climate change will increase climate-related extremes (e.g. heat waves, heavy precipitation, droughts, top wind speeds and storm surges) in many European regions.
- Climate change has wide-ranging impacts on ecosystems, economic sectors and human health
- Different regions and sectors in Europe are affected differently by climate change
- Climate change impacts interact with other developments inside and outside Europe. [...] Future climate change will interact with other socio-economic developments. [...] Europe is vulnerable to climate change impacts outside Europe
- Mitigation of climate change is required to limit the long-term risks from climate change. The magnitude of future climate change and its impacts from the middle of the century onwards depend on the effectiveness of global climate mitigation efforts.
- Adaptation to climate change is necessary to reduce short- and long-term risks from climate change.

Source: www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016/key-findings - last accessed April 2018

In France, the National observatory on the effects of global warming (ONERC) provides a set of 28 indicators to describe the state of the climate and its impacts. Followed by national research centers for different types of environments, those indicators for instance deal with

temperature and precipitation, agriculture (e.g. date of the beginning of grape harvest) or health (population exposure to climate risks):

“The evolution of average annual temperatures in metropolitan France shows a warming since 1900 with a particularly marked increase since the 1980s. Over the period 1959-2009, the observed trend is about + 0.3 ° C per decade. The three warmest years, 2014, 2011 and 2015 respectively, were observed in the 21st century”.

“Today in Champagne, the harvest takes place on average 2 weeks earlier than 20 years ago”.

“Currently 50% of metropolitan French municipalities are exposed (at least moderately) to climate risks”²⁶.

We are thus facing a high-stake phenomenon with very strong and growing consequences to economic and social systems. The emission pathway we will follow is the first factor determining the level of impact we can expect, especially for the second half of the century.

II. FROM SCIENCE TO DECISION: A PROBLEMATIC INTERFACE

1. *A science made to be “policy-relevant” for adaptation*

Compiled in reports such as the IPCC assessments, the EEA reports or the national reports and databases we mentioned, this knowledge is intended to be “policy relevant” (IPCC, 2014a). Most of the knowledge infrastructure built around the question of climate change are designed to provide *useful science*²⁷ (Carmen Lemos & Rood, 2010; Edwards, 2010). As Van der Sluij already noted in 1997, “important trends in the [...] history of climate change analysis were a shift from scientific-curiosity-driven towards issue-driven research, an increased demand for assessment of the risks of climate change, and an increased demand for analysis of the policy-meaning of the knowledge and theories about the human influence on climate” (Van der Sluijs, 1997, p. 18). More recently, Wise et al. observed “a growing intensity of calls for more decision-oriented research [...]. as priorities have moved from estimating impacts and vulnerabilities in order to make the case for mitigation, to adaptation planning and action in a world that is looking less and less likely to stay within 2°C of global warming” (Wise et al., 2014).

²⁶ <https://www.ecologique-solidaire.gouv.fr/impacts-du-changement-climatique-atmosphere-temperatures-et-precipitations> - last accessed March 2018

²⁷ Actually, Guillemot has even shown that weather then climate sciences have been developed since 1945 with operational, military (in the context of the Cold War) and political goals (Guillemot, 2007).

Authors generally assume that this corpus of knowledge will be useful to drive adaptation. The IPCC defines adaptation as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects” (IPCC, 2014c, p. 1758). In the summary for policy makers of the last assessment report, we can read that “limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.[...] Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change.” (IPCC, 2014a, p. 8).

With this last report, this notion of adaptation gained a larger understanding. Initially limited to adjustments, it now encompasses a broader range of possible responses. It also comes with several related concepts such as adaptive capacity or transformation within the more general framework of “iterative risk management”. Simonet analyzed these conceptual advances on adaptation across the five IPCC reports from 1990 to 2014. He noted that “comprehension of adaptation has evolved considerably since its recognition as a response to climate change in the 90s” with “[...] a shift toward a ‘transformation adaptation’” approach being observed” (Simonet, 2015).

However, societal or political uptake of this information is far from being straightforward. Many scholars observe that decision-making “failed: to progress as quickly as once hoped” (J. Porter & Dessai, 2016). “Despite the rapid evolution and growing complexity in models of science-policy interaction, the rate and breadth of the use of scientific knowledge in environmental decision-making, especially related to climate variability and change, remain below expectations” (Kirchhoff, Carmen Lemos, & Dessai, 2013). “Evidence suggests such investments in adaptation science have not necessarily translated into adaptation implementation” (Preston, Westaway, & Yuen, 2011). There is a persistent “gap” between available knowledge on consequences of climate change and the observed response from society (Briley et al., 2015; Carmen Lemos, Kirchhoff, & Ramprasad, 2012; Flagg & Kirchhoff, 2018; Kiem & Austin, 2013).

According to Hulme, we struggle to take full consideration of the results from climate science, not because the society does not know about them, or because they are not clear enough but

because drawing the relevant implications of these results raises difficulties. What should we do with this knowledge, what does it do to us? When socialized, it becomes problematic. “We disagree about science because we have different understandings of the relationship of scientific evidence to other things: to what we may regard as ultimate 'truth', to the ways in which we relate uncertainty to risk, and to what we believe to be the legitimate role of knowledge in policy making. [...] We need to appreciate that such knowledge can be (perhaps inevitably will be) transformed in the process of leaving the laboratory and entering the social world” (Hulme, 2009, p. 103). Hulme shows how climate change has moved from being predominantly a physical phenomenon to being simultaneously a social phenomenon offering contrasting interpretations and narratives.

Scientific knowledge about climate change conveys representations and worldviews that can be very disruptive or controversial. Richard for instance writes about an “unprecedented posture of awareness of the adaptations of humans to their environment” [...]. According to her, “climate change reminds modern man his forgotten interdependencies”, and “questions human beings over themselves” (Richard, 2016, p. 29). Godard talks about adaptation as a relationship of “entanglement” between the climate and socio-economic and natural systems (Godard, 2010).

2. A post normal framework for wicked situations

We understand that climate science and society are entangled in complex ways. Simple representations of a linear diffusion from science to socio-economic decision are of little help. The interface between science and decision is problematic. There were many attempts to propose alternative models that would be more operational. Proposed frameworks put the complex relationship between the climate system and our sociotechnical systems at the heart of the responses to the challenge. According to them, we have to adapt in and with this context of uncertainty.

This ends up favoring certain types of adaptation. For instance, Kirchhoff et al. write about an “effective management processes [which] will be iterative, consultative and holistic, and above all acknowledge the assumptions embedded in any conclusions” (Kirchhoff et al., 2013).

This type of posture is well reflected in frameworks such as the one of post-normal science, suitable to address “wicked problems” as defined by Rittel and Webber (Rittel & Webber, 1973). Developed in a context of planning - especially relevant for some adaptation issues - and later generalized (Conklin, 2005) this label would apply to particular situations, such as those created by climate change, when: problems are not understood until after the formulation of a response; problems have no stopping rule; solutions are never right or wrong; there is no two similar wicked problems; every solution is only valid once; there is no given alternative solutions.

As we have briefly shown, with climate change, (a) facts are often uncertain, (b) stakes are high, (c) values are in dispute and (d) urgent decisions need to be made (Funtowicz & Ravetz, 1993; Kønig, Børsen, & Emmeche, 2017). Because of those characteristics, it has been analyzed as a “post-normal” issue (Blanchard, 2011; Dankel, Vaage, & Van der Sluijs, 2017; Krauss, Schäfer, & von Storch, 2012; Petersen, Cath, Hage, Kunseler, & van der Sluijs, 2011). In such a context, those authors advocate for a reconfiguration of the science-policy interface towards more interdisciplinarity and more transdisciplinarity (i.e. a science opens on various forms of knowledge), more reflexivity and a stronger participation of all stakeholders. For Da Cunha and Vanderlinden it is for instance “necessary to build a space of integration of natural sciences, social sciences and human sciences in the analysis of the dynamics of adaptation to global changes” (da Cunha & Vanderlinden, 2014).

Frameworks, tools and methodologies were developed to operationalize this conception. They share some key principles among which:

- A strong attention given to local-contexts elucidation with no “on-size-fits-all” approach (Magnan, 2010);
- A participation framework to involve relevant stakeholders (Carrozza, 2015; Jasanoff, 2004)²⁸;
- A proactive and iterative approach relying on monitoring and learning systems more than a command-and-control process;

²⁸ Recent works nevertheless show that implementing such approaches also implies risks and is not a guaranty for success (J. Porter & Dessai, 2016).

- The conviction that we need to “work deliberately within imperfections”(Van der Sluijs, 2012). These approaches call for moving beyond the “uncertainty fallacy”: “in the context of high uncertainty, decision makers should not look for ‘perfect’ forecasts, but seek to implement knowledge systems that integrate climate projections with other kinds of knowledge and that consider the multiple stressors that shape their decision environment” (Carmen Lemos & Rood, 2010). Richard writes about “accepting ignorance, thinking to the unintended consequences of action, including unpredictable, accepting not to be able to foresee, to improvise - exercises of exploration of the possibilities”(Richard, 2016, pp. 97–98). Da Cunha and Vanderlinden describe adaptation as a concept which intends “to manage the uncertain [and] unconventional” (da Cunha & Vanderlinden, 2014).
- In order to do so, those approaches promote to use climate projections as heuristic tools to explore possible futures instead of planning for a unique reference situation. They favor an exploratory over a predict-then-act process (Weaver et al., 2013). “For some scholars, complex models of open systems are best viewed as heuristic tools which help our understanding of what we can observe, measure or estimate, rather than ‘truth machines’ which determine our future.” (Dessai et al., 2009).
- Favoring robustness and flexibility as important decision criteria: “Evidence based policy has to be replaced by robust policy, where robustness is tested with respect to feasibility (compatibility with processes outside human control); viability (compatibility with processes under human control, in relation to both the economic and technical dimensions), and desirability domain (compatibility with a plurality of normative considerations relevant to a plurality of actors)”. (Saltelli, Giampietro, Avon, Ambientals, & Autonomia, 2015).

There is a growing number of tools, including economic tools (Dittrich et al., 2016; Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Hallegatte, 2009; Walker et al., 2013) to identify and evaluate vulnerabilities then appraise adaptation options and support such decisions under deep uncertainty:

“Deep uncertainty exists when parties to a decision do not know, or cannot agree on, the system model that relates action to consequences, the probability distributions to place over the inputs to these models, which consequences to consider and their relative

importance. Deep uncertainty often involves decisions that are made over time in dynamic interaction with the system. “Society for Decision Making Under Deep Uncertainty.”²⁹

We now find communities of experts and professionals such as the Society for Decision Making Under Deep Uncertainty³⁰ working on the development and implementation of such methods. Several recent European projects among which MEDIATION or ECONADAPT contributed to this knowledge base and provided complete toolboxes (Box 2-2).

Box 2-2 - Resources and toolboxes for making decision under deep climate uncertainty

MEDIATION: Mediation (standing for Methodology for Effective Decision-making on Impacts and AdapTaTION) is a European project funded from the European Community's Seventh Framework Programme which intended to gather scientific and technical information about climate change impacts, vulnerability and adaptation options which was fragmented and incomplete (Swart & Singh, 2013). A key outcome of the project (along with an Adaptation Pathfinder and a Case Study Navigator) is the MEDIATION Toolbox, a “structured database of methods and tools that are available to support the assessment of climate change impacts and vulnerability, and adaptation decision-making”: <http://www.mediation-project.eu/platform> (last accessed June 2018).

ECONADAPT: “ECONADAPT is an EC FP7 research project whose purpose is to support adaptation planning through building the knowledge base on the economics of adaptation to climate change and converting this into practical information for decision makers. The project is being undertaken by a pan-European consortium led by the University of Bath” (Econadapt Consortium, 2015). A major deliverable of this project is a comprehensive toolbox that provides “easy accessible information on the economic assessment of adaptation”: <https://econadapt-toolbox.eu> (last accessed June 2018).


The IPCC recognized in its fifth Assessment Report the relevance of this general mindset to address some of the climate challenges. In chapter two – titled “Foundations for decision-making” - of the contribution to the Working Group 2 to the report we can read (Table 2-1):

“Complexity is an important attribute for framing and implementing decision-making processes (very high confidence). Simple, well-bounded contexts involving cause and effect can be addressed by straightforward linear methods. Complicated contexts require greater attention to process but can generally be unraveled, providing an ultimate solution. However, when complex environments interact with conflicting values they become associated with wicked problems. [...] In complex situations, sociocultural and cognitive-behavioral contexts become central to decision making.” (IPCC, 2014c, pp. 200–201)

²⁹ <http://www.deepuncertainty.org> - last accessed June 2018

³⁰ The Society for Decision Making Under Deep Uncertainty is a multi-disciplinary association of professionals working to improve processes, methods, and tools for decision making under deep uncertainty, facilitate their use in practice, and foster effective and responsible decision making in our rapidly changing world.”

Table 2-1 - Hierarchy of simple, complicated & complex risks in the IPCC report



| Characteristics of decision making | Simple risk | Complicated risk | Complex risk |
|------------------------------------|--------------------------|--|--|
| Methodology | Linear, cause and effect | Top down and/or bottom up, iterative | Iterative and/or adaptive, ongoing and systemic |
| Approach | Analytic and technical | Collaborative process with technical input | Process driven. Frame and model multiple drivers and valued outcomes |
| Stakeholder strategy | Communication | Collaboration | Deliberation, creating shared understanding and ownership |
| Mental models | Common model | Negotiated and shared | Contested initially and negotiated over project |
| Values and outcomes | Widely accepted | Negotiated over project by user perspectives and calculated risk | Contested initially and negotiated over project |
| Monitoring | Straightforward | With review and trigger points | As real-time as possible, adaptive with management feedback and trigger points |

Source: (IPCC, 2014c, p. 202)

This is a recent evolution in the way IPCC is framing decision-making for adaptation. It comes from a better integration of insights from various disciplines including human and social sciences in response to criticisms received by previous IPCC assessments:

“Previous assessment methods and policy advice have been framed by the assumption that better science will lead to better decisions. Extensive evidence from the decision sciences shows that while good scientific and technical information is necessary, it is not sufficient, and decisions require context-appropriate decision-support processes and tools. [...]” (IPCC, 2014c, p. 198).

However, this view of the science-decision interface, trying to reflect the complexity, is still not the dominant one. Neither the post-normal framework, nor alternative approaches (e.g. (Gibbons et al., 1994; Jasanoff, 2004; Nowotny, Scott, & Gibbons, 2001)), have succeed to penetrate deep enough to broadly spread the form of - contextualized, participative, iterative, working with uncertainties, etc. - adaptation they come with. This representation is only one among many that coexist and lead to multiple approaches of adaptation. The IPCC reports about the coexistence of multiple “ways of knowing” which might be “source of widespread misunderstanding and disagreement”.

Indeed, fieldwork on adaptation demonstrates that, in practice, adaptation remains a polysemous notion (Simonet, 2009) surrounded by many other polysemous and sometimes ambiguous concepts (Gallopín, 2006; Godard, 2010; Kane & Vanderlinden, 2015). There is a great diversity of adaptation approaches, both in scientific literature and in the grey literature

designed to inform adaptation practitioners. Literature talks about adaptation as a process or an outcome (Simonet, 2010), being reactive or proactive, incremental or transformational, spontaneous or planned, local or systemic, more or less urgent, having always existed or totally new, etc. But, as analyzed by Preston et al., those heuristics “often fail to reflect the nuances associated with the practical pursuit of adaptation” because of an “apparent lack of critical reflection upon their robustness” (Preston et al., 2011).

Despite their conceptual appeal, we cannot take a framework such as this of Post Normal Science, for granted. Even if it looks very well fitted to deal with the properties of climate change, such model is not immediately shared. It is therefore necessary to return to the initial perception and representation of phenomenon at work in order to test and refine the interpretive frameworks and adaptation approaches proposed in the literature in real-life situations. We will maybe be able to build on the heuristics developed in these frameworks but not before having connected them to the actual worldviews of actors involved in adaptation. This dissertation intends to contribute to this “reality-checking”, focusing on adaptation of railway infrastructure to climate change.

III. ADAPTATION OF INFRASTRUCTURES TO CLIMATE CHANGE: WHERE ARE WE? FOCUS ON TRANSPORT AND RAILWAYS

1. Active research communities on transports adaptation and resilience

There are active research communities working on resilience and adaptation of transport systems, with dedicated publications (e.g. several volumes of the Journal of the Transportation Research from the US National Academy of sciences (TRB, 2015, 2016, 2017)) and events (e.g., the EU–U.S. Transportation Research Symposium (Turnbull, 2016))(Aparicio, 2017, 2018).

An important part of these researches focuses on technical aspects of adaptation and engineering solutions to reduce vulnerability. However, many authors call for more interdisciplinary work (Jaroszweski, Baker, Chapman, & Quinn, 2013; Jaroszweski, Chapman, & Petts, 2010; Mattsson & Jenelius, 2015) and displace the focus from technical to sociotechnical systems (Amoaning-Yankson & Amekudzi-Kennedy, 2017).

A core body of research is growing to make the relationships between transport systems and weather better known. Climate change appears in this context as an additional motivation to improve our understanding of these relationships. The assumption behind is that increasing resilience to weather conditions will increase resilience to future climate. Resilience is defined here as “engineering resilience” (Aparicio, 2017) or “the ability of a transportation system to withstand shocks, respond appropriately to threats, and mitigate the consequences of those threats” (Amoaning-Yankson & Amekudzi-Kennedy, 2017).

As a result, vulnerability analysis is often the first step of existing work on adaptation (Dobney, Baker, Quinn, & Chapman, 2009; European Environment Agency, 2014; Love, Soares, & Püempel, 2010; Pant, Hall, & Blainey, 2016). The objective is to draw more precise maps of networks vulnerabilities (e.g. for Swedish railway (Lindgren, Johnsson, & Carlsson-Kanyama, 2009)) and to identify critical points (or “hotspots”(Armstrong, Preston, & Hood, 2016)).

A common technique used to improve the understanding of networks’ vulnerability is to adopt an historical perspective. Analyzing past events such as heatwaves (Dobney et al., 2009; Ferranti, Chapman, Lee, Jaroszweski, & Lowe, 2017) or extreme floods (Pams-Capoccioni et al., 2013; Pams Capoccioni, Nivon, Amblard, De Cesare, & Ghilardi, 2015) helps researchers to describe causality-chains from weather impact to consequences on transportation.

The first attempts to consider climate change employ existing climate projections such as the UK09 data-set in the UK (Palin et al., 2013) and a variety of methods. Some focus on frequency analysis (e.g. in Austria (Kellermann, Bubeck, Kundela, Dosio, & Thieken, 2016)) or variability analysis (Love et al., 2010). Others propose to use climate analogues (Dobney et al., 2009; Sanderson, Hanlon, Palin, Quinn, & Clark, 2016) to get a better representations of what future climate will look like through analogy with situations already existing elsewhere.

Modeling methods adapted to specific weather situations and transport modes (Baker, Chapman, Quinn, & Dobney, 2010; Gonzva & Gautier, 2014; Tavasszy, Bollinger, & Dijkema, 2016), innovations in weather services (Pilli-Sihvola et al., 2016) and networks’ monitoring (Chapman & Bell, 2018) are among key building blocks mentioned in this literature to increase the ability to address identified vulnerabilities.

In our review of the literature, we found many case-studies of national contexts, for instance on US networks (Chinowsky, Helman, Gulati, Neumann, & Martinich, 2016), in the UK (Pant et

al., 2016) or in the Netherlands (Oslakovic, ter Maat, Hartmann, & Dewulf, 2012). In many of these studies, the economic consequences of weather have a prominent position in the analysis (e.g. (Doll et al., 2014)). Heat (e.g. through rail buckling (Baker et al., 2010)) and floods are the two most cited hazards

From data to uptake and adaptation

Beyond vulnerability analysis, another growing body of research is dealing with adaptation since the late 2000s. It explores in particular the ways for addressing the increasing frequency and intensity of extreme weather events (Stamos, Mitsakis, Salanova, & Aifadopoulou, 2015).

This is a technical issue but also a matter of governance (Kwiatkowski & Chinowsky, 2017; Rotter, Hoffmann, Pechan, & Stecker, 2016) with knowledge uptake and management questions (Ryghaug & Solli, 2012). Some authors develop conceptual frameworks (Chappin & van der Lei, 2014; Eisenack & Paschen, 2016) and decision making tools for adaptation, highlighting the importance of criteria such as flexibility and robustness of decisions (Armstrong et al., 2016; Kiel, Petiet, Nieuwenhuis, Peters, & Van Ruiten, 2016). Others monitor actions already implemented (Savonis, Potter, & Snow, 2014) or focus on specific aspects of adaptation like assessment and reporting of physical climate risks (Cochran et al., 2017; Jiricka et al., 2016) or assets management (Meyer, Amekudzi, & O’Har, 2010; Tacnet et al., 2016; Vidaud et al., 2012).

A significant portion of this research is part of national and European initiatives about adaptation (European Environment Agency, 2014). For instance, the situation in the UK is especially well documented because of convergent research and institutional initiatives. On the research side the ARCC network, funded by the *Engineering and Physical Sciences Research Council* “brings together researchers and stakeholders involved in adaptation to technological, social and environmental change in the built environment and infrastructure sectors”³¹. Specifically on railways, the RSSB carried out the TRaCCA project and create a knowledge-sharing platform with a section dedicated to weather and climate change³². On the institutional side, an early and sustained mobilization of authorities (DEFRA, 2013; UK

³¹ <http://www.arcc-network.org.uk> - last accessed April 2018

³² <https://www.sparkrail.org> –last accessed April 2018

government, 2011, 2014) led to the 2008 Climate Act with reporting obligations for actors such as infrastructure managers (ARCC, 2017; Jude et al., 2017; Network Rail, 2015).

At the European level, several research projects supported by the EU addressed the issue of vulnerability and adaptation of transport systems to climate change. Among them, EWENT, ECCONET and WEATHER (Michaelides, Leviäkangas, Doll, & Heyndrickx, 2014); aimed at analyzing projections of the future climate in relation to their impacts and economic implications to the transport system. They covered “all the transport modes as well as all of the critical phenomena present within the European area”. ToPDAd was also an EU-funded initiative which objective was to “develop tools to help European regions adapt to a new climate and avoiding the costly consequences of climate change” (ToPDAd, 2014). MOWE-IT was another project aiming at identifying best practices and developing methodologies to assist transport operators, authorities and users to mitigate the impact of natural disasters and extreme weather phenomena on transport system performance (Jaroszweski et al., 2014). A common knowledge-sharing platform named Climate Adapt³³ (Figure 2-4, Table 2-2) aggregates results from such projects, case studies and material developed to facilitate adaptation (Econadapt Consortium, 2015; European Environment Agency, 2014; Watkiss & Hunt, 2013).

Figure 2-4 – Screenshot of the CLIMATE-ADAPT European Platform



Source: <https://climate-adapt.eea.europa.eu> (June 2018)

³³ <http://climate-adapt.eea.europa.eu/> - last accessed April 2018

Table 2-2 - Assessment of adaptation actions recorded on CLIMATE-ADAPT

| Adaptation action | Technol.innovation | Modal change | Infrastructure | ITCs & Users |
|--|--------------------|--------------|----------------|--------------|
| Research and Studies | | | | |
| EWENT Project | + | ++ | +++ | ++ |
| WEATHER Project | 0 | 0 | +++ | ++ |
| ECCONET Project | ++ | +++ | ++ | + |
| MOWE-IT Project | 0 | ++ | | +++ |
| TOPDAD Project | 0 | ++ | 0 | +++ |
| Vulnerability assessments | | | | |
| Nice airport | 0 | 0 | +++ | 0 |
| Copenhagen airport | 0 | 0 | +++ | 0 |
| Scottish road network | 0 | 0 | +++ | ++ |
| xGEO (Norway roads) | 0 | 0 | ++ | +++ |
| Blue spot concept (roads) | 0 | 0 | +++ | 0 |
| ÖBB database on rail disruption | 0 | + | ++ | + |
| Maintenance & Design | | | | |
| UK railway drainage standards | 0 | 0 | +++ | 0 |
| EC's revision of standards | 0 | 0 | +++ | 0 |
| French revision of standards | 0 | 0 | +++ | 0 |
| Copenhagen metro design | 0 | + | ++ | 0 |
| Contingency and long-term plans | | | | |
| RENFE weather information | 0 | + | + | 0 |
| Long term plans | | | | |
| Working plans for TEN-T priority corridors | 0 | + | + | + |
| DHL: Resilience of future logistics chains | + | +++ | + | +++ |

Source: (Aparicio, 2017, p. 3535)

2. Interaction with institutional and private dynamics

Concomitantly to this research effort, we observe an institutional move towards adaptation of transport infrastructures to climate change. Infrastructures being critical assets of the economy, public authorities face major adaptation challenges (European Environment Agency, 2014)³⁴.

In the coming years, thousand billions of euros will have to be invested in transport, energy, water and telecommunication networks to preserve the connectivity, the efficiency and the resilience of the economies (Dobbs et al., 2013; The new climate economy, 2014; Vallejo & Mullan, 2016)³⁵. This is a window of risk and opportunities to make relevant adaptation choices. On one hand, there is a risk of lock-ins within unfit or maladapted choices creating

³⁴ "Transport is today a critical support system for the smooth operation of our societies and economies. At the European level, the political relevance of transport is high as a necessary instrument for the facilitation of trans-boundary relationships and the physical and economic integration within the EU. Changes in climate could compromise the smooth operation of our societies and the economy."

³⁵ Mc Kinsey Global Institute estimates global infrastructures needs between \$2.5 (current expenses) and 3.3 trillion per year – 40% in developed countries.

situations with systems and capital stocks that would not be able to face or to adapt to climate changes. Many infrastructure related decisions are indeed hardly reversible and create path-dependencies. On the other hand, decisions to be made today are an opportunity to anchor virtuous adaptation pathways.

“Outside rare moments of creation or major transitions, infrastructures change too slowly for most of us to notice; the stately pace of infrastructural change is part of their reassuring stability. They exist, as it were, chiefly in historical time.” (Edwards, 2003)

A 2017 OECD working-paper describes four adaptation challenges to manage those risks and seize those opportunities: (i) improving risk information and assessment to support decision-making; (ii) screening and factoring climate risks into public investments; (iii) enabling infrastructure resilience through policy and regulation and (iv) encouraging climate risk disclosure (Vallejo & Mullan, 2017).

The EU adopted its Adaptation strategy in 2012 (European Commission, 2013b) “to contribute to a more resilient Europe at national, regional and local levels, thereby focusing on enabling Member States and local governments to take action and to mainstream adaptation into different policy areas”. This strategy has specific actions for transports (Action 7) and transversal actions relevant for this sector (e.g. Action 4 on research or Action 8 on insurance). The European Commission also developed series of guidelines to mainstream this concern in major sectoral policies and actions (European Commission, 2013a; European Environment Agency, 2017b) like projects management (European Commission, 2011, 2014) or climate-proofing of major investments (European Commission, 2012, 2015).

This “mainstreaming” approach is visible in policies such as the TEN-T Programme established to support the construction and upgrade of transport infrastructure across the EU. Indeed, this program explicitly mentions adaptation: “during infrastructure planning, Member States and other project promoters should give due consideration to the risk assessments and adaptation measures adequately improving resilience to climate change and environmental disasters (§34, Preamble; Article 35)” (European Environment Agency, 2014, p. 19).

European agencies perform a continuous monitoring of adaptation uptake and actions in national contexts (Isoard & Prutsh, 2014) or sectoral level (European Environment Agency, 2014).

At the national level, adaptation of transport is still at the initial stage, and it is not yet a central issue for national adaptation strategies. Nevertheless, some countries among which the UK, France, Austria, Germany and Switzerland included this sector in their action plans. In its 2014 report on adaptation of transport in Europe, the EEA noted that “the transport sector seems to be very receptive on this topic, and research and vulnerability assessments on transport systems develop rather quickly once the transport sector itself becomes active, usually going well beyond the initial mandate in national adaptation strategies and plans” (European Environment Agency, 2014, p. 23).

In France adaptation appeared on the agenda in the early 2000s (with creation of ONERC in 2001) and then spread in a top-down way down to infrastructure managers. The Ministry for Environment and its subsidiary bodies³⁶ led the French national climate adaptation plan (PNACC) released in 2011 (MEDDTL-DGEC, 2011), in partnership with research centres and utilities³⁷. The process began with a demand to climate scientists for providing baseline scenarios of climate change in France. The experts group, appointed by the Minister for the environment³⁸ and led by a climate scientist member of the IPCC, published several reports³⁹ describing climate projections for France based on three of the GHG concentration scenarios from the IPCC (RCP2.6, 4.5 and 8.5) (Jouzel et al., 2014). Those reports established the basis for 20 sectorial action-sheets constituting the PNACC. One of these sheets is dedicated to infrastructures and transportation systems. It highlights four actions:

1. General screening of the vulnerability of technical references and standards to climate change (CEREMA, 2015a);
2. Analysis of the impact of climate change on transport demand;
3. Development of a common methodology for vulnerability assessment (CEREMA, 2015b);
4. Realization of a state-of-the-art assessment of the current vulnerability of the French transportation system (CEREMA, 2017; DirMed, 2017).

The government released an evaluation of this first plan in 2015 (CGEDD, 2015) and prepared in 2016-2017 a second plan (ONERC, 2018) to be adopted in 2018.

³⁶ DGITM (transport and infrastructures department), DGEC (energy and climate department)

³⁷ This described process is in many ways similar to what has been observed in other European countries (AEE, 2014)

³⁸ The letter of appointment sent by the Ministry of the Environment to Jean Jouzel in July 2010, requested an “in depth synthesis on climate scenarios to consider in order to implement the National climate adaptation plan”.

³⁹ On the basis on modelling work of two climate-science teams from CNRM-Meteo France (Aladin-climat model) and from IPSL (WRF model).

To implement these general policy-frameworks, more operational documents exist, for instance risk-management processes (OECD, 2015)⁴⁰, reporting frameworks (ARCC, 2017; Cochran et al., 2017; Jiricka et al., 2016; Vallejo & Mullan, 2017), guidelines for norms and standards updates (CEN-CENELEC, 2016; CER et al., 2012) or vulnerability assessment toolboxes (CEREMA, 2015a; Ingénieurs Canada, 2011)⁴¹. In a 2016 report, the International Transport Forum reviewed the range of threats to transport system performance that are posed by climate change and provided guidance to transportation assets owners and network managers to help ensure assets integrity and contribute to continued network performance (IFT Research Reports & OECD, 2016). Following and participating to this science and policy driven dynamics, key players of the transport sector have initiated work of adaptation.

Focus on railway

The International Union of Railways (UIC) set up its first task force on the topic in 2006 in order to examine the consequences of climate change on rail infrastructure. In 2007 the task force launched a feasibility study to explore if and how the impacts of extreme weather events are an issue for UIC members. Finalized in 2008, this report demonstrated that the impact of global warming is indeed an important issue – and that the future work would target three phases⁴²: readiness for extreme weather events; robustness when extreme weather events occur and recovery ability after extreme weather has occurred.

Launched in 2009 a major research project called ARISCC - Adaptation of Railway Infrastructure to Climate Change - provided good practice and case studies of adaptation plans and made recommendations on how to develop these strategies (UIC, 2011) (Box 2-3).

⁴⁰ Proposing an iterative four steps approach: (i) identifying risks , (ii) characterizing risks, (iii) choosing and exploring policy responses, (iv) feedback and learning

⁴¹ Cf. action 3 in the PNACC action-sheets dedicated to infrastructures which led to the development and experimentations of such a framework (CEREMA, 2015b, 2017; DirMed, 2017)

⁴² <https://uic.org/adapting-to-climate-changes> – last accessed April 2018

Box 2-3 - Objectives and main outputs of the ARISCC project (Adaptation of Railway Infrastructure to Climate Change), 2011

- To give an overview over ongoing and planned activities regarding the adaptation of railways to extreme weather situations and climate change;
- To identify and classify the main effects of climate change on railway infrastructure and rank the main impacts according to their damage potential;
- To identify the areas of highest priority in this field and provide a systematic inventory of adaptation measures, strategies and policies in each of the high priority areas;
- To assess risks and associated costs, potential damage, performance and economic costs.
- To identify the Impact on standards and the options of adopting standards for new and existing infrastructure to the effects of climate change.
- To write a practical easy-to-use Guidance document on how to identify vulnerable assets and locations for a concrete line, how to choose the appropriate adaptation measures and how to assess related costs and benefits (toolbox).
- To provide a good practice collection of adaptation measures.

Source: <http://www.ariscc.org> – last accessed March 2018

In 2015, a new project took over. Called Rail Adapt, this initiative “aimed at keeping UIC Members informed and prepared, in support of national Adaptation Plans, UN agreements and EU encouragement to reduce risks and costs whilst improving railways’ resilience in the face of Climate Change. [...]. In 2017, UIC supported its members by arranging a series of fact-finding and briefing workshops. Members and other key stakeholders were invited to share experience and outline what support railways have and will need from governments and investors to help make the case and secure funding for improving the resilience of rail services.” (UIC, 2017)

This sustained mobilization demonstrates a true concern from the actors of this sector regarding climate change. Many national railway companies have also begun to work on the issue. Benchmarks realized through different research projects or presented during workshops (e.g. RailAdapt workshops⁴³, or ECCA 2017⁴⁴) describe the actions of different railways companies through the world. The comparison reveals similar approaches, often starting from current vulnerabilities, but with different focuses depending on local climate and environment (Gregori, 2017) (Table 2-3).

⁴³ <https://events.uic.org/railadapt-workshop-london-86> - last accessed April 2018

⁴⁴ <http://ecca2017.eu/conference/wp-content/uploads/2017/06/ECCA-Poster-Book-V4.pdf> – last accessed April 2018

Table 2-3 - Examples of adaptation focus in different countries

| Examples of countries | Example of focus |
|------------------------------------|---|
| China (CRDC) | Cold weather, handworks, adaptation by design high-speed lines |
| Egypt (Egyptian National Railways) | Heat and deserts, protection devices |
| Hong-Kong (MTR) | Typhoons, extreme events, construction norms, inspection policy, crisis management (training, traveler's information, etc.) |
| Scotland (ScotRail) | Climate-risk approach: identification and monitoring |
| Austria (ÖBB) | Adaptation of the ÖBB infrastructure to climate change — assessed Disruption events since 1990 (project KLIWA); partnership with weather service provider, live information, monitoring, modeling |
| Spain (RENFE) | Prediction of adverse weather events to anticipate adjustment of rail operations |
| Swiss (SBB) | Natural hazard (e.g. snow, landslide), doctrine in case of extreme event |
| Germany (DB) | Part of a broader work on the future of Rail, vision 2050 du transport |




Source : Author, from (Gregori, 2017), [Climate Adapt](#), EEA 2014 and companies' websites

Stakeholders and partners involved might also change from one country to another, relying on private consultancies in some places, internal expertise or collective working groups elsewhere. Other actors like rolling-stocks constructors also take public position on the topic. For Alstom for instance, climate change may require changes in infrastructure and rolling stocks requirements but a portfolio of proven solutions exist and it is possible to make performing railways in almost any conditions, providing the relevant design (Figure 2-5) (Alstom, 2011).

Figure 2-5 - Slide from a presentation by Alstom Market and Product Strategy officer

Great diversity of climate conditions experienced by our equipment

- **Northern** conditions: low temperatures, snow, ice (Sweden, Finland, China, Russia...)
- **Desert** conditions: high temperatures, solar radiations, sand (Dubai, south of Spain and Italy, Marocco, Iraq, Iran...)
- High humidity, saline environment, rapid temperature changes (Eurostar, Singapour, India)
- Strong **wind** (south of France)

Adaptation to extreme climate conditions

Solutions

and constraints

TRANSPORT | **AL**

Source: SNCF, 2011 - translation: Author

From other modes & sectors

Other areas in the field of transportation are also developing research and starting to adapt (European Environment Agency, 2014). We found similar initiatives in the road sector (with the projects ERA-NET, RIMAROCC, Roadapt and WATCH⁴⁵), for airports (Eurocontrol, 2014; Kwakkel, Walker, & Marchau, 2010; Lepousez, 2018), bridges (Schulz, Zia, & Koliba, 2017), sea-ports (NCCARF & RMIT, 2013), waterways (BMVI, 2013). Beyond transports, we found interesting inputs from the power sector (WBCSD, 2014), from the water sector (e.g. (Gersonius, Ashley, Pathirana, & Zevenbergen, 2013)), coastal management (GICC, 2012) and buildings (ADEME, 2013b).

3. Discussion and take-home messages: emerging and incomplete processes

This quick overview of the academic and grey literature shows that adaptation of transport to climate change covers a wide range of measures including adaptation of norms & standards; technological innovations; evolutions in infrastructure designs; relocation of assets; changes in operator's organization or services; information management or redundancies within and between transport modes. Originally focused on engineering measures adaptation in this sector is gradually opening to organizational and behavioral changes.

As noticed by the EEA, "up until now, the dominant approach for reducing the vulnerability of transport systems has been to make incremental changes" (European Environment Agency, 2014, p. 48). These changes are otherwise often limited to a single mode and struggle to gain a systemic coherence. Some authors and institutions argue that this incremental approach can be "insufficient to deal with disruptive or very fundamental changes in climate, the society or the economy. When changes of this sort happen, transport systems will need to adopt a more fundamental and comprehensive change, involving both the use of new technology and the implementation of alternative approaches for managing transport demand and supply" (ibid). There is "a risk for incremental adaptation approaches to involuntarily consolidate already-prevailing unsustainable transport practices, so that transition efforts towards low-carbon transport would become more difficult to undertake. [...] This assessment suggests that

⁴⁵ <http://www.cedr.eu/publication-cedr2016-5-acting-climate-change> – last accessed April 2018

adaptation actions are currently taking a short-term perspective, with a focus on maintenance and quick recovery of operations.[...] The paths explored in adaptation actions in Europe do not pay much attention to long-term mitigation strategies and their transition paths towards low-carbon mobility.”(Aparicio, 2017).

For actors in the transport sector, key barriers lead to this situation. They especially quote issues of knowledge availability and usability (especially because of uncertainties) and governance.

“The responsibility for adaptation action in the transport sector is often not clear. Some adaptation happens spontaneously by single transport stakeholders as current events make action necessary. Systemic approaches fall in some countries into the responsibility of public authorities dealing with climate change, in other countries dealing with transport and again others dealing with disaster risk management. Some stakeholders may prefer to wait for other players to act first and take leadership: users will generally rely on transport providers; transport providers will expect the vehicle industry and infrastructure managers to provide 'adapted' or 'climate-proof' solutions. The providers of equipment and infrastructure will expect new standards and guidelines from regulators. Policymakers and regulators will look at researchers for collecting evidence and providing options”. (European Environment Agency, 2014, pp. 14–16).

Adaptation of transport to climate change is still an emergent topic. Even if bigger stakeholders like railway companies start to become familiar with the issue, the general level of maturity within mobility-ecosystems is far from being homogeneous. Fundamental debates – regarding for instance social preference for redundancy, flexibility, resilience and efficiency – are still to be held. Up to now, adaptation is mostly taking a short-term perspective while the broader science of adaptation is advocating for forward-looking approaches. Synergies with other ongoing transformations and structuring policies are still to be found.

CONCLUSION OF THE CHAPTER: AN AMBIGUOUS REPRESENTATION OF THE ADAPTATION CHALLENGE

These debates observed in the field of transportation in Europe are representative of broader discussions in the literature about what is an efficient and sufficient adaptation. “Uncertainties around future changes in climate, technology and society, timescales and issues of scale (Adger, Arnell, & Tompkins, 2005) make it very difficult to define and assess

adaptation. We hardly know what “successful” adaptation means or the conditions necessary or sufficient for evaluating successful adaptation” (Wise et al., 2014).

“Approaches to selecting adaptation options continue to emphasize incremental change to reduce impacts while achieving cobenefits, but there is increasing evidence that transformative changes may be necessary in order to prepare for climate impacts [...]. While no-regret, low-regret, and win-win strategies have attracted the most attention in the past and continue to be applied, there is increasing recognition that an adequate adaptive response will mean acting in the face of continuing uncertainty about the extent of climate change and the nature of its impacts, and that in some cases there are limits to the effectiveness of incremental approaches. While attention to flexibility and safety margins is becoming more common in selecting adaptation options, many see the need for more transformative changes in our perception and paradigms about the nature of climate change, adaptation, and their relationship to other natural and human systems” (IPCC, 2014c, p. 836).

Progressive adjustments vs. actual system transformations is a one of the critical oppositions structuring the debate⁴⁶ (Table 2-4):

“Within the climate change adaptation research community there is a growing tendency to discuss adaptation using the language of transformation, reflecting a sense that the current status quo will not secure a sustainable future, especially in light of the lack of sufficient progress to mitigate the causes of anthropogenic climate change”. (Lonsdale, Pringle, & Turner, 2015).

Transformation is required when combination of climate changes and vulnerabilities exceeds the “coping-range” of the system (Kates, Travis, & Wilbanks, 2012) and crosses vulnerability thresholds. It implies more creativity to imagine alternative pathways (O’Brien, 2012, 2016; Wise et al., 2014). Deliberate transformation often comes with a forward-looking attitude. It is about “designing the future” (O’Brien, 2012).

⁴⁶ “Transformation—a change in the fundamental attributes of a system including altered goals or values—has emerged as a key concept in describing the dimensions, types, and rates of societal response to climate change. In the context of adaptation, we can distinguish between incremental and transformative adaptation, the latter referring to changes in the fundamental attributes of a system in response to climate change and its” (IPCC, 2014c, p. 181)

Table 2-4 - Criteria used to distinguish incremental and transformational adaptation

| | Incremental | Transformational |
|-------------------|--|---|
| Framing | Framed as 'complicated' | Framed as 'complex', 'wicked' or 'super wicked' |
| Learning | Single and double loop learning (Agyris & Schön, 1978) | Triple loop learning |
| Scale | Smaller, discrete, within system changes | System wide change or across many systems |
| Temporal | Focus on current conditions and short-term change and future uncertainty is not acknowledged | Focus on future, long-term change and uncertainty in the future is acknowledged and built into decision-making. |
| Power | Generally greater control over outcome | Outcome open ended or uncontrollable (and could be positive or negative) |
| | Seek to operate within the status quo to maintain and/or increase efficiency of existing systems | Addresses power imbalance and the causes of social injustice to induce a step change /radical shift to the operation of the existing system |
| Management | Reactive management of change, focusing on current conditions | Anticipated, planned management of change |
| | Management of change is focused on finding ways to keep the present system in operation | Management of change includes questioning the effectiveness of existing systems and processes |
| | Aim to address Type I (resistance and maintenance) and Type II (change at the margins) management problems (Handmers & Dovers, 1996) | Aim to address Type III (openness and adaptability) management problems |

Source: (Lonsdale et al., 2015)

Authors who consider that reactive incremental adaptation is insufficient often talk of an adaptation gap. This gap describes the misalignment between what we learn from science both of the implications of climate change and the actual adaptation actions that are carried out, ;levers for action and adaptation that actually takes place on in the field. Building on this diagnostic, they explore what are the barriers to bridge this gap (Eisenack & Stecker, 2012; Gawel, Lehmann, Strunz, & Heuson, 2016; Oberlack & Eisenack, 2018; Rotter et al., 2016; Stecker et al., 2011). Barriers to climate change are “impediment[s] to specified adaptations for specified actors in their given context that arise from a condition or set of conditions.” (Eisenack et al., 2014). They find barriers directly related to the available knowledge which is not always precise (Shukla et al., 2009), credible, salient or legitimate enough (Cash et al.,

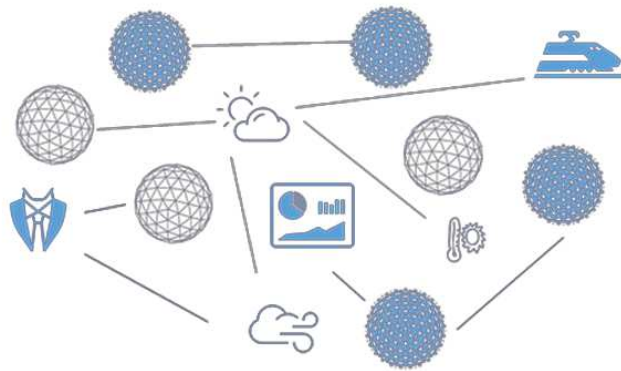
2003), with information hardly accessible (Moser & Ekstrom, 2010) or too costly to use. They also find barriers endogenous to the adaptation context and regarding leadership, governance & coordination, normative frameworks or available resources (Briley et al., 2015; Flagg & Kirchhoff, 2018; J. Porter & Dessai, 2016; Rotter et al., 2016).

In contexts in which proactive and/or transformative adaptation would be required these barriers generate two type of risks: the risk to not be able to meet the challenge and to be overtaken by rapid climate changes; and the risks to lock-in in short-term decision detrimental in the longer run. In both cases this can lead to situations of maladaptation (Jon Barnett, Saffron O'Neill, Barnett, & O'Neill, 2010; Magnan et al., 2016):

“Maladaptation arises not only from inadvertent badly planned adaptation actions, but also from deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions.” (IPCC, 2014c, p. 837).

This shows that knowing what to do out of scientific results on climate change is equivocal. In order to prevent the risk of a badly informed adaptation, authors advocate for a science “of” adaptation complementary to a science for adaptation (Swart et al., 2014). According to us, such a science of adaptation has to rely on a rich representation of the interface between climate science and society, acknowledging the complexity and uncertainties. However, as we saw in the second section of this chapter frameworks (such as PNS) which meet this criteria are poorly shared. Multiple representations of the reality cohabit and we are far from a generalized acceptance of the situation as being “wicked” or “post-normal”. Actors do not share *a priori* the same understanding of the risks and the urgency of the situation. Yet, sharing a common representation of the issue faced is an essential step to be able to deploy a decision-making process adapted to a specific context (Carrozza, 2015).

The only option is therefore to start our study of SNCF without assuming any preexisting right or wrong representation or the climate adaptation challenge. We can keep in mind the interesting insights from theoretical models but before trying to work with them, we need to elucidate the specific situation we work on: Which type of adaptation are we targeting? Are we really facing a closable adaptation gap? What are the existing representations, path-dependencies, and ongoing evolutions of the context we are interested in?



*"Chez tout homme, il y a le désir d'avoir un petit train."
Bernard Blier*

Chapter 3 - Studying SNCF corporate adaptation

As there is apparently no consensual one-best way of seeing and dealing with the consequences of climate change, we begin our inquiry by giving the floor back to the actors of the case we are studying. We start this chapter (section I) with a brief introduction of SNCF. Then we report about how the organization has responded to external incentives and internal signals to consider climate changes until now, in order to understand where its current attitude towards adaptation comes from. We identify and describe various initiatives - an attempt to launch a transversal adaptation approach (section II), SNCF's contribution to the national adaptation policy and a construction of a pragmatic corporate discourse on the topic (section III) and multiple bottom-up initiatives (section IV) - showing there are many places within the organization where adaptation dynamics can start. Nevertheless, each of them, is only a first step toward an efficient uptake of the issue in the company. At each stage of this "interressement" process it is challenging to demonstrate why adaptation is a critical issue for SNCF. The first attempts intended to be very transversal but mainly top-down, they achieved limited results. The ongoing adaptation policy is more pragmatic, focusing on what makes more immediate sense for the company.

I. PRESENTING SNCF

1. Profile and ongoing changes

This thesis focuses on railway in France as well as on the main player in this sector, SNCF (*Société Nationale des Chemins de Fer Français*). SNCF is a state-controlled group created in 1938, which currently have about 650 branches and 250 000 employees as well as operations in 120 countries around the world⁴⁷. SNCF had a turnover of 33.5 billion euros in 2017 – 2/3 in France - and a net income of 680 M€ (SNCF, 2015, 2016c). The SNCF group offers a "complete range of mobility solutions through six business lines" (Table 3-1).

⁴⁷ Map and details: http://medias.sncf.com/sncfcom/pdf/corp/CARTE_TITRE.pdf - last accessed April 2018

Table 3-1 - Major entities of the group SNCF

| Business lines | Corporate presentation |
|---|--|
| <p>SNCF Réseau (network)</p>  | <p>“SNCF Réseau manages, maintains and develops the French rail network, with existing line and the Paris region as its top priorities”.</p> <p>4 majors activities: Engineering & Projects; Access to the network, Maintenance & Works, Traffic management</p> |
| <p>SNCF Voyageurs (passengers)</p>  | <p>“SNCF Voyageurs makes travel easier, with shared mobility solutions provided by its business units—Transilien (suburban railway service Ile-de-France), TER (regional passenger rail), Intercités (non high speed services on the 'classic' network), Oui.snCF (high-speed trains-TGV, long-distance coaches in France and Europe and distribution)”.</p> |
| <p>SNCF Gares & Connexions</p>  | <p>“Gares & Connexions brings together various skills to renovate and develop the 3,000 railway stations of the French railway network”.</p> |
| <p>Keolis</p>  | <p>“Keolis is multimodal and international—a major mass-transit player serving transport organizing authorities. Keolis offers a complete multimodal transport chain: buses and coaches, subway systems, light rail, trains, bicycles, parking, car-sharing, ride-sharing, ferries and river shuttles”.</p> |
| <p>SNCG Logistics</p>  | <p>“SNCF Logistics is a full-service logistics partner, making businesses more competitive through its four business lines: Geodis, TFMM to handle rail and multimodal freight transport, STVA to transport finished vehicles, and Ermewa to manage equipment”.</p> |
| <p>SNCF Immobilier</p>  | <p>“A key player in urban transformation, SNCF Immobilier is dedicated to better urban living and has joined a nationwide drive for better housing in France”.</p> |

Source: SNCF website⁴⁸

⁴⁸ <https://www.sncf.com/sncv1/en/meet-sncf/public-service-company> - last accessed April 26th 2018

Since 2015⁴⁹, SNCF Group is organized into three EPIC (*Etablissement public à caractère industriel et commercial*) (CEREMA, 2014). In France, an EPIC is a public service company with a commercial and industrial mission⁵⁰: SNCF EPIC to set overall Group strategy; SNCF Réseau (Network) EPIC to manage, operate and develop the French rail network and SNCF Mobilités (Mobility) EPIC to transport passengers and freight.

Box 3-1 - The ongoing 2018 SNCF Reform

After the 2014 railway reform, key questions remained unsolved. Among them, the modalities of the coming liberalization of regional traffic, social issues and the heavy debt of SNCF (Arafer, 2016) . In addition, roles and power-relationship changed in three years.

The French President, Emmanuel Macron, announced a new reform in July 2017 while inaugurating the high-speed line between the cities of Paris and Rennes. He announced a clear new political line prioritizing the durability of the existing network over any further development. The government organized between September and December 2017 a national concertation – *les Assises de la Mobilités*⁵¹ – and commissioned special reports on the *French railway model* and on future infrastructure investments. This process prepared the ground for two laws to be voted in 2018:

- A “new railway pact” passed in June 2018. This bill especially deals with the modalities and calendar of liberalization (open access for TGV, call for tenders for TER), social issues and a new organization of the Group SNCF which will become a limited company 100 % State owned.
- A broader “mobility package” to guide future political choices among which new investments and great projects.

A complementary work has also been launched on the future of secondary railway lines.

Source: Author

The French railway network

The French railway network has progressively developed since the years 1830s. It is today the second largest in Europe, with more than 30,000km⁵² of tracks and 3,000 passenger terminals (Figure 3-1). Fifteen thousand trains use the network daily, in carry 5 million people and 25kt of freight. More than 162 000 “cheminots” (railwaymen) work in the three EPIC to operate such network.

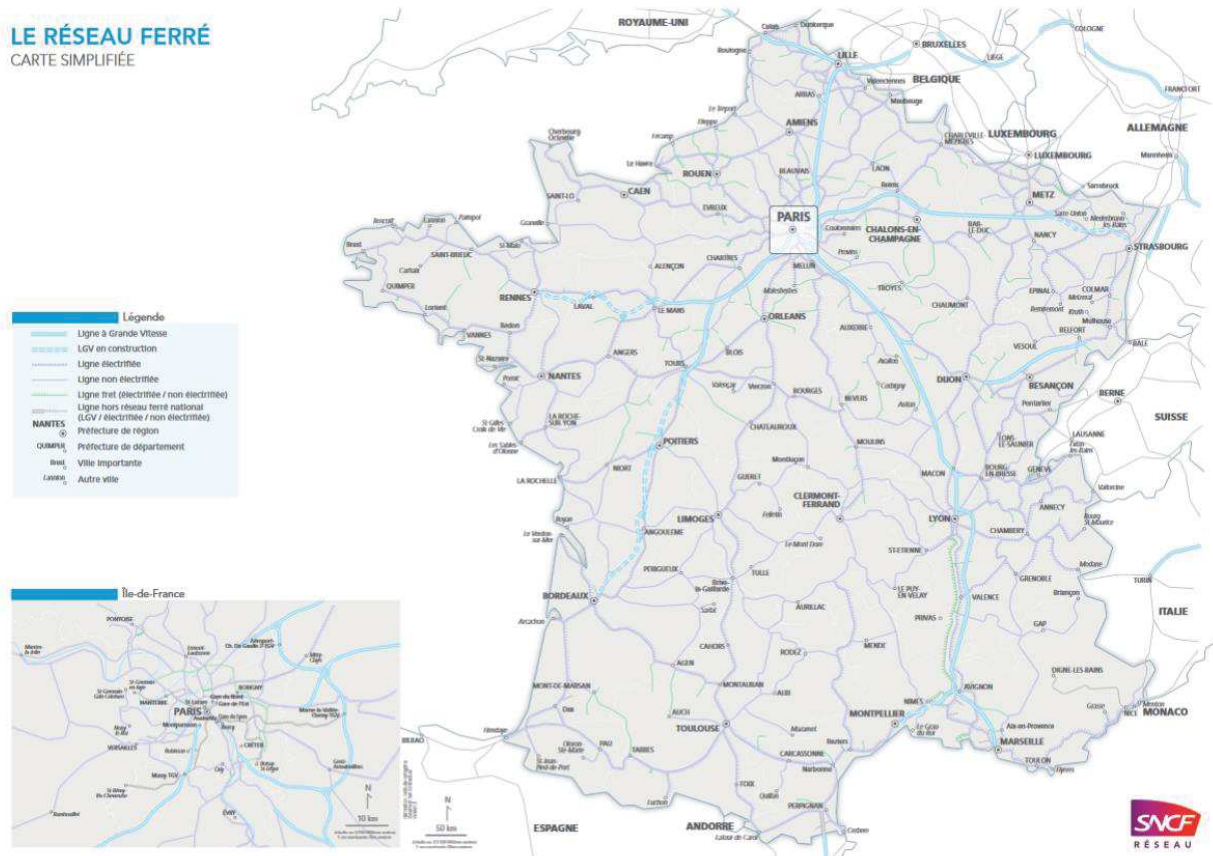
⁴⁹ Between 1997 and 2015, two distinct organizations existed. RFF (Réseau Ferré de France) owned the national railway network while SNCF operated and maintained it as the delegated infrastructure-manager. Following the “Assises du Ferroviaire”, the 2014 reform - LOI n° 2014-872 du 4 août 2014 portant réforme ferroviaire - put an end to this separation and created SNCF Réseau to regroup RFF and the infrastructure-management part of SNCF.

⁵⁰ <https://www.legifrance.gouv.fr/affichSarde.do?reprise=true&page=1&idSarde=SARDOBJT000007104810&ordre=null&nature=null&g=ls> – last accessed April 2018

⁵¹ <https://www.assisesdelamobilite.gouv.fr/> - last accessed April 2018

⁵² 42 000km in 1938

Figure 3-1 - Simplified map of the French railway network



Source: SNCF Réseau⁵³

Current challenges

Railway systems in general and SNCF in particular, are complex objects with unclear boundaries but presenting some key features. In our research process, we did not try to identify those features *a priori*, or to assume pre-existing, general, structures explaining how SNCF works. Nevertheless, some key points appeared to be fundamental to make sense of our empirical observations. They are the prevailing representations, the most common perspectives to describe and analyze this organization and how it changes.

The first of these features is a mixed, multi-actors governance. The whole history of railway is a history of interactions between the government and private companies. The configuration is getting even more complex with the processes of decentralization that involves local authorities (mostly Regional councils⁵⁴) in, and liberalization that both opens the game and

⁵³ www.sncf-reseau.fr/sites/default/files/upload/ Carte/2015-mars/carte-simplidee-reseau-20150330.pdf - last accessed May 2018

⁵⁴ Loi n° 2015-991 du 7 août 2015 portant nouvelle organisation territoriale de la République

changes the rules. SNCF Réseau, branches of SNCF Mobilités, SNCF competitors, multiple traffic authorities, local governments, regulators, etc. are all key players of the system, with potentially different views and interests. In addition, railways belong to larger mobility systems with other forms of interdependencies, collaboration and competition, like intermodal competition.

Within this heterogeneous system, several (not always compatibles) rationales and worldviews coexist, creating tensions that drive the evolutions of French railways. Is the train a public or a commercial service? Should it be based on self-sustained economy or be subsidized by the state? These are key questions that surface regularly in the public space. The privileged answers have changed over time and have become more differentiated depending on the different activities (TGV for instance is a 100 % commercial while TER is 74 % subsidised (Finez, 2013a)). The hierarchy of SNCF missions is also a constantly renegotiated equilibrium: connecting rural areas, catalysing economic exchanges between major cities, strengthening territorial cohesion, accelerating valuable flows, etc. (Finez & Quessette, 2018).

Each actor – including each SNCF sub-entity – can have a different perspective on these issues, depending on its interests or preferences. SNCF Réseau focuses on rail attractiveness while SNCF Mobilités focuses more on mobility-solutions, connecting transport modes and valuing information for example. Economic challenges, land use planning, industrial policies, regional development, jobs creation and political image are some of the multiple issues constantly at stake.

This leads to a diversity of discourses and discursive focuses, for instance: an accounting perspective will focus on price-competitiveness (Spinetta, 2018), while transport users' associations will rather concentrate on regularity and service quality (FNAUT-Mobilettre, 2016) or concerns about available resources to maintain a public transport service (Auxiette, 2013).

Moreover, there is a very strong affective dimension to the debate about SNCF. In France, everyone has been somehow dealing with SNCF. It is part of French identity, of daily life, of special moments like holidays (Guibert, 1970; Regniault, 2017; SNCF, 2016a; Verderosa, 2004).

All of these considerations are in the background when dealing with SNCF's key challenges regarding both its future business-models and the future of the network itself:

- *Intermodal-competition.* With “classical” competitors (roads, planes) and newcomers such as long distance coaches, car sharing.
- *In-rail competition.* Liberalisation can take different forms depending on the service, from open-access competitive markets (as it is for international lines) to contested markets through calls for tenders (apparently the solution preferred for TER). This raises critical issues especially regarding cost-competitiveness (Boston Consulting Group, 2015), social model for workers, and pricing policies.
- *The energy transition to a low carbon economy.* Being an electrified⁵⁵ mass-transit system, rail certainly has a great potential to serve climate objectives, both for passengers and freight, if it is well integrated to comprehensive mobility strategies (Armstrong & Preston, 2010; Leguet & Dépoues, 2018; SNCF, 2017c; SNCF Réseau, 2018b).
- *Debt.* The total SNCF debt reaches more than 54 billion of euros (47 bi € for SNCF Réseau; 8 bi€ for SNCF Mobilités) and is growing by 3 bi every year (including one million just for the debt burden) (Cour des comptes, 2008; Cour des Comptes, 2017). This debt comes from the initial and structural deficit of the sector and major investments in high-speed lines in the last decades (Fourniau, 2011). It is a burning political issue. Discussions are going on for a possible partial reabsorption by the Government in the coming years, but for now this debt has direct consequences on the financial capacities of the SNCF.
- *New infrastructures development.* After years of massive investment in new infrastructures, especially high-speed lines, France is facing a critical question of prioritization of future needs in a context of very limited resources. Several reports have made recommendations to address this issue (Capo-Canellas et al., 2014; Cavagné et al., 2018; Commission Mobilité 21, 2013; MEDTL, 2011). The current government (2018) gives priority to daily transports and retrofitting of existing infrastructure (regarding railway almost all new development is frozen).

⁵⁵ With a low-carbon, electricity mix in France.

- *Retrofitting.* Maintenance and renewal of the existing network is an undiscussed necessity after years of delays (RFF, 2013; Rivier & Putallaz, 2005; SNCF, 2016a). Many recent alert signals led to a national consensus on this question. Among the most visible signals was the resignation in February 2016 of the former CEO of SNCF Réseau (Sénat, 2016) and critical incidents like a major blackout at the Parisian Montparnasse Station for a holiday in summer 2017 (SNCF, 2017a). SNCF launched a great retrofitting plan, investing 5 billion every year to modernise the network. In 2017, 1500 operations - including large-scale operations - were conducted.
- *Future risks.* SNCF has also identified and now monitors and manages emergent or recurrent risks. Among them risk of possible technological breakthroughs, news uses or mobility patterns coming from the “digital revolution” or security-related risks (for instance new rules of safety inspection for boarding because of terrorist-risks).

We note that these challenges are mainly socioeconomic concerns, directly related to the core-business of the company. Most of them have been there for decades and are well documented by SNCF itself.

To take them up and manage the related risks, SNCF Mobilités and SNCF Réseau have set up specific strategies. SNCF Réseau is especially focusing on strengthening safety, renewing the network, modernizing maintenance and developing an attractive rail network where this mobility-solution is the most relevant, with an economic lens (SNCF Réseau, 2018b). SNCF Mobilités presents itself as a “mobility architect”, designing door-to-door mobility services thought for the consumers. As such, it does not hesitate to invest in coaches, car sharing or IT-solutions.

SNCF Mobilités and SNCF Réseau have also a common focus on increasing their performance and robustness. Robustness is defined in this context as the “ability to deliver the service promised to customers”. Following the incidents mentioned above and a special report (Damas et al., 2017) an action plan – called ROBIN⁵⁶ - for robustness and passenger information is currently under implementation. Innovation is a very important aspect for both organizations as well. SNCF showcases an intense innovation activity on topics such as digital and big-data, predictive maintenance, autonomous vehicles or energy savings (SNCF, 2017b).

⁵⁶ <https://www.sncf.com/sncv1/en/passengers> - last accessed April 2018

2. SNCF as a case study

There are many researches, mostly written in French, taking SNCF or the SNCF context as their object to study. We find examples in fields such as economics (e.g. (Dehornoy, 2011; Finez, 2013a; Perennes, 2014; Regniault, 2017)), history (cf. <http://www.ahicf.com/>, e.g. (Bernheim, 2003)) and engineering sciences. SNCF is “an object of back and forth” between theory and practices, sometimes analyzed as a case study, sometimes transformed following a theory (Finez, 2013b; Perennes, 2014).

Several features of SNCF encouraged us to take this organization as our case study. For this research, SNCF is many things at the same time:

- A case which complexity cannot be denied; involving multiple coexisting forms of regulations (or justification (Boltanski & Thévenot, 1991) – market, industrial, civic (Finez, 2013a)); a “magmatic” (Venturini, 2010) multifactor governance with shared uncertainties about the future and multiple visions not always compatibles.
- A changing organization with its own evolution patterns – legacies and perspectives - and many interactions with its broader ecosystem. It is both possible to detect and describe groundswell and observe moments of crystallization⁵⁷.
- A company which is both (i) an actor deeply embedded in the French economy, society, territory and context, reflecting successive eras of their evolution and (ii) a key player in shaping this economy, society, territory and context.
- A globalized firm, big enough to be a political and economic actor at the global, EU and national levels which is also deeply grounded in local territories and daily lives of millions of people.
- An partner immediately interested by our proposition to conduct a research on the topic of climate adaptation (cf.Chapter 1).

In the next sections and chapters of this dissertation, we focus on this specific case study. We assume that it will also help to feed broader ongoing research on adaptation of organizations to climate change. Depending on the aspects covered, the conclusions will be relevant for

⁵⁷ It is interesting to note that the events we observed at the end of this thesis (discussion and contestations regarding a new SNCF reform – spring 2018, (Box 3-1) awoke those issues which become burning again, revealing trends and tensions existing for decades. This moment really helped us a lot to understand SNCF dynamics.

actors partially sharing some of SNCF's characteristics, especially infrastructure managers, mobility providers or utility companies.

II. HISTORY OF ADAPTATION AT SNCF: THE D-RAIL PROJECT IN 2011

1. *Objectives and process of a first attempt to address adaptation in the company*

We found the first SNCF attempt to deal with adaptation to climate change as a specific issue with the D-RAIL project led by the Sustainability Department from October 2011 to May 2012. Some of the people we interviewed had taken part in this project and shared some of their archives with us. In particular, we had access to the initial concept note; the emails sent by the project leaders to participants, the material prepared for workshops organized between October 2011 and March 2012 (context-note, presentation, discussion reports, etc.) and the *final brief* prepared in June 2012 for the company executive board.

According to the initial concept note, the project aimed at “proposing strategic directions for adapting to climate change, allowing SNCF to offer new services in terms of ecomobility, even if our knowledge of the impacts of this change is incomplete”:

“Is SNCF able to cope with the extreme weather events that hit it today and hit it more intensely tomorrow? How will the SNCF be able to change its offer if the outside temperature increases by 2°C by 2030 and by 4°C by 2050? Climate change, resulting from this temperature variation, will have consequences for rolling stock (technical characteristics and maintenance cycle, cleaning, air conditioning, etc.), stations (choice of location and design) and infrastructure (tracks, vegetation,). In addition, it will be necessary to adapt the circulations to preserve their safety. In short, the complete transport plan needs to be reviewed and the strategies to be adopted in order to make the right decisions need to be defined.” D-Rail scoping brief

The scoping paper of the project mentioned key background reasons that encouraged SNCF to launch this project. The publication of the fourth IPCC Assessment Report in 2007 and other scientific conclusions focusing for example on heatwaves in France are a first category of reasons but not the only one. We also find institutional incentives at different levels: the ARISCC project launched by the UIC (UIC, 2011); similar work undertaken by railway companies elsewhere such as Network Rail in the UK; or the coming European Adaptation Strategy (European Commission, 2013b) and the first PNACC which has “invited transport utilities to establish their own climate change adaptation plan”. The document also mentions

recent weather events in France (storms Lothar and Martin, 1999, Klaus 2009, Xynthia 2010; floods in the Rhône region in 2003) and in Europe (heatwave in Germany in July 2010) as an additional motivation. Tackling the adaptation challenge is therefore not just about drawing the right conclusions from science. It is also about providing a satisfying answer to external concerns and demonstrating that the company learns from the past experience.

At this initial stage, D-RAIL leaders identified the resilience of the technical system; the management of weather crisis and potential changes in mobility patterns and working conditions as the major concerns for the company. The initial intention of the project was as ambitious as producing a regionalized map of potential impacts, selecting tools to mainstream adaptation in decision-making, prioritizing adaptation measures and implementing devices to monitor adaptation.

In order to do so, the sustainability department chose a very inclusive approach, working through workshops opened to many units of the company⁵⁸: SNCF Voyages, SNCF Infrastructures, Gares & Connexions, department in charge of rolling stock, HR department, Research and Innovation, Géodis & Kéolis⁵⁹ - and external partners such as research centers (CEA, IPSL, CEC, LAUREPS, CEMAGREF, CERTOP, LAMSADE...), technical bodies (CSTB), public institutions (ADEME, the Institute of Health Surveillance), etc. It decided to consider the railway system “as a whole, rather than conducting a specific study for each of the components”. Finally yet importantly, D-RAIL adopted a forward-looking perspective with 20 to 30 years horizons.

The initial design of the project had four work-packages (WP), following a rather classical top-down process, starting with identification of critical vulnerabilities then moving down to an adaptation strategy:

- WP1 - Identification of the impacts of climate change, their timeframe and vulnerability zones;
- WP2 - Identification of priority adaptation measures, based on the identified impacts;
- WP3 - Assessment of the priority measures;
- WP 4 – Selection of actions, consistently with the overall strategy.

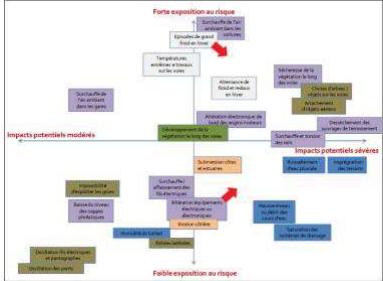

⁵⁸ SNCF + RFF (the distinct company which owned and maintained the French national railway network before it became SNCF Réseau)


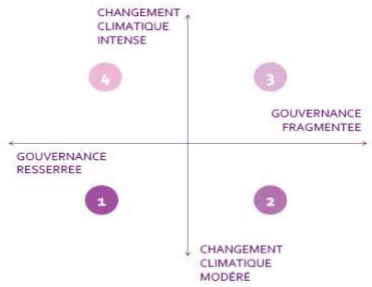

⁵⁹ Two subsidiaries offering services of freight & logistics (Géodis) and urban transport (Kéolis)

The focus on “potential consequences of climate change relevant for SNCF”, “SNCF exposure”, “potential consequences on the activities of the company”, the “current adaptive capacity” and ‘residual impacts not yet handled by the company’ indicates that the DRAIL team chose to implement an approach centered on the organization’s vulnerability and preparation. According to this approach, adaptation is more about knowing about itself than knowing about what science tells about the climate.

To perform this self-assessment, the project included four workshops with external presentation and working-questions animated by external consultants (Table 3-2). Only a small proportion of the 25 people invited to those workshops actually attended one or several of them. The overall attendances remained quite low (between 4 and 12 participants). External presentations and material – for instance a benchmark of initiatives conducted in other countries with harsher weather conditions (Jitex, 2011) – were used to encourage the discussion at each stage.

Table 3-2 - Synthesis of the 4 workshops organized or planned through the D-RAIL project

| Workshop # | Initial input | Working-agenda | Modus operendi | Deliverable form |
|---|--|---|---|--|
| <p>1- Vulnerability assessment</p> <p>(2011-10-05)</p> | <p>Presentation by Stéphane Hallegatte (climatologist & economist, CIRED-Météo France) on the science of climate change :</p> <p><u>Outline:</u></p> <ol style="list-style-type: none"> 1. Climate change and its impacts, focus on infrastructure & transport. 2. Adapting a city: illustration of the Paris region, the role of transport, & the synergies with mitigation. 3. Decision-making methodologies for adaptation measures, and uncertainty management. 4. The French PNACC <p><u>Message taken-home:</u> multiple impacts but strong uncertainties on time-horizons, adaptation is first about managing the “value-of-time” (no regret, safety margins, reversibility).</p> | <ul style="list-style-type: none"> • Assessing SNCF exposure to climate change. • Simulation and discussion of sequences of causes and effects. | <ul style="list-style-type: none"> • Internal experts-survey • Discussion from two fictive case-studies: (i) “heatwave in Paris”; “Marseille under the snow.” | <p>First qualitative risk-mapping of climate related-risks according to SNCF experts views.</p>  |
| <p>2- Preparing for tomorrow</p> <p>(2011-11-23)</p> | <p>Presentations by representatives of other companies:</p> <ul style="list-style-type: none"> • Bouygues on Real estate issues (eventually focused on mitigation) • Alstom on adaptation to rolling stocks with one key message: it is possible to design trains for virtually any climatic conditions providing that the right specifications are given. | <p>Work based on the risks identified during the previous seminar in order to find potential technical or organizational measures to address them.</p> | <p>2 sub-workshops with specific focus:</p> <ul style="list-style-type: none"> • Rolling-stocks • Railway stations. | <p>Summary tables inventorying all identified risks with their implication and potential measures to deal with them.</p>  |

| | | | | |
|--|---|---|--|---|
| <p>3- Priorities for tomorrow</p> <p>(2012-01-10)</p> | <p>Presentations by the <i>Head of Sustainability and Political Risk Management</i> of Swiss Re: “Economics of Climate Adaptation A framework for decision-making.”</p> <p><u>Outline:</u></p> <p>We need to adapt</p> <ul style="list-style-type: none"> • Climate risk are highly inter-connected • Climate-resilient development needs to address total climate risk • Case studies <ul style="list-style-type: none"> ○ City of Hull, UK: climate-resilient city development, taking into account risks from multiple hazards ○ Entergy, US Gulf coast: climate-resilient development of an energy utility company <p><u>Message taken-home:</u> an approach, assessing the consequences of various scenarios on the activity using a broad understanding of current climate risks: increased exposure because of economic development + climate change</p> | <p>Collective work to list the stakeholders of the rail eco-system on which SNCF depends, regarding vulnerability to climate change and adaptation.</p> <p>Exploration of contrasting climate change scenarios for SNCF activity, discussion of the relevant adaptation response.</p> | <p>Collective drawing of sociograms, i.e. mapping of actors and their relationships.</p> <p>Work based on a scenario-matrix: intensity of climate change (low-high) vs. governance of the system (integrated / fragmented) to identify no-regrets measures and unacceptable risks.</p>  | <p>Sociograms of interdependencies between SNCF and:</p> <ul style="list-style-type: none"> • Other utilities (technical) • Public authorities and regulators (institutional) • Clients, competitors (commercial) • External stakeholders (political-social) <p>+ Scenario matrix</p>  |
| <p>4- Opportunities</p> <p>(initially planned for March 2012)</p> | | | <p>Work based on the method proposed in the UK by Defra – drawing of influence diagrams.</p> <p>Travail type DEFRA de diagramme d’influence par activité: fret, gares, infra, proximités (TER), voyages).</p> | <p>Four “influence diagrams” - one for each of the following businesses-unit : Freight (Fret SNCF), railway-stations (G&C), regional lines (SNCF Proximités), high-speed lines (SNCF Voyages).</p>  |

Source: Author from various SNCF working-documents

2. Projects' outcomes and persistence

Minutes of meetings give an interesting insight regarding key-elements that the coordinators of the project considered as the most important lessons learnt. Out of one of the initial presentations, for instance, they report a simple picture of future climate with hotter and drier summers, wetter and sweeter winters, more extremes events and sea-level rise. Based on this picture, participants to the workshop drew a clear representation of the risks faced by SNCF summarized as follow in the report:

- "No unknown risks but frequency and geographic locations of events already experienced likely to change";
- "Technical solutions available but with a cost-benefit ratio not easy to compute because of uncertainties";
- "Three main uncertainties regarding climate change itself (pace and intensity); technical solutions (evolutions, cost, performance) and governance as SNCF is entangled in a complex ecosystem of actors".

According to this list, the issues at stake were well defined and the risks were manageable, even if some information lacked to optimize the company's response. Mitigating immediate risks then waiting, consequently appeared as a rationale option. At the end of the process (Figure 3-2), a draft-strategy prepared for the executive-board was going in this direction. It proposed an analysis of the situation and a few general principles for the corporate adaptation policy. According to the note:

"[SNCF understands] quite well what the impacts of new weather conditions on its activities. The studies already carried out by foreign railway operators, the analysis of the operating conditions encountered by the operators of countries with a warmer, colder or wetter climate, as well as feedbacks of the incidents climatic conditions experienced by SNCF in the past years make it possible to draw up a list of their implications".

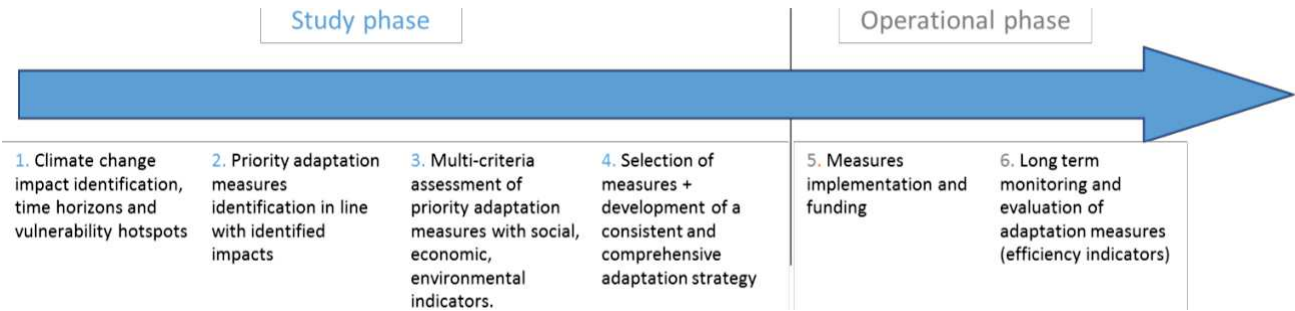
The major obstacle identified for SNCF was the time-horizon (that appeared too distant) and the remaining uncertainties: the company has to keep a consistent roadmap ("it cannot disperse") and cannot "invest without a prospect of return". Consequently the heart of the proposed strategy was based on "low-regret measures, which cost-benefit balance remains positive independently from the pace of climate change" (European Environment Agency, 2014). It suggested three categories of prudent actions: (1) creating a knowledge base to

refine the measurement of risks and associated losses to better assess the feasibility and cost of technical solutions⁶⁰; (2) developing tools for support to the different relevant timeframes: crisis management in emergency situations, prevention plans and medium-term investments⁶¹ and (3) mobilizing internal and external stakeholders without which the SNCF cannot take action: staff, organizing authorities, public authorities, customers. These general principles were very similar to what was observed in other sectors or contexts (Berkhout, 2012; Stecker et al., 2011). They already took into account major issues regarding governance and proposed responses adapted to each branch of SNCF activities.

However, the material we could read revealed that the coordinators of the project struggled to mobilize people and to generate momentum for adaptation. We could not find any information about what the project became after the presentation of the final note to the board. People who mentioned D-RAIL in interviews were sometimes quite critical about it.

We can make the hypothesis that this very ambitious project lacked a stronger political support from the institution and suffered from the internal turnover in the sustainability department. At the end of the day, D-RAIL did not demonstrate that climate change adaptation was a critical issue for SNCF.

Figure 3-2 - Timeline of the D-RAIL project



Source: J.L. Jourdan, former SNCF chief sustainability officer (2011) – translation: Author

D-RAIL had been over for five years when we began our research. This first episode reminds us that mobilization around adaptation cannot be taken for granted and requires an efficient *interessement* strategy (Callon, 1996). Climate change does not immediately appear as disruptive, even for a company like SNCF. Creating ownership of such an emergent phenomenon takes times and is not a one-shot process.

⁶⁰ For example by developing a regionalized map of climate vulnerabilities based on climate projections.
⁶¹ For instance by updating construction and maintenance standards of the infrastructure.

D-RAIL is still mentioned today as the first attempt to raise awareness in the French railway sector about this challenge. It set the ground of a first corporate uptake of this emergent topic. The way SNCF is addressing adaptation has then progressively changed. In fall 2015, there was no one specific adaptation program but a distributed work on the topic.

III. ONGOING ADAPTATION INITIATIVES: ADAPTATION AS A CORPORATE POLICY

In order to get an overview of the diverse initiatives and individuals dealing with adaptation today, we ran a first series of semi-directed exploratory interviews. We met 25 people within the company for whom adaptation to climate change is a well-identified issue (Table 3-3). Most of these interviewees are in charge of technical or institutional support functions at SNCF headquarter. We started our interviews with people in charge of SNCF adaptation policy in the sustainability department, and then we identified further interviewees by snowball sampling. This process revealed two distinct approaches of adaptation (i) a corporate response to external expectations and (ii) internal initiatives focused on the ability to better manage the effects of weather on the railway system.

Table 3-3 - Description of the sample for the exploratory interviews conducted between March and September 2016

| | |
|-----------------------|--|
| SNCF group | Strategy & Research (n=2) |
| | Safety – “Mission Inondations” (flood) |
| | Interoperability & Standardization |
| | Digitalization |
| | Rolling-stock engineering |
| | Sustainability (n=3) |
| SNCF Réseau | Engineering (n=6) |
| | Work & Maintenance (n=2) |
| | Economic Assessments |
| | Traffic organization & management |
| | Environment and sustainability (n=2) |
| SNCF Mobilités | Voyages (Great projects and future studies) |
| | Transilien (Marketing & customers relationships) |
| Others | AREP (SNCF consultancy focusing on railway stations and their urban environment) |
| | SNCF Energy supply |
| | CEREMA and DGITM (technical and administration departments of the Ministry for the environment working on transport and infrastructures) |
| | Météo-France & IPSL (research institute also developing climate services) |

Source: Author

1. Building a corporate response to external expectations

SNCF and SNCF Réseau sustainability departments are officially in charge of dealing with adaptation to climate change. SNCF Sustainability department (the “3D” standing for “*Direction du Développement Durable*”) directly reports to SNCF’s executive committee (SNCF, 2017c). This department has three missions: establishing and monitoring SNCF Corporate Social Responsibility policy, supporting all the divisions in implementing this policy and reporting about achieved progresses⁶².

The D-RAIL project described above was carried out by this department until 2012. Since then, the team has been completely renewed. A new director arrived in 2014⁶³ – Christian Dubost – followed by a new project officer in charge of adaptation among other responsibilities. Even during this transition period, the Ministry of Transports continue to identify SNCF as a key operator of the French National Adaptation Plan (PNACC), especially regarding two actions of the transport chapter:

- Action1 - General screening of the potential impact of climate change on design, maintenance and operation norms and standards;
- Action 4 – Realizing a state-of-the-art assessment of the current vulnerability of the French transportation system.

SNCF also regularly received invitations to contribute to working-groups or forums on adaptation, for example sectoral or cross-sectoral professional groups such as the International union of railways (CER et al., 2012; UIC, 2011) or ‘*Entreprises pour l’Environnement*’, a French association of forty large companies working on environmental issues (EPE & ONERC, 2014).

Convinced by the relevance of the topic and in order to be able to take position and to answer to these requests, the sustainability department decided to be proactive in developing its expertise on adaptation along several axes:

⁶² SNCF Réseau also has a department of environment and sustainable development (DEDD) reporting to the Deputy Chief Executive Officer. It establishes its CSR policy, within the framework of the Group’s CSR policy.

⁶³ And remained until September 2018

SNCF provided a first answer to PNACC Action 1 before 2014, establishing a list of about 100 technical documents with explicit mentions of climate variables that would require revision. It was part of a transversal systematic review of standards and guidelines on the design, maintenance and operation of transport infrastructures. Experts classified those standards in three groups, “in accordance with the needs for revision from a climate change adaptation perspective: those with no need for revision; those in need of revision, and those needing more precise information of the climatic variables and indicators involved for assessing their revision needs”⁶⁴ (CEREMA, 2015a). However, at the end of the period covered by the plan (2011–15), critical railway standards were identified but not yet updated (CGEDD, 2015).

Experts from SNCF sustainability department were rather critical about this process. It was not the revision of norms and standards by itself that raised the concern of the interviewees, but rather the fact that the revision process set up was at the national level and not transversal enough. According to several interviewees, climate change will not just affect a few procedures or standards that could be easily listed. It will also have impacts across the whole railway system. The mere listing of instances of climate parameters in technical documents is therefore perceived as a symptom of a poor understanding of the system’s complexity. It assumes that it is possible to draw a linear link between climate impacts and standardization documents. Instead, our interviewees claimed that there are thousands of interactions between the climate system and the infrastructure life cycle. These interactions are not always formalized. Climate indicators available in the “Jouzel reports⁶⁵” are insufficiently tailored to allow the kind of in-depth analysis necessary to provide a better answer to the question⁶⁶.

Moreover, a significant part of SNCF’s work on norms and standards now happens at the European level, through the European Committee for Standardization-European Committee for Electrotechnical Standardization (CEN-CENELEC). SNCF is associated with the CEN-CENELEC group working on adaptation of industrial standards to climate change. Representatives of the

⁶⁴ <http://climate-adapt.eea.europa.eu/metadata/case-studies/adaptation-of-french-standards-for-design-maintenance-and-operation-of-transport-infrastructures> - last accessed April 2018

⁶⁵ Series of reports on “the climate of France in the 21st century” commissioned to scientists by the French government, (Jouzel et al., 2014) (cf. Chapter 2).

⁶⁶ This appeared to be a critical sticking point, never called into question. Neither the availability of further information nor the possibility to decide without it (Dessai et al., 2009) were explored.

company took part in drafting of specific technical guidelines that propose a step-by-step approach to address climate change in any existing standardization process (CEN-CENELEC, 2016). SNCF executives we interviewed perceive this logic of mainstreaming climate change questions into the general standardization process as potentially more relevant and efficient.

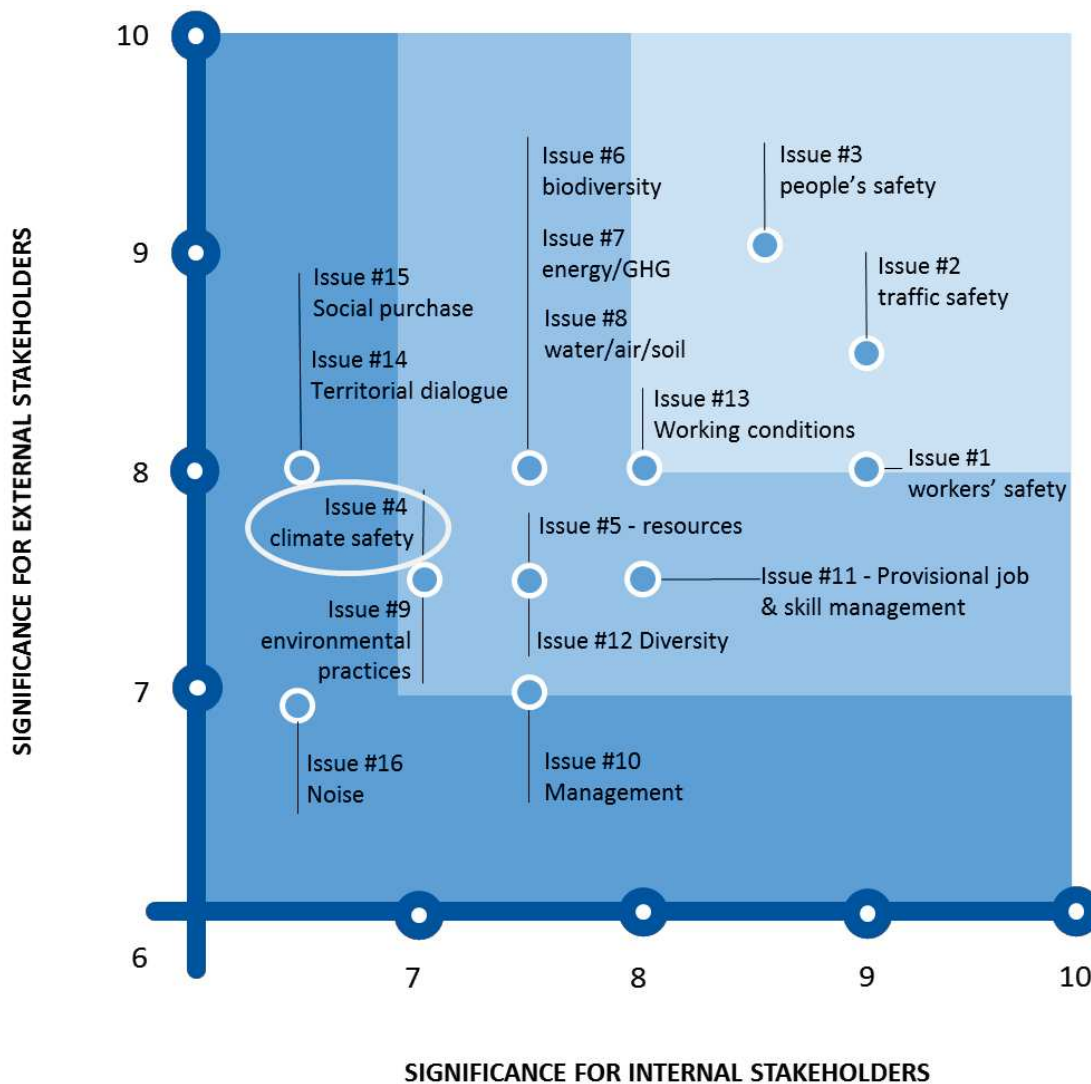
Contribution to the PNACC: Vulnerability assessments

Building on a methodology developed by the CEREMA (CEREMA, 2015b) – technical body of the Ministry of Transport - the government has strongly encouraged SNCF to assess its network vulnerability to future climate changes. In a letter dated July 25, 2017, the Ministry of Transport requested that SNCF General Direction reports about the vulnerability assessments that had been conducted. It also requested that a contact-person be nominated to participate to cross-sectoral knowledge sharing exercises. Other infrastructure managers experimented this method on local examples. Some instances are urban transports in the city of Marseilles (CEREMA, 2017), roads in the Mediterranean region (DirMed, 2017) no example for railways as of now. Tailoring and implementing this method, first developed in the road context, to the national railway network would require a large amount of work with dedicated resources. The PNACC did not provide such resources. SNCF Réseau did not take it on its own either – not considering climate risks among top-priority issues (Figure 3-3). According to SNCF experts we interviewed, addressing already identified retrofitting and maintenance needs will be a first significant step towards an increase robustness.

Box 3-2 - A dedicated Mission to address flood-risks

Apart from the PNACC, SNCF top-management decided in 2014-15 to create a transversal “mission” to address the specific risk of flooding. Led by the safety division, this experts-group started with a basic vulnerability assessment to identify and prioritize critical areas and installations. Then, it set up a process to support prioritized local entities in establishing an in-depth diagnosis. The ultimate goal was to identify relevant measures to mitigate the risk and establish business continuity plans. This is a process quite long, complex and costly. Up to now, it has not considered future climate changes. According to the mission-director, talking about climate change is not the best argument to provide incentives for immediate action. To mobilize across the company, the mission has focuses on the most prevailing and salient existing risks: floods with 10 to 30 years and floods with 100 years return periods. The guidelines are different for new infrastructures. Recent greats projects such as new high-speed lines or major engineering structures has been designed with flood safety requirements considering more extremes events with return periods of 1:1000. Moreover, the regulation on environmental impact assessments, revised in 2016, now requires describing the impacts of the project on climate and the project vulnerabilities to climate change (article R.122-5 - Environmental Code).

Figure 3-3 - Materiality matrix of sustainability issues for SNCF Réseau, 2016



Source: (SNCF Réseau, 2018b) - translation: Author

In 2016, SNCF Réseau produced a materiality matrix to identify the most relevant sustainable development issues according to its employees and external stakeholders. Interviews and an online survey among a sample of 4,500 employees and external stakeholders drew a matrix of 16 challenges, mapped along two axis: their perceived importance by employees (x-axis) and external stakeholders (y-axis). Even if climate-security appears on the map, it is not among the most important issues. Work, circulation and people safety rank highest in the list and so concentrate resources.

2. Towards a “pragmatic” corporate position

To overcome the limitations of the PNACC original framing, SNCF expanded its work on adaptation to aspects other than standardization and vulnerability assessments. The approach changed after the relative lack of success of the D-RAIL initiative. Instead of organizing a heavy, systematic and transversal program, the 3D has adopted a light-touch approach. This intends to be more pragmatic, to take into account the reality of the railway system and context and

to look for synergies with other corporate priorities. Christian Dubost explicitly defended this attitude internally and publicly, for instance during the 2017 edition of the International Weather and Climate Forum in Paris (Daudier, 2017): “the issue is to no oversell the topic to maintain credibility for priority actions [...] we have to be smart, to find co-benefits of adaptation investments, synergies”.

In 2015, climate change, including adaptation, climbed at the top of SNCF management agenda in the context of COP21. The organization of this major international climate summit in Paris drew attention to the actions implemented by a variety of non-state actors. As part of this momentum, SNCF set-up internal working groups to create ownership of climate issues across the organization. A working-group, chaired by Alain Quinet - Deputy CEO of SNCF Réseau - focused on resilience and adaptation. It did not release any public communication but strongly contributed to shape current SNCF doctrine on this topic. Most of the individuals we interviewed in the company heard about or participated to this group and mentioned it. From this participation, they took home several key messages all going in the same direction of a reinsuring, prudent (e.g. climate resilience for new equipment), non-stand-alone approach to adaptation: SNCF should move forward on adaptation but cooperating with external partners (i.e. adaptation is a theme for cooperation, not competition),

Following this group, and to structure the knowledge that already exist across the company, SNCF Réseau (Jean-Claude Larrieu, deputy CEO for Traffic Management) and SNCF Mobilités (Alain Krakovitch, Transilien director) commissioned in-depth studies to a specialized consultancy firm called Carbone 4⁶⁷ (Dubost, 2017). The first study aimed at making a precise inventory of the information available internally, then to propose a method for assessing and monitoring the climate impacts on SNCF activities. The objective was to propose performance indicators (KPIs) relevant for decision-making. The second study aimed at making recommendations to anticipate and manage climate-related risks for regional railway transit in the *Ile-de-France Region*.

Consultants conducting this work first had to localize and gather data available in SNCF information systems to characterize the relationships between weather parameters and the railway system. This was not an easy task as SNCF’s knowledge is vast but hardly formalized

⁶⁷ <http://www.carbone4.com/?lang=en> – last accessed April 2018

and centralized. This knowledge is rather embodied by experts who work for the organization. Moreover, existing databases – such as BREHAT⁶⁸ - have not been designed to compute correlations between railway performance and weather conditions. As a result, one of the major final Carbone 4 recommendations was to improve the monitoring system to allow better analysis and increase performance management in the future: “transversal recommendations: adapting or complementing to the nomenclature of the BREHAT database to better reflect events due to weather hazards; improving the weather indicators provided in the France Weather History”.

All of the actions described above contributed to shape an internal policy and a corporate discourse on adaptation to climate change. In addition to the pragmatism we mentioned earlier, the 3D has tried to carry on the message that adaptation is neither just a constraint nor a technical problem. Moving away from the initial focus on norms and standards, perceived as too rigid and compelling, to a more positive innovation-centered language. As a result, adaptation for instance becomes as challenge for new IT solutions (e.g. using big data to enable rolling-stocks predictive maintenance and be better prepared to severe weather⁶⁹). It is also an issue of comfort (e.g. railway stations in summer), working conditions (e.g. during heat-inspection) and future mobility patterns (e.g. potential displacement of flows of tourists).

On the engineering (“hard”) side, SNCF is rather confident on the robustness of the system and its capacity to react to future changes. On the “soft” side, there are many complementary actions to conduct. Adaptation appears as a technical challenge for research and innovation with promising ideas such as the use of smart sensors (IoT) to monitor track-temperature and replace arduous heat-inspections. It also raises economical and organizational questions: “heat softens the sciences” as Dubost writes (Dubost, 2017). Promoters of this thesis within the organization regularly quoted the project as an initiative to better understand how to mainstream climate concerns in decision-making. Foresight and long-term thinking appear as key challenges to guarantee the durability and the future performances of the company.

The general idea is that a smart adaptation can contribute to the ongoing modernization of SNCF and might be a source of performance and competitiveness. Along with buzzwords like innovation, agility or resilience, this discourse serves the strategy pursued by SNCF top-

⁶⁸ BREHAT is tracking tool of any train circulating the French national railway network. It provides records of positions, times and incidents and is also used to compute statistics of regularity and determine ex-post which entity was accountable for an incident (cf. Chapter 6).

⁶⁹ <http://www.innovationrecherche.sncf.com/category/maintenance-predictive/> - Last accessed April 2018

management. (SNCF, 2013, 2017b). It is consistent with the objective of moving from a product-focus (i.e. the train) to a service-focus (i.e. mobility) and adopting a customer-centered attitude.

Those transformations are nevertheless an ongoing process that is not unanimously accepted and generates tensions. Many internal stakeholders still perceive adaptation only as engineering issue. For instance, the demand to get ready to contribute to the PNACC 2 in 2017-18 was redirected to the engineering department, which planned to prepare notes on each component of the infrastructure (tracks, electrical equipment's, civil works, etc.). Those notes should include information about the temperature sensitivity, vulnerability to flooding, the prevention measures already implemented, the additional measures required with a basic economic and technical assessment of options and an estimation of their urgency (especially comparing wait and see and proactive approaches). Another example is a follow-up proposition of SNCF-Voyages after COP21 to conduct a prospective analysis of the climate-induced evolution of transport demand that has not been implemented.

Adaptation is framed at this level as a specific corporate policy, whose objective is to guarantee that SNCF is active on this issue and will be able to deal with related risks and opportunities. It is about paying attention to internal and external weak-signals and being able to technically answer potential questions from stakeholders. The relation to external stakeholders appears as particularly important through the hierarchical and reporting link of the sustainability department – in charge of the topic – to the “General Secretariat” of the company in charge of public affairs, safety and European cooperation. Up to now, besides the PNACC, there is limited evidence of actual expectations from major SNCF partners or stakeholders regarding adaptation to climate change. However, SNCF anticipates potential questions, critics and get prepared to answer further requirements by publicly showing that the organization is able to and know how to manage this risk in an autonomous way. We can qualify this as a form of “preactive” attitude (Godet, 2007), trying to get prepared to react to expected evolutions.

Parallel with the case of Network Rail in the UK

The process we have just described is similar in many aspects to what Network Rail – the national railway network owner and manager– did in the UK. Following triggering weather events and in order to address external requirements (under the 2008 National Climate Act,

(UK government, 2011)) Network Rail started to work on this issue quite early, first by contributing to research projects (Network Rail, 2015; RSSB, 2016). The company chose an approach focusing on improving the knowledge of the relationships between railways and weather. As in France, this first step was already not an obvious one:

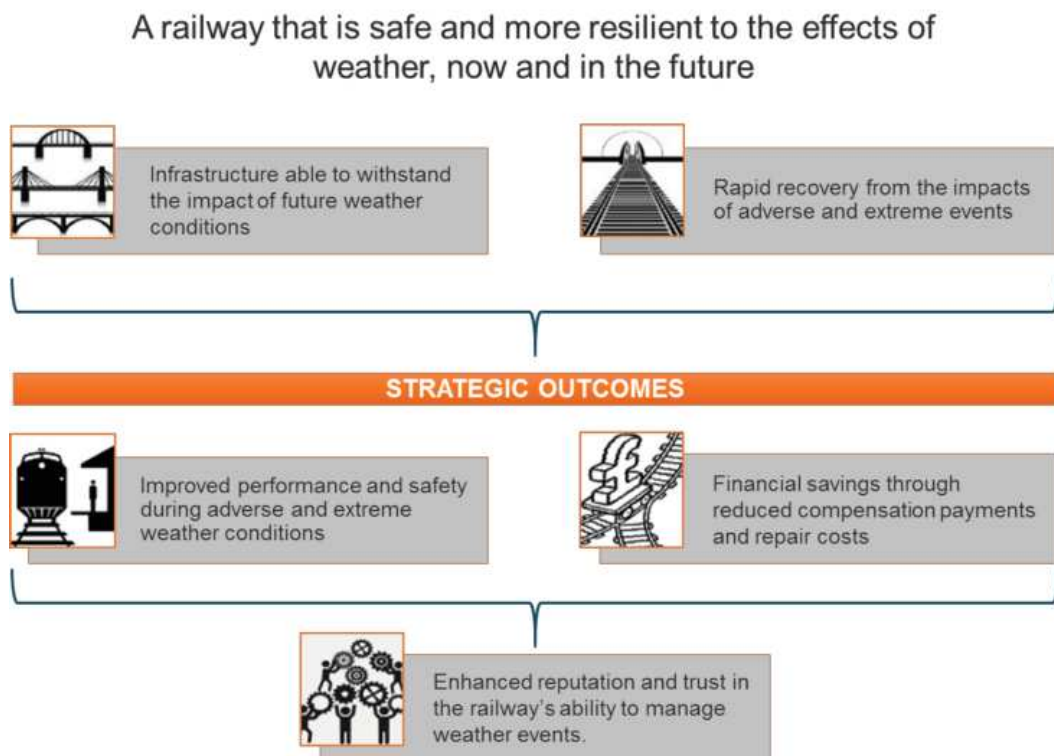
“Network Rail has come a long way in understanding the impact of weather events on the railway, however, we are still in the early stages of our journey to understand and quantify the impact of climate change and the cost associated with a changing risk profile” (Network Rails, 2017).

Climate change was perceived in continuity with current trends (it "will amplify the risk") with a focus on improving the organization capacity to deal with any severe event. Network Rail's initial diagnosis identified mobilization, governance or knowledge management as critical challenges for adaptation.

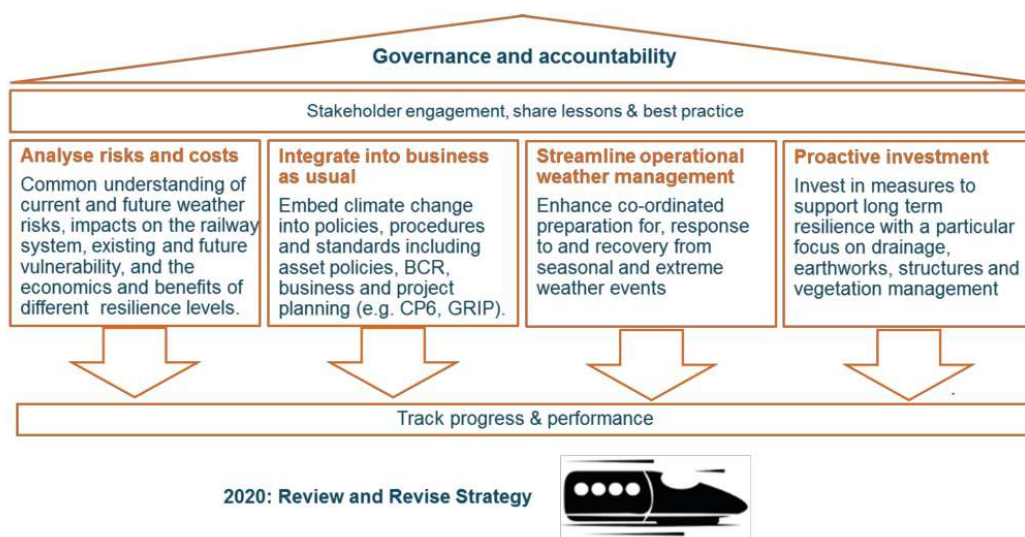
However, contrary to SNCF, Network Rail went up to establishing a comprehensive resilience and adaptation strategy around four pillars with quantified objectives, key performance indicators and dedicated resources (Figure 3-4). The obligation to report their “current and future predicted impacts of climate change on their organization, proposals for adapting to climate change and the assessment of progress towards implementing the policies and proposals set out in previous reports” (ARCC, 2017) appeared as a major lever for action.

“Network Rail is aspiring to reduce the gap between performance on adverse compared with normal weather days by 1% PPM through improved weather resilience. This will be delivered through increased investment in drainage and vegetation management (0.6% - included within core CP6 asset plans), 0.2% from proactive investment in resilience measures and 0.2% through continuous improvement (e.g. reducing Delays per Incident) and innovative technologies and approaches.” (Network Rail, 2017, p. 30)

Figure 3-4 - Major components of Network Rail Adaptation & Resilience Strategy



(a) Network Rail “Strategic vision and outcomes for enhancing resilience of the railway”



(b) Network Rail’s “four pillars of resilience”

Source: (Network Rail, 2017, pp. 17–19)

This parallel with this example of UK is interesting, as it help us insist on two essential characteristics of adaptation thought as a corporate level. Firstly, it appears as a pragmatic answer to external pressures and requests (mostly to manage an institutional risk up to now). Secondly, companies are trying to make adaptation consistent with a broader move from an

industrial to a management mode of regulation. In this context, performance indicators and economic analysis become important components to frame the vision of climate adaptation from an organizational perspective.

IV. ONGOING ADAPTATION INITIATIVES: INTERNAL INITIATIVES FOR RESILIENCE

In addition to this institutional uptake of climate change adaptation as a new and specific item on the agenda, there are many individuals people across SNCF concerned with the impact of climate on the system. Major events in recent history – e.g. *Lothar and Martin* storms in 1999, heatwaves in 2003 and 2006, floods in Cannes in 2015 and Paris in 2016 –; the growing awareness in the general public after 2014 IPCC report and COP21 and institutional talking points described in the previous section⁷⁰; increased the attention on the climate issue. They encouraged people in the company to address it within their scope of attributions.

1. Improving the understanding of the relationship between the weather and railway: a first step towards adaptation?

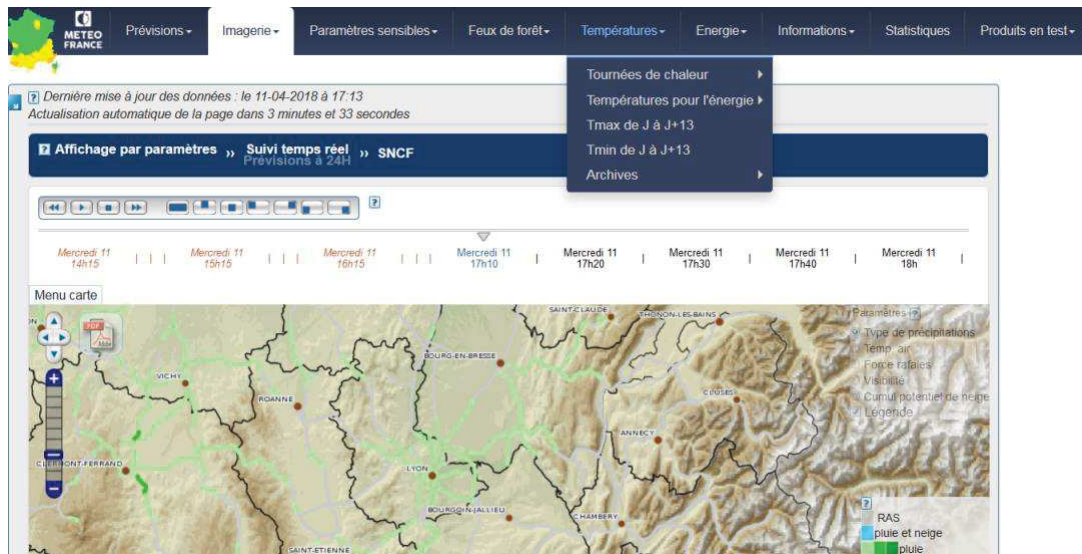
A new weather service contract

We were able to identify and meet many of the experts involved in bottom-up adaptation actions by following the relations woven around the new contract between SNCF and Météo France for weather services. Before 2015, there was no harmonized weather information management. Many different SNCF units bought information from Météo France or from other information providers, regularly or punctually, with no pooling of resources and no archiving process. In 2015, a common project gathered data users to share needs and write the specifications for a unique tender for weather information (Figure 3-5). The contract signed between SNCF and Météo France in 2015 (and covering the next four years) had two objectives: efficiency (especially cost-efficiency) and allowing the creation of series of data in order to detect patterns and improve management processes:

"The reconciliation and pooling of meteorological and climatological needs for the various railway domains is essential for the knowledge of the interactions of the complete railway system, but also for the technical and economic performance of the responses provided by the meteorological providers" (Document presenting this new convention)

⁷⁰ Including the D-RAIL project

Figure 3-5 - Screenshot from the weather-data portal provided to SNCF by Météo-France



Source: SNCF

It provides a direct access to 10 weather variables among which air and ground temperatures, dew point, hygrometry, wind speed and direction or rainfall. Both observations and 72h, 48h, 24h then hourly forecasts are available for each 5km section of the network (7600 points). A record is made every 5'. Many uses work with daily or hourly averages and specific additional indicators are provided (e.g. for fire risks).

Around this project and those who carry it, a community of experts, working on the tools and studies mentioned above has progressively emerged. It contributed to design common devices to share data, information and feedback. In 2015, an SNCF internal innovations call “*And you, what are you doing for climate?*” awarded a project called IMPRESSYF which proposed to “develop a meteorology and climate engineering for performance, resilience, expertise and monitoring of the railway system”. IMPRESSYF has helped to constitute this informal network of experts with representatives all across SNCF Mobilités and Réseau:

“Knowledge or expertise on the impacts of weather/climate phenomena on security Installations, network operation, transit optimization, work organization, human resources... is only partially controlled. Defining information needs, and alert or vigilance thresholds is a subjective exercise combining formal knowledge, skills and experience of railway and climate professional.

Following-up with the new weather Convention, we need to settle an actual weather-engineering approach in order to mutualize and coordinate SNCF information needs and so to professionalize the relationship between weather or climate experts and railway experts. A better/clearer definition of our requirements would increase the relevance of our partner's response and therefore lower the final cost of information provision. Relevant consolidated weather and climate information would provide a solid reference state of the current impacts of weather factors on the railway system. It would help to mitigate those impacts on the production, maintenance and management of the system.

It would enable to anticipate changes in the design of future infrastructures, rolling-stock and organizational plans building on the description of the coming climate evolutions by the IPCC”.

Original presentation of IMPRESSYF as one of the 5 laureate out of 489 ideas proposed to the internal challenge: “*How to mitigate or anticipate climate change in our business?*”

Many initiatives to value the data acquired from Météo-France arose from this process among which studies and decision-support tools. They all adopt a vulnerability first approach, focusing on adaptation to current climate before future changes (Dépoues, 2017c). They implicitly or explicitly assume that reducing today vulnerability is the first step to manage future climate risks.

Studies focusing on relationships between components of the railway and weather or climate.

The *Engineering and Projects* department especially conducted several analyses with a focus on hydrological aspects, e.g.:

- An “Evolution of risk of flooding for the Languedoc-Roussillon Infrapôle (2017)”;
- A work in progress on heavy rains and mudslides (2017-18);
- GIS approaches to improve the understanding of the spatiotemporal dynamics of the natural risks (a PhD thesis supported by SNCF especially applied this type of techniques to historic floods on the railway network (Saint-Marc, 2013))⁷¹;
- A risk analysis for rail traffic of high speed line drain overflow (Pams Capoccioni et al., 2015).

There also are a few examples intending to assess the economic impacts of weather on costs of operations: e.g. “Incorporating weather conditions into railway infrastructure cost-functions” (Bruscoli, 2016).

These examples show that, even from a technical perspective, providing a robust analysis of the relationship between railway and weather is still a challenge for experts. It raises issues of

⁷¹ This study explores the benefits of a geomatics (GIS) approach to improve knowledge about flood risks for the railway network. It provides descriptions and representations of past flood episodes with detailed chronologies of the events and how they were managed. The purpose is to strengthen the institutional memory in order to mainstream the culture of risk within the company. At the moment, it is indeed very hard to understand and compare individual weather events because the relevant circumstances are not systematically recorded, especially when the damages are not exceptional (Pams-Capoccioni et al., 2013).

data availability, compatibility and consistency and necessitates a long work, even for railway experts, to deal with the multifactorial nature of the issues at stake.

Tools development to support decision-making.

Classical management tools have been existing for many years to support routine decision-making based on the weather conditions. For instance, empirical tables connecting air-temperatures with rail-temperatures has helped for decades to decide when to start heat-inspections. Since 2010, the “Previ-neige” model provides information to adapt trains’ speed to minimize damages on glasses in case of accumulation of snow on the tracks. Thanks to the enriched weather-information, those tools were improved, and new tools emerged. They build on the possibility to establish robust statistical relationships to replace the former approximations: e.g.

- “J+13”: to anticipate rail-temperature based on weather forecast – useful to schedule maintenance (inspections, etc.);
- “Prédicteur”: to model the risk of conducting some heavy maintenance operations depending on weather conditions by computing the relationship between observed anomalies in the past and three critical atmospheric parameters.
- “Déclencheur”: to replace the tables used to decide when to conduct heat-inspections. It aims at reducing the number of non-useful inspections conducted and useful inspections not conducted.

Most of the experts involved in those initiatives told us they would like to move forward from current weather to future climate. In order to do so they would like to address questions such as: “do we detect changing-trends in weather records over time?”; “Can we explain observed changes and trace their implications?”; “will future extreme event be similar to past ones?”, “Can we stress-test the relationship we established between railway and weather with future climate scenarios?⁷²”. The overall idea is first to improve our understanding of current vulnerability, then to assess how the system may react to climate changes. This appears as first steps towards an active management of the relationships between the railway and

⁷² This approach was proposed as a follow up study to the “Evolution of risk of flooding for the Languedoc-Roussillon Infrapôle” but not (yet) approved.

climate systems. This step is already not trivial as there is no pre-existing material or data (one did not monitor what was seen as stable).

These initiatives are also consistent with the “performance” narrative we described in the previous section. They converge with major developments happening in the company like the creation of a new department in 2014 to deal with digital transformations at the group level⁷³. This direction is hosting the weather convention and in charge of “scaling-up weather-related innovations to improve business processes.”

“Improving our capacity to correlate data becomes more and more important, especially with the development of performance management systems⁷⁴ like the ones in use in the UK or Northern Europe. New guaranty engagements with travelers based on delays materialize the correlation between minutes of delays and euros. We need to be able to accurately attribute the causes of delays to attribute the costs. Fifteen years ago it was inconceivable to compute such correlations; it now becomes possible with new technologies.” Quote from an interview, SNCF Réseau

2. An incomplete interestment process

Existing adaptation initiatives are still work in progress, involving a few driving persons in the organization. As innovative propositions, they still have to build a network of allies strong enough to produce profound transformations (Akrich et al., 1988). The capacity to move to the next phases and to mobilize resources to consider future changes is not guaranteed.

The “SYNAPSE” Experts-Group on climate adaptation

In 2017, a broader working-group on climate adaptation was launched in the SYNAPSE Network. SYNAPSE is the internal community of SNCF experts created in 2010. In 2014, it gathered more than 200 in-house experts around transversal topics. SYNAPSE experts commit to participating in the development and sustainability of strategic skills for the group. They also take part to the construction and implementation of the innovation and research programs. The company values their contribution by giving them access to specific training, high-level conferences, a summer university or even financial bonuses. Every year, a special commission composed of SNCF's scientific, technical and HR representatives, select new entrants in the network.

⁷³ <https://www.digital.sncf.com/transformation-numerique> - last accessed June 2018

⁷⁴ <https://www.sncf-reseau.fr/fr/acces-reseau-ferre/boite-outils/systeme-amelioration-performances> - last accessed June 2018

Many of the experts involved in IMPRESSYF also belong to the working group on adaptation created as part of the SYNAPSE sustainability cluster. Nevertheless, it is opened to experts from other clusters across the company (SNCF Réseau and SNCF Mobilités). It fosters collective work on knowledge development on ongoing climate-related changes and the vulnerabilities of the railway system; the assessment of climate-related risks for the company; adaptation actions; mainstreaming of adaptation in infrastructure design. These objectives reflect the will to create momentum among experts currently working on the very first stages of adaptation.

The original presentation of this working-group – animated by three persons from SNCF Réseau (Work & Maintenance department) and Mobilités - announced several objectives, focusing on information flow and knowledge management:

- “Supporting the company to build an adaptation strategy and address external requests;
- Detecting weak-signals in social, political economic fields;
- Organizing a scientific and technological watch to support SNCF in implementing its adaptation strategy;
- Fostering knowledge and feedback sharing across the organization and providing useful information to managers”.

However, the group is not mandated to define the corporate adaptation strategy.

The group plans to hold five meetings every year. The first one took place on June 22, 2017; the second on September 27 and the third one on February 1, 2018. We attended these three sessions. Each one last for about four hours and gathered between 10 and 15 participants (about 20 people on the mailing list). Some of them attended all the sessions, other only came to one or two. After each meeting, the organizers write and circulate a brief recap. A common *Sharepoint* on the Intranet also enable documents sharing.

During those sessions, a lot of information was exchanged. We for instance had presentations on: the two studies conducted by Carbone 4 described earlier; the ongoing work of the transversal mission on floods; the PNACC; studies conducted by the Engineering department; the Weather-service convention and IMPRESSYF; pieces of benchmark about adaptation initiatives conducted by railway companies in other countries; national and international consortium and projects SNCF is involved in, such as Railenium⁷⁵; insurance and flood-risk for

⁷⁵ <http://railenium.eu/fr/> - last accessed April 2018

SNCF; future work and perspectives for adaptation (for instance a guided innovation process that the maintenance department of SNCF Réseau is planning to launch in October 2018).

While, through our interviews, we knew about most of these initiatives, most of the participants often heard about the other's work for the very first time showing that the need of an improved flow of information in real . Out of these discussions, some key messages have emerged. Participants for instance noted the prevalence of infrastructure-related issues over mobility-related issues, even if SNCF Mobilités was actively represented. They shared a common description of the railway system as a complex socio-technical system well known by SNCF experts but not well understood by external stakeholders. They agreed on a common diagnosis of existing barriers to adaptation which includes the lack of dedicated-resources and strategic support or cultural obstacles to properly use existing data.

Many participants to the group are really concerned by climate change and perceive themselves as frontrunners. They are sorts of “gatekeepers” or knowledge brokers (Haas, 2015; Tushman & Katz, 2015). However, all of them are experts and not decision-makers. Even if they are looking for arguments – especially economic elements - to find sponsors among top managers to move forward on adaptation, their priority is to mitigate the risks and optimize how the system is functioning, not to transform it.

CONCLUSION OF THE CHAPTER: A TRUE CONCERN, NOT A STRATEGIC PRIORITY

This chapter has explored where and how SNCF raises adaptation issues at a corporate level. This first series of observations led to a clear conclusion regarding how SNCF is currently framing adaptation to climate change. Many experts in the company – from technical specialists to top-managers – are aware of the issue and do not contest its veracity. However, as shown by D-RAIL, translating this awareness in decision-making is not a straightforward, “one-shot” process. Centralized top-down approaches did not prove very effective. Adaptation takes time; mobilizing and interesting people in the organization is a challenge.

To tackle this challenge, promoters of adaptation at the corporate level chose to focus on actions that also contribute to operational performance of the railway system. Their distributed initiatives converge towards a better understanding and management of the relationships to the weather. This is already a challenge as SNCF has been working for decades

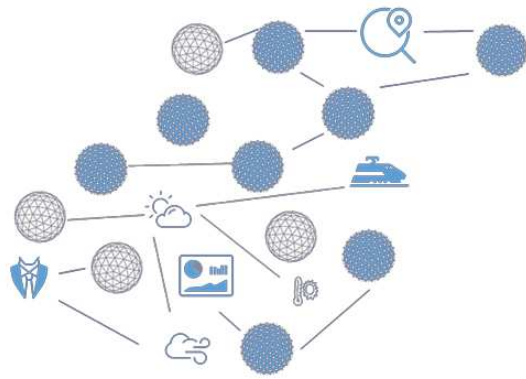
with informal, empirical, distributed expert-based knowledge with very little equipment to monitor and record these interactions. People conducting this work have tried to convince the rest of the organization to dedicate resources for recording and analyzing data.

Up to now, adaptation is still perceived as a technical issue, handled by experts, “a concern but not a priority”. SNCF discourse is rather reinsuring, considering that adaptation is a well-identified issue that needs to be carefully managed but which is not a major threat. As a result, it remains a second-order stake, locally addressed by a variety of departments on their own scope (as a component of the discourse on sustainability, as an engineering concern, etc.) with no effort to build a shared strategic vision. It is mainly about marginal optimization.

In the first paper stemmed from this thesis (Dépoues, 2017c), we proposed levers of action to address three critical bottlenecks and enable a more proactive preparation to climate change and to mainstream adaptation into major relevant decisions:

- i. Satisfying the necessary conditions (a stronger leadership, a clear and transparent governance, enhanced engagement of external stakeholders, dedicated resources, etc. as suggested by (Ford & King, 2015)) for adaptation to address the lack of a consistent institutional framework;
- ii. Creating opportunities for a strengthened dialogue to address the poor engagement with climate science;
- iii. Experimenting alternative decision-making tools to mainstream adaptation to replace or complement processes and procedures not adapted to an uncertain dynamic.

According to Dubost (2017), one of the major challenges is to manage time scales ranging from the minute (SNCF, ensure the safety and comfort of four million passengers every day) to the century (lifetime of major infrastructures). Adaptation decision is a tricky issue because it has to find its way in this tension. It can only find its feet at the nexus between strategic will and signal from the field. As it is framed for now, adaptation – as a specific topic – appears far from operational activities of SNCF (very short term) and secondary in relation to strategic decisions. To find how to unfold the broader implications of climate change, we need to explore other places and understand how the issue is perceived in operational activities and what the connections between various sites of the organization are.



"For a railroad engineer, the rails are not infrastructure but topic." Susan Star

Chapter 4 - Operating the railway system in a Mediterranean climate

In this chapter, we explore another site within the SNCF organization, considering a different perspective on adaptation. We travel from Paris to Montpellier to study the actual operation and management of a section of the railway network at the regional scale. Here, we do not intend to identify adaptation as a topic *per se*. We rather try to get a better understanding of the actual relationships – as experienced, perceived, and rationalized – that connects the weather and climate with the life of the railway system. We want to observe adaptation as it happens, explicitly or implicitly: What is it the symptom of? Which changes does it bring about? Which perception of changes?

In order to do so, we have conducted an in-depth analysis of a section of the railway system, located in the south of France (which will be presented in the first section of this chapter). As we have seen at the very end of the last chapter, the management and operation of the network encompass activities that have characteristic times ranging from less than a minute to more than one hundred years. Depending on the focus, variations in hours, seasons or decades might be meaningful to make relevant decisions. In sections 2 and 3, we consider the perception and consequences of climate change along this full spectrum. We then discuss these observations in a fourth section before concluding on this chapter and, more generally, on how adaptation is happening for now at SNCF.

I. INTRODUCING THE CASE-STUDY

1. Location and context

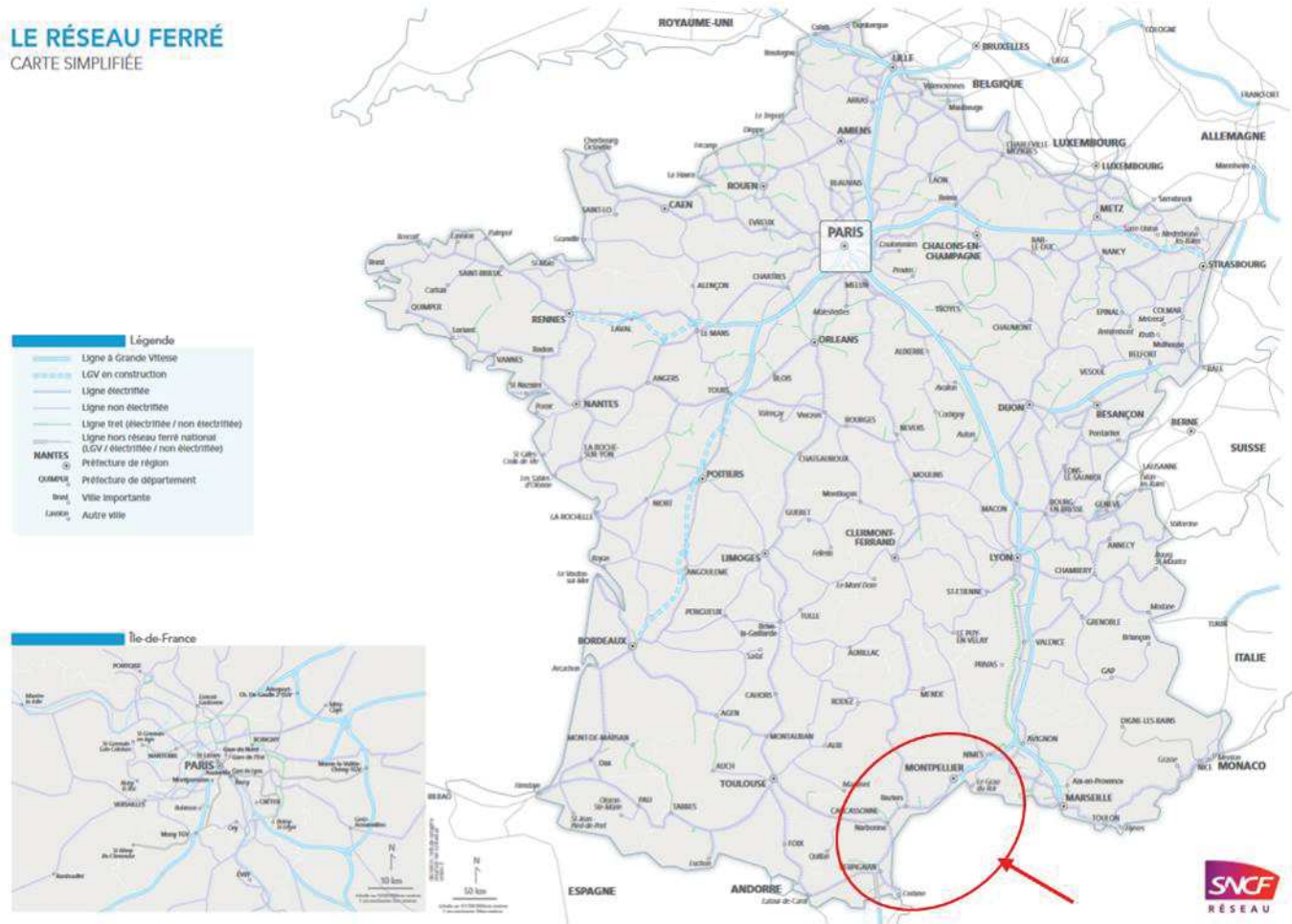
In order to get a grounded view of the interactions between railway management and the weather and climate, we located our sub-case study of a section of the French railway system, in the *Occitanie* region (Figure 4-1 and Figure 4-2), between the cities of *Nîmes* and *Perpignan*. There are three main reasons justifying this choice of location:

- First, the specific and diversified rail context: this is a place with important maintenance and retrofitting challenges for the existing network on one side (the main

line opened in 1839, (SNCF Réseau, 2018a)), and ongoing development projects on the other side (new high-speed lines and stations)⁷⁶;

- Second, the specific and diversified weather situation: sea-level rise, heatwaves, rapid floods are actual issues experienced there (ADEME & Météo-France, 2011; Jacques, 2016) ;
- Third, the positive feedback of SNCF staff in this region when we proposed this study, which is a critical aspect to ensure a full access to the relevant information.

Figure 4-1 - The region studied on the simplified map of the French railway network

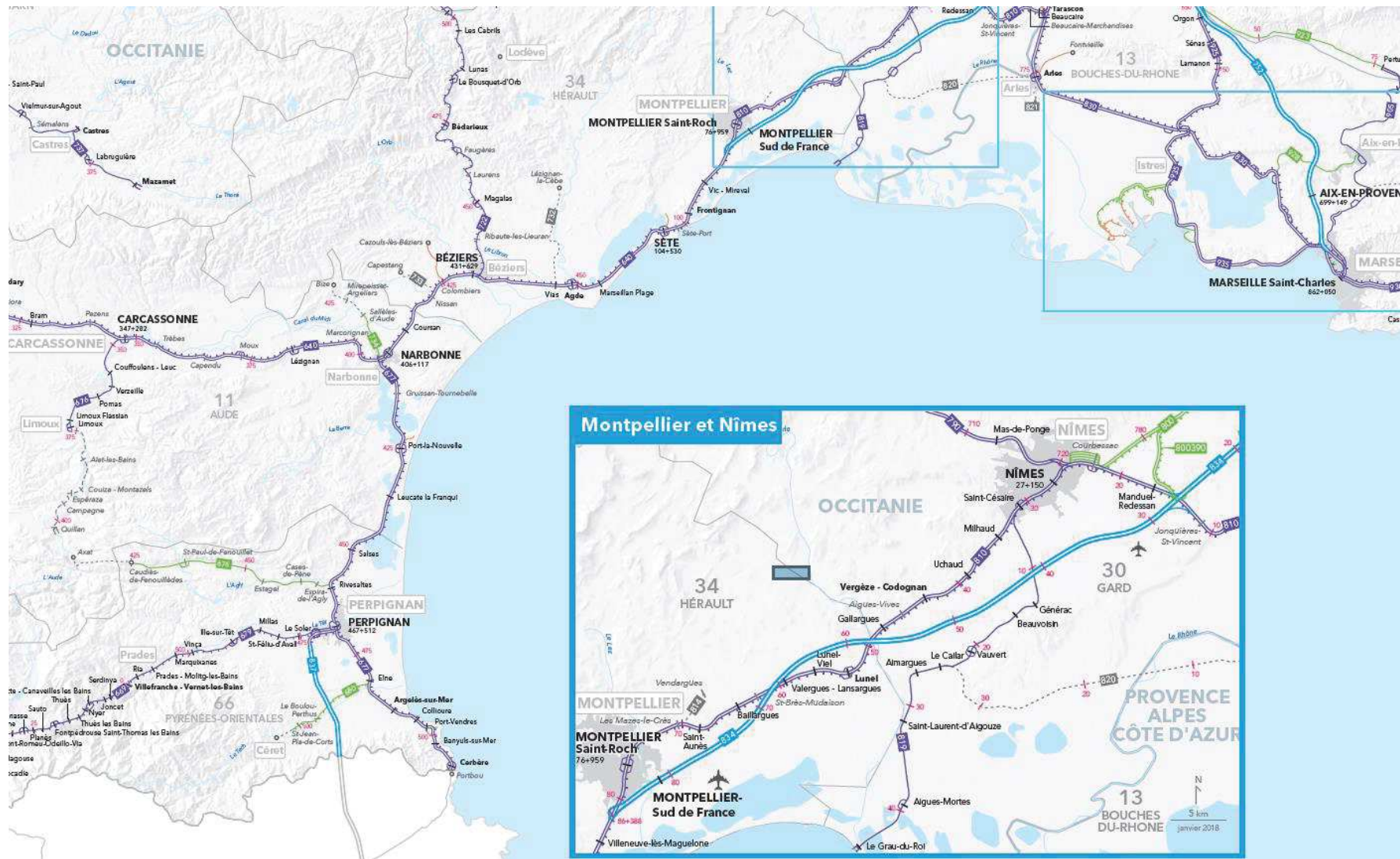


Source: SNCF Réseau⁷⁷

⁷⁶ Detailed list of planned works in this Region https://www.sncf-reseau.fr/fr/projets-chantiers-ferroviaires/tous-projets?field_localisation_projet_tid%5B0%5D=41 – last - accessed May 2018

⁷⁷ www.sncf-reseau.fr/sites/default/files/upload/Carte/2015-mars/carte-simplifiee-reseau-20150330.pdf - last accessed May 2018

Figure 4-2 - Zoom on the region studied on a detailed map of the French railway network



Source: SNCF Réseau

2. Conducting interviews

We conducted 29 semi-directed interviews, talking to 35 people between December 2016 and February 2017. The (Table 4-1) presents this sample. This new corpus supplements the previous interviews conducted in Paris between March and December 2016 (cf. chapter 3).

Table 4-1 - Description of the sample for the interviews conducted between December 2016 and January 2017

| | |
|------------------------------|--|
| SNCF Réseau | Major projects: new lines and stations |
| | Design and implementation of development + regeneration projects (I&P) |
| | Organization of maintenance and modernization (M&T) |
| | Network maintenance operations (telecom, cross-rails-ballast, catenary, etc.) (Inflation and Infralog). |
| | Allocation of network capacity and traffic management |
| SNCF Mobilités | Daily traffic management: nominal mode and crisis situations |
| | Rail Security |
| | Stations operations |
| | Maintenance of rolling stock (technicentres) |
| External stakeholders | Transport user associations (e.g. FNAUT) |
| | Local authorities (technical advisers of the Occitanie Regional Council, Hérault departmental council and Metropolis of Montpellier) |
| | Scientists & experts (Water Agency, University of Montpellier, BRGM, EID) |

Source: Author

With this sample, we tried to collect the views of a wide variety of professions involved in the development, administration and operation of this section of the network. We identified some of these persons thanks to our previous interactions with SNCF and then proceeded by snowball sampling.

Three main axes structured the interviews:

- The main drivers of development and management of the railway system at a regional level. Major trends to consider for understanding its current evolution, from an operational perspective.
- The experienced and formalized relationships between the railway system (operations and infrastructure) and the climatic conditions.
- The current perception of climate change: awareness, experience, knowledge about it. Potential existing response or discussions about adaptation.

II. LIFECYCLE OF A RAILWAY-SECTION: WHERE AND WHEN DOES THE CLIMATE ISSUE APPEAR?

1. Long-term projects: example of a new high-speed line, Montpellier-Perpignan

When we started our inquiry, several new development projects were ongoing. Among them, the construction of a new high-speed section between the cities of Montpellier and Perpignan, which has been discussed for almost 30 years and is currently in stand-by. This *LNMP project (Ligne Nouvelle Montpellier-Perpignan)* encompasses 150 new kilometers of tracks and several new TGV stations. This example is particularly interesting for our study. Indeed, new infrastructures are designed to last several decades (Table 4-2) and will therefore experience future changes in climate. Moreover, this upstream phase of project planning is *a priori* relevant to take into account the anticipated impacts of climate changes through a form of *adaptation by design*.

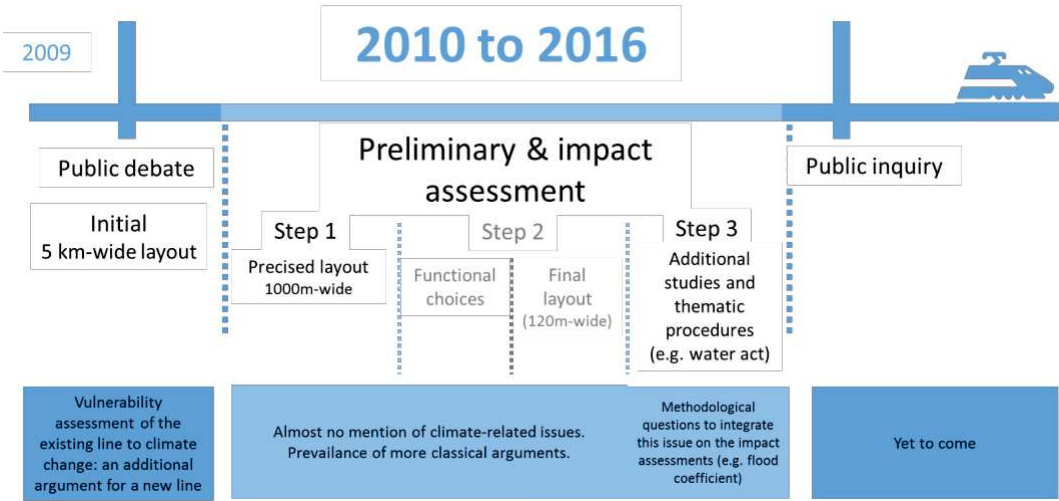
Table 4-2 - Characteristic time of railway system components – horizons of decision

| Infrastructure | Years | Marketing systems | Years |
|---|-------|--|-------|
| Designing and building civil works | ➤ 150 | Management software | 10 |
| Electrification | ➤ 80 | Distribution-sell devices | 10 |
| Producing and laying tracks | ➤ 50 | Pricing | 3 |
| Revegetation | ➤ 15 | Communication campaign | 0,5 |
| Stations | Years | Rolling-stock | Years |
| Building and operating a new station | ➤ 100 | Investing in new trains | ➤ 40 |
| Creating a new platform | ➤ 50 | New locomotive | ➤ 20 |
| Designing a new station | ➤ 30 | Addition comfort devices | ➤ 20 |
| Reorganizing spaces | ➤ 20 | Installing toilets in existing trains | ➤ 20 |
| AC/heating system | ➤ 15 | Retrofitting of rolling stocks | ➤ 15 |
| Creation of new facilities (bathrooms, water fountain, etc.). | ➤ 15 | AC/heating system | ➤ 15 |
| Creating a new waiting room | 10 | Acquiring new navigating and driving system to optimize consumptions | 10 |
| Reorganizing welcome desks | 5 | Leasing operation | 10 |
| Implementation of an customers information system | 5 | | |

Source: SNCF - translation: Author

This type of projects follows a very structured process with many compulsory stages spread over several years⁷⁸ (Figure 4-3). These steps involve various actors among which SNCF Réseau, local authorities, ministries, financial partners, or local associations. When we began our study of LNMP, the roles’ distribution was already quite stable. There was: SNCF Réseau as project leader; the Regional Council positioning itself as the leader (“*chef de file*”) of local authorities engaged in the project⁷⁹; a coalition of local associations (users’ associations like the FNAUT⁸⁰ and environmental groups) and finally the successive Transportation ministers who generally temporized the process. Not all these actors have the same resources to dedicate to the project. A stable team of six persons is in charge of the project at SNCF Réseau with significant resources to mobilize additional or external support. About 40M€ were spent for the initial studies phase. At the Region, there are two specialists working in the transport infrastructure division to follow all the major projects. Associations are mainly working with volunteers and have no dedicated financial resources.

Figure 4-3 - Emergence of the climate issue through preliminary studies



Source: Author from LNMP website⁸¹

We identified three moments when the climate issue emerged in this process (Figure 4-3)

1. The public consultation procedure⁸² as it is defined in the Barnier Law, which took place in 2009 and led to the definition of a 5 kilometers-wide layout for the line.

⁷⁸ In the case of LNMP this process is particularly long. We find the very first mention of this new line in the beginning on the 1990s and if the project succeeds, the first trains will circulate between 2025 and 2030.
⁷⁹ The [law NoTRe \(n°2015-991\)](#) of 7 August 2015 “portant nouvelle organisation territoriale de la République” strengthens this position. With this bill, the Regions became the unique traffic authority for inter-urban transit.
⁸⁰ *Fédération nationale des associations d’usagers des transports*
⁸¹ www.ligne-montpellier-perpignan.com/pages/le-processus-detudes - last accessed December 2017
⁸² More on this procedure in France - Cf. <https://www.debatpublic.fr> – last accessed June 2018

2. Preliminary technical studies and a phase of concertation with stakeholders on the proposed layout and functional choices (connections, new stations, passenger/freight options, etc.) between 2010 and 2016. It resulted in a more detailed 100-120 meters layout approved by a ministerial decision on January 2016 (Figure 4-4).
3. Completion of additional studies – especially impact assessments and analysis required through the water-act⁸³ (SNCF Réseau, 2014) – necessary to the “declaration of public utility” procedure, i.e. the formal recognition that the project has public benefits before the construction can actually start⁸⁴.

Figure 4-4 - Map of the preliminary outline of the LNMP endorsed by the Government



Source: LNMP website⁸⁵, January 2016

The notion of climate change made its first appearance in this project in a document entitled *Assessment of the impact of global warming on the existing railway infrastructure between*

⁸³ Ministerial Circular DE/SDGE/BPIDPF- CCG n° 426 – 2002, July 24th http://circulaires.legifrance.gouv.fr/pdf/2009/03/cir_27184.pdf - last accessed December 2017

⁸⁴ As we write this chapter (May 2018) the project is still in stand-by for financial and political reasons: it is not totally funded and the French government declared a moratorium of major mega-projects to review its investment policy. An ongoing legislative should prioritize the future projects and redirect an important part of the effort on the renewal of existing assets.

⁸⁵ www.ligne-montpellier-perpignan.com/sites/ligne-montpellier-perpignan.com/files/rff/doc_de_com_dm3_hd.pdf - last accessed May 2018

Montpellier and Perpignan (RFF, 2009). Commissioned by the project manager, this original assessment is regularly mentioned by all the project's stakeholders including SNCF Réseau, users' associations and local authorities.

An "independent expert" conducted the study. Although he has sometimes been confused with a scientist "of the IPCC", this expert was not a researcher but a specialist of environmental issues formerly working for the national administration. As indicated on the report, Michel Mousset was a former president of the French national environment and energy agency (ADEME – 1992-94), of the interministerial group on greenhouse effect (1997-2002) then of the French committee for the Preparation of the World Summit on Sustainable Development (2002). He also served as a State financial officer in charge of SNCF. His report is 98 pages long and is principally based on a state of the art on the existing knowledge regarding the vulnerability to the existing section of the network to climate change. It mentions several impacts but eventually focusses on sea-level rise:

"We will leave aside, after having recalled them, questions closely related to railway technology such as those of tracks dilatation induced by temperatures increase [...]; or resistance of catenaries to strong winds. These problems do not seem out of reach of the regular improvements in the safety of installations [...]. It is on the infrastructure itself that problems may appear. The infrastructure is mainly exposed to erosion, submersion and flooding as well as the joint effects and the simultaneity of these phenomena. One can assume as very probable the continuation of sea level rise and its consequences during this century [...]." p.28 "General context"

The study summarizes what we knew after the IPCC fourth assessment report (2007) and assumes "about 1 meter" of sea level rise at the end of the century in order to consider a wide spectrum of risk.

The third section of the report draws a landscape of the risks associated with a "business as usual" climate scenario. It describes what could happen to the present line because of storm surges, waves, erosions, submersion, continental floods or the concomitance of events. The fourth section gives the results of a vulnerability analysis of the present line decomposed in sub-sections. A table localizes "hotspots" and characterizes existing, coming and possible future risks. 89km out of 162 are labelled as vulnerable. Recommendations to improve the situation are proposed in the fifth section. They include the need for knowledge building, especially through regional climate modelling, and an improved governance of local climate adaptation.

These results have first and foremost been used as an additional element to justify why a new line is necessary for the region:

"We really wondered, during the public debate: do we need a new line? We had to demonstrate that it was necessary and why the development of the existing line was not an adequate response to the ambitions of the territory and to the coming challenges. In this respect, we considered the option of adapting the existing infrastructure" – quote from an interview with SNCF Réseau staff.



The key message the stakeholders took home, including SNCF Réseau was that the existing line would not remain a viable option in the long term, because of sea level rise. Consequently, as there is no alternative route on this structuring axis connecting France and Spain, a new line becomes essential.

Many other arguments went in the same direction, among them: the age of the existing infrastructure and the cost of its modernization; regional development ambitions and the necessity to build the missing link of the European high-speed corridor. The topic of climate change only confirms a conclusion already consensual. Since the beginning of the 90s, the issue is about how to build a high-speed line more than whether to build it or not. The scenario of a complete retrofit and modernization of the existing line – one of the fourth initially debated (Table 4-3) – was quickly eliminated. According to some actors, SNCF Réseau even presented this scenario as a false option: costly and non-satisfying.

"Of course, we considered a modernization scenario but they [SNCF Réseau] maximized the estimate of costs with almost no performance increase. At the end of the days, this option was close to 2bi€. It was the absurd, repellent scenario" Quote from an interview with an association of transports users.

The climate impact assessment we mentioned came as an additional and objective argument to strengthen the relatively consensual idea – at least locally – that a new high-speed line is the best solution for the region. We did not find any trace of discussion regarding the results of this assessment, the assumptions it makes or the knowledge it relies on. Some of the discussions we had with actors in charge even suggest that the result was already known when the study was commissioned, on purpose.

Table 4-3 - Synthesis of the 4 scenarios (modernization of the existing line + 3 options for a new line) proposed during the Public debate

| SCENARIO OF A PARTIAL DOUBLING OF THE EXISTING LINE | | Estimated cost: 2,1 bi€ | | |
|--|--|--|---|--|
| In this scenario, there is no new line between Montpellier and Perpignan but new sections with 3 or 4 tracks both ways on the existing line. All trains – TGVs with a maximum speed of 160 km/h and freight trains - circulate on the same line. Two new stations are planned around Nîmes and Montpellier. Existing stations deserve the other cities. This scenario does not enable any gain in time nor development of freight and regional traffic after 2020. | | | | |
| | Scenario 1: Passengers high-speed line – 320 km/h | Scenario 2: Passengers line – 220 km/h + freight – 120km/h | Scenario 3: Passengers high-speed line – 320 km/h + freight – 120 km/h | |
| Properties | High-speed line only for passengers' traffic with a maximum speed of 320 km/h | Hybrid passengers-freight line, with a limited maximum speed | Hybrid line with high-speed for passengers and limited speed for freight | |
| Trains on the new line |  |  |  | |
| Trains on the existing line |  |  |  | |
| Number of new stations | 5 (Nîmes, Montpellier, East of Béziers, west of Narbone, North or West of Perpignan) | 1 (Montpellier) | 4 (Nîmes, Montpellier, between Béziers and Narbone, North or West of Perpignan) | |
| Gain in time on one direct journey | 45 min less for a Montpellier-Perpignan, or Paris-Barcelone journey | 35 min less for a Montpellier-Perpignan, or Paris-Barcelone journey | 45 min less for a Montpellier-Perpignan, or Paris-Barcelone journey | |
| Number of Regional trains and possible freight circulation after 2020 | ≈ 10 additional trains | ≈ 70 additional trains | ≈ 50 additional trains | |
| Freight trains | All go through existing stations | 30 % avoids existing stations | 30 % avoids existing stations | |
| Main line services | Many more TGVs desserving mainly new stations (70 – 90 %) | Many more TGVs desserving existing stations + the new Montpellier station | Many more TGVs desserving mainly new stations (70 – 90 %) – not desserving Sète. | |
| Tons of CO ₂ saved per year in 2050 | ≈ 870 000 | ≈ 775 000 | ≈ 980 000 | |
| Estimated cost | 3.7 bi€ (including 0.6 bi for new stations) | 3.9 bi€ (including 0.15 bi for the new Montpellier station) | 5.2 bi€ including 0.5 bi for new stations) | |

Source: SNCF Réseau - translation: Author

Once the modernization scenario left out, most of the discussion focused on the functional choices and the layout of the future new line. Several alternatives projects were on the table with different options regarding which cities to connect along the way, which optimal speed for which type of circulations. When the debate ended in 2009, local elected officials followed by SNCF Réseau kept as the best option a project of fully hybrid line (passengers + freight, 4th scenario) with the highest speed possible and four new stations. This option was one of the most expensive. Complementary studies later highlighted additional costs to implement this choice which would especially require to build a very expensive tunnel. The project progressively evolved toward a partial functional mix (no freight between Béziers and Perpignan) and only three new stations. The key drivers of this choice were the expected

future traffic demand for rail, the associated economic benefits of reduced journey time and the political will to preserve and develop local transport services.

Some associations advocated against this choice. They preferred a fully hybrid option even if – in order to avoid the costly tunnel – the trains had to limit their speed to 220km/h instead of 300⁸⁶. They mentioned again the vulnerability of the existing line to climate change to justify this preference. In their view, sea level rise is already a problem that jeopardized freight traffic and so business activities in the region. They cite photos to support their arguments:

"We have curators, people who take pictures and keep the memory of the territory. When these elements are put into perspective over 10, 20, 30 years, when we compare snapshots, we observe a phenomenon: the track is closer and closer to the Mediterranean near Port-la-Nouvelle for example. We already observe impacts of climate change. We have to look to the future, we have to anticipate. [...] This line is doomed, it will ultimately be submerged. [...] There will be temporary or permanent traffic interruptions in several places [...] this is a problem that will only get worse." Quote from an interview with an association of transports users.

"The existing line is already not reliable enough, not only because of future global warming that you don't take into account, but in light of the current situation". Quote from the minutes of a public concertation meeting on July 2015 in Lattes (Association *No Pasaran*, *Comité Partenarial d'Information n°4*).

According to those associations, this situation is not acceptable because it threatens the reliability and therefore the viability of railways as a mobility option. The service becomes less attractive and less competitive compared to road even though travelling by road generates more negative externalities. This loss on the existing part of the network would exceed the benefits created by the higher speed on a new branch which would be inaccessible to freight.

SNCF Réseau does not contest that the existing line is vulnerable to climate change but explicitly choose to postpone this question. According to the project manager, the existing line will eventually become unviable but only in the long term. Based on traffic projections, he considers that in the long run the existing line will be saturated anyway making another new branch necessary for freight. In this situation the optimal decision sequence is first to build a new high-speed line only partially hybrid and to deal with the consequences of climate change when the question of a new freight line will arise.

⁸⁶ We find for example press releases by actors such as the FNAUT, a national association, www.fnaut.fr/actualite/communiqués-de-presse/402-ligne-nouvelle-montpellier-perpignan-pour-une-revision-du-projet but also communications from more local organizations such as <http://tgv sud.over-blog.org/> or <http://www.tgv-roussillon.fr> created especially to protest against this project as it is designed.

"From the projections at the time it was 60 cm on average in 100 years plus the phenomena of swell, plus storms. We know that there were problems ahead. We did not kick into touch, but we separated the problems, we told people, we were totally aware of what was happening but that at the moment our goal was not to solve the 2100 problems but to solve problems for the next 20 years". [...] "Let's try to meet this ambition in first, it may solve some of the longer term problems. If we want to do everything at the same time, we will not do anything." – quotes from an interview with *SNCF Réseau* staff

We find a detailed version of this argument in the report submitted to the Government in a dedicated paragraph titled "Adaptation of the French national railway network to climate change". This paragraph provides a very precise analysis based on demographic factors:

"Some participants to the public debate advocated for a full-hybrid option between Montpellier and Perpignan. This reasoning, based on long-term but incomplete projections, intend to be conservative, leaving open the LNMP as a continuity option for freight traffic in case of an incident on the existing line, or even the construction of two new tracks along the LNMP. This argument deserves careful consideration to ensure that it does not lead to bad investment choices. Given the demographic weight of the cities of Sète and Agde, it is reasonable to think that these populations will not migrate inland and that the current infrastructure will be protected and preserved [...]. South of the city of Narbonne and up to the Roussillon plain, however, the population density is low. At the scale of a century according to the projections of the IPCC, sea-level rise could induce a strategic withdrawal of the populations. It is also likely that this withdrawal will not consist of a simple translation of about ten kilometers inland but will focus on the agglomerations of Narbonne and Perpignan. Therefore, the question of serving populations through a TER service will result in the establishment of Intercités missions or ICGV, between major cities. The Montpellier-Perpignan high-speed line could address this need providing the relevant equipment. In these conditions, the creation of a second new line (horizon 2100) would result in an infrastructure dedicated to freight. This infrastructure could more easily be built along the current highway (which slopes and radii of curvature are more easily compatible with a line suitable for 120 than 350 km/h). This would avoid an immediate and massive investment in a hybrid infrastructure by 2020." LNMP, Ministerial Brief – end of Stage 1. April 2011. p35

A part from this issue of sea-level rise, we did not find many other mentions of climate change during the public debate process. Socioeconomic assessments do not incorporate this variable. There is no mention of interactions between climate change, transport demand and demographic evolutions either. The team in charge of conducting these studies just apply national frameworks without discussing their methodology or the assumptions they make. As for now, these frameworks exclude climate change from the analysis because of uncertainties and methodological difficulties (Gollier et al., 2011; Le Maître, 2015; Quinet et al., 2013)

“We implement socio-economic assessment as prescribed by the last version of the institutional framework (2014). These elements do not include climate change. [...] For LNMP we could have made scenarios to test the climate sensibility of some of the traffic assumptions or the impact of a newline on the overall robustness in case of traffic disruption. However, in order to conduct the socio-economic assessment we need reliable input data that can be explained and justified. As for now, we don't have such legitimate data”. Quote from an interview with *SNCF Réseau* staff

Climate surfaced again later in the process, within the impact studies prepared for the public inquiry on the issue of flooding risks. According to a recent evolution of the official requirements – article R.122-5 of the Environmental Code – impact studies have now to report about the "project impacts' on climate (GHG emissions) and the project vulnerability to climate change". This was quite new for the project managers who had no previous experience nor systematic method to do so. The same question might appear – if the project passes to the next stage – for choosing the flood coefficient used for designing drainage systems and major bridges and comply with the regulation on water and environmental risks⁸⁷. A previous project⁸⁸, completed in 2017 in the same Region where Cevenol⁸⁹ episodes cause rapid floods, faced this problem. Because of evolutions in the environment, including urbanization (soil sealing) and climate change, larger coefficients had to be used and generated significant extra-costs. According to some of the stakeholders to this other project, this additional precaution is not always relevant but hardly discussed. As we finalize this chapter, (May 2018) the LNMP project has not yet reached this phase of discussion.

"A particularity of the region, obviously, are the Cevenol phenomena and the risks of floods. Some people are afraid that the new line becomes a sort of dam and increase the risk of flooding in the plain. Obviously, we conducted all the studies to design a project that prevents this risk [...], this is our leitmotiv. The authorities will check all the design choices to ensure we fully comply with the regulation which is highly demanding regarding this issue". Quotes from a public intervention of E.Parent - head of the project management team at *SNCF Réseau* – during the concertation phase.

"National authorities tend to require a level of precaution even higher than what is in the regulation" Quote from an interview with *SNCF Réseau* staff

⁸⁷ According to this regulation, the project should not have any consequences on how the waters flows through the landscape.

⁸⁸ Called CNM (Contournement Nîmes-Montpellier), i.e. Nîmes and Montpellier high-speed bypass - <http://www.ocvia.fr/> - last accessed May 2018

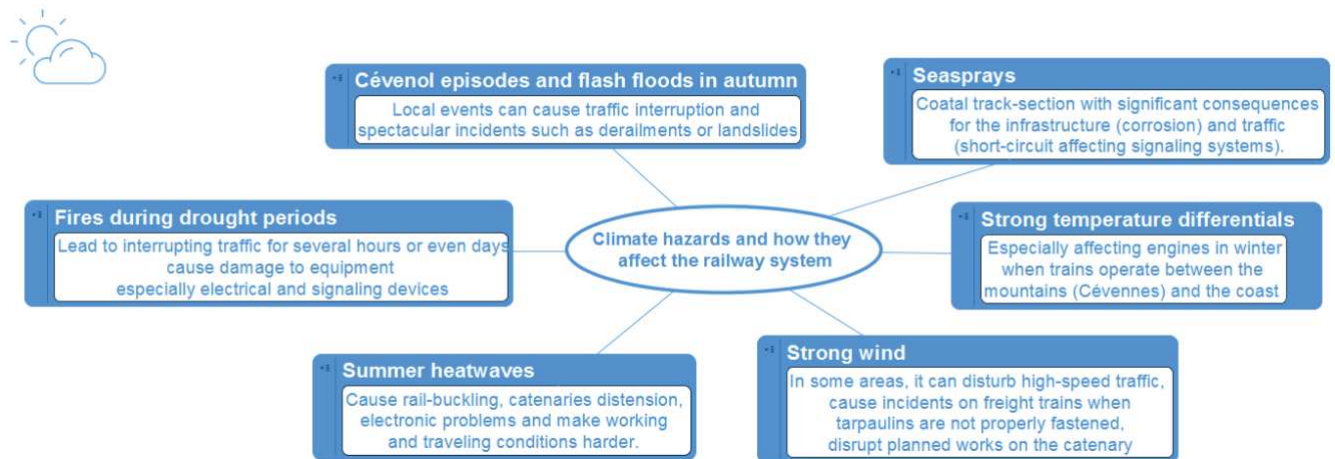
⁸⁹ Cf. note 24

2. Daily traffic operations and resilience

It is quite common to distinguish the resilience – defined as the capacity to cope with current weather conditions – and adaptation to future changes in climate. During our inquiry, we met people in charge of operational traffic management and maintenance of the existing railway network. Those discussions initially confirmed the reflex to send back the question of future changes to people in charge of planning for new infrastructures and equipment’s (“this is something to take into account for new projects”). Nevertheless, as we went forward in the interviews, this distinction between future adaptation and current resilience faded away. We discovered that adaptation to climate change is already taking place in the current management of the system. Once the infrastructures are in place, their functionalities and fundamental characteristics change little. Yet, they live and interact with their environment every day. They are exploited, maintained, renewed according to a whole set of procedures, habits and modalities which, without fundamentally transforming them, make them evolve.

We interviewed people in charge of traffic management, daily maintenance, crisis management, etc. All of them are deeply aware of strong interaction between the railway system and local climate (Figure 4-5).

Figure 4-5 - Diagram of the main climate hazards in this region affecting railways

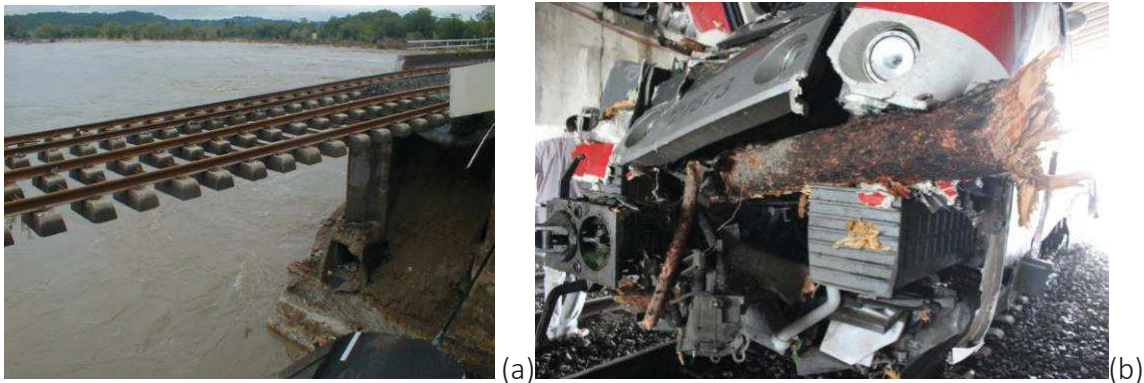


Source: Author from interviews

Because of the specificities of the regional climate, seasons are also a salient issue for maintenance. Critical operations have to be systematically conducted every year in preparation of recurrent events: changing the wipers at the end of summer before the first cevenol rains, checking AC equipment before heat waves arrives, etc.

Regular incidents – due to sea sprays on the coast or fires in drought periods - have revealed the major vulnerabilities of the system in the region, progressively drawing an implicit map of hotspots. Many of our interviewees regularly quoted examples of past events associated with particular weather conditions that they could very precisely localize and describe, (“everybody knows about the major incidents, the information flows quite well” (Figure 4-6)).

Figure 4-6 - Photos of major incidents: often mentioned during interviews



(a) Consequences of the 2002 Gardon overflow on the Nîmes-Alès line ; (b) TER accident because of a tree which fell on the track during a Cevenol episode in Saint Aunès in 2016

Sources: Dubost, 2017 (a); SDIS 34 (b)

The company deals with those events as exceptional crises. The objective is to manage the consequences of each one, in a reactive mode. The collective capacity to handle such situations is proudly quoted as a key component of SNCF identity and teams’ cohesion. In spite of these remarkable events, SNCF executives agree to say that the network is quite well adapted to the local climate.

However, the actors also talk about the evolution of risks. They have the feeling that the sensitivity to some categories of hazards such as fires or cevenol rains is increasing but they cannot totally explain the trend. The last few years gave the impression of repetition of problematic events with growing consequences always more important. Many factors are to blame, including climate change, an aging infrastructure with delayed investments in retrofitting, a saturation of the network and a lower acceptability of risks from users and stakeholders. These events make the intrinsic vulnerabilities of the network – which main axis has no bypassing option – event more visible. Attributing an incident to specific climate conditions is however very difficult, first because the tools used to manage the traffic and report about incidents (such as the BREHAT database, cf. Chapter 6) are not designed for this use. Moreover, the relationships between a weather event and the performance indicator is

multifactor and barely direct – a heatwave for instance can accelerate the wear of equipment without triggering an immediate breakdown. As a result, there is almost not objective statistics of the impact of weather to the regularity or performance and no possibility to report about precise trends.

[Regarding Cevenol episodes] "[...] we have more and more impacts. The only figures we have, give this impression that the phenomena are more frequent and violent. Incidents that become recurrent for external reasons. Is it climate change, urbanization? We don't exactly know".

"Is the national rail network still adapted to its environment?" Quotes from an interview with SNCF Réseau staff

Up to now, SNCF responds to these events as it has always done without really changing its practices. Most of the options proposed are standard technical solutions based on national technical guidelines and local empirical experience. These solutions are implemented only once the damage actually appeared is observed ("The look of the maintenance staff is fundamental"). When maintenance staff detect an abnormality, their report can launch a process of "émergence" with a specific degree of urgency and time horizons ranging from 3 years to more than 5. During this period, the relevant departments – including maintenance and engineering departments - assess the opportunity for specific investments to fix the problem (renewing equipment's, building new elements, switching to an alternative technique). Their role is to assess the relevance and the priority of each situation with an asset-management perspective. Depending of the costs, different levels of validation may intervene in this process. Successive studies, following a classical engineering project cycle, provide information for the decision (preliminary study, initiation study, development study). According to our interviews, most of the arguments exchanged during "émergence" meetings are based on experience (the history of the concerned-line and analogue situations). Budget and human-resource constraints are the main limiting factors. Before this process comes to an end, temporary or emergency measures can be implemented.

Usually SNCF addresses those problems building on internal knowledge and previous feedbacks without trying to expand its knowledge base with external advice.

"It is the accumulation of anomalies, verifications, successive adjustments through maintenance that ultimately determine when we need to renew the infrastructure."

"There are standards for some categories of risks but there is also the experience of agents"

"There is no anticipation [...] we work through successive adjustments ", in "reaction only".
Quotes from an interview with SNCF Réseau staff

The example of heatwaves

Heatwaves provides a good illustration of the current practices of the company. These practices have deeply changed in the recent years following a series of key events. Recently built railway take into account the specificities of the regional Mediterranean climate. However, their design does not explicitly mention climate change projections. The design of the Montpellier station for instance integrates an insulating roof cover to offer "a great comfort to users both in term of temperature and natural light. This insulation is made of a translucent membrane that lets light through. This material makes unnecessary to heat in winter and cool in summer⁹⁰". The project for a new station in the city of Manduel, near Nîmes, meets the requirement of a label specifically designed for Mediterranean buildings⁹¹. Since the 2003 catastrophic heatwave, SNCF also has a "heatwave plan" which includes anticipatory measures implemented at the beginning of summers. Among these measures, we can quote preventive maintenance operations on AC devices, special interventions on the vegetation to prevent fires, adjustment in the work organization to strengthen technical teams, a hotline for controllers and conductors, communication campaigns on good practices in case of heatwaves (SMS, displays in stations, etc.) or increase of water bottles stocks. This plan takes the 2003 event as reference point to calibrate those actions, it does not go beyond.

III. ANALYSIS AND DISCUSSION: LIMITED PERFORMATIVITY OF SCIENTIFIC DISCOURSE ON CLIMATE CHANGE

1. How does SNCF deal with changes in climate?

The situations described above show that people in charge of developing and operating the railway system are fully aware of climate-related issues. They have a detailed experience-based knowledge on the relationship between the weather and railways. They have to manage this interaction every day as many other components of the system. They do not ignore that this relationship may not be stable. They observe many changes in the environment of the system and totally acknowledge that climate change resulting from human

⁹⁰ <http://projets-architecte-urbanisme.fr/transformation-gare-saint-roch-montpellier-pole-echange/> - last accessed September 2017

⁹¹ Label Bâtiments Durables Méditerranéens <http://polebdm.eu/> - last accessed September 2017

greenhouse gases emissions is one of the causes of these changes. They are generally aware of expected trends, at least regarding average temperature changes.

In the case of LNMP project, sea-level rise is the main focus. It is perceived as a progressive trend and never described in very precise terms in discussions. Time horizons are barely mentioned, underlying assumptions, models, scenarios are never questioned. Actors do not quote any source of knowledge other than the vulnerability assessment we mentioned. Railway experts conduct the compulsory assessments with almost no direct interaction with climate experts or scientists. We did not find in our interviews traces of other climate concerns related for instance to changes in seasonality or potential consequences of more frequent or intense heatwaves on traffic demand or users' expectations.

Regarding the daily management of the existing system, most of the mention of climate-related issues deal with the current climate. Interviewees mentioned climate change as an extension of current trends, sometimes as an "acceleration". It is about an exacerbation of the difficulties already experiences today (e.g. more fires in summer, more flood risks related to Cevenol episodes, etc.). These evolutions become additional reasons to reduce the current adaptation deficit and improve SNCF capacity to deal today with inconvenient weather:

"Whether this type of incidents occur five or ten times a year, it is already significant and we need to find solutions, even if the frequency does not increase" Quote from an interview with SNCF staff.

This type of "incremental", "autonomous" adaptation – as opposed to transformational⁹², planned adaptation (Kates et al., 2012) – does not fundamentally challenge the basic principles of the system or its general organization:

"As long as we manage to deal with each individual incident, we don't question our practices... may it the best thing to do." Quote from an interview with SNCF staff.

2. Unasked questions

This interpretation of climate changes and this vision of adaptation have a major drawback: by focusing on average trends and continuities, they do not question the variety of existing scenarios or the changes of climate variability, and do not take into consideration the

⁹² "Adaptation that changes the fundamental attributes of a system in response to climate and its effects". (IPCC, 2014, p. 1758)

full richness of the scientific research on climate change. This research shows changes in average and trends but also in extreme distribution and variability. Climate change challenges the climate stability we have been experiencing for decades. Beyond this general conclusion the scientific knowledge base is very diverse, reporting about heterogeneous evolutions depending on the geographical contexts and time horizons. This diversity, resulting from the fundamental complexity of the climate system. It is even more salient as extreme events are concerned.

Any results we have on the future are probabilistic and come with uncertainties that we need to handle (Dessai & Van der Sluijs, 2007; Henry, 2013; IPCC, 2014c; Lempert et al., 2004; Van Bree & Van der Sluijs, 2014; Vanderlinden, 2015). These uncertainties are first stochastic or ontological, related to the natural variability of climate. There are also scientific (or epistemic) uncertainties related to our limited capacity to understand and represent the climate complexity. Eventually there are socioeconomic uncertainties (or decision, reflexive or volition uncertainties) depending on how much GHG we will emit in the coming decades (depending on which socioeconomic pathway we will follow) (cf. chapter 2). We usually deal with this last category of uncertainties by working with climate scenarios. Choosing the scenario or the scenarios we use to make decisions or build a policy is a strategic choice made by decision-makers depending on their experience, knowledge and representations. This attitude is quite common for decision-makers who face major socioeconomic uncertainties for almost any choice they make. In the railway context, the future demand of transport is for instance a critical but also uncertain variable. In the examples we could study, we found no evidence of working with several climate scenarios.

Full consideration of these characteristics for adaptation would imply raising new questions, for example: What type of unprecedented events could disrupt the system? Does it make sense to anticipate? Is it still relevant to use of statistics based on past-events to design new infrastructure? Would a precautionary increase of the robustness of new equipment be economically profitable? Would we operate a railway system with the same standards and organization with most frequent severe weather hazard? Will the users expect the same service in a warmer or a more variable climate? Addressing this type of questions would challenge traffic management policies (introducing possibilities such as contingency

circulation plans or acceptable preventive cancellations), network planning (e.g. priority axes) but also social consensus: What do we expect from SNCF (in terms of service, of security, of comfort, etc.)? What is an acceptable risk? Etc.

Already risen and addressed in other sectoral or national contexts (de Haan, Rogers, Brown, & Deletic, 2016; Kane & Vanderlinden, 2015; Network Rail, 2017; Simonet, 2016) those questions appear relatively new here. According to what we could observe, they are not (yet) explicitly put on the table. Progressive and reactive adaptation is the prevailing logic. Potential breakthroughs or surprises are not really considered possibilities and so not anticipated. “Wait and see” is, for the moment, the preferred strategy;

"With climate change we are talking about evolution in the long run. If we end up having more violent and more frequent phenomena, then maybe we will change the logic"; "We may have to do more if the track collapse too often". Quotes from interviews with SNCF staff.

3. Climate change as one trend among others

Many factors can contribute to explain this apparent gap between a science meant to encourage large-scale actions and an adaptation that remains limited and incremental. Climate changes would be too uncertain, too far away from now; they would lead to structural changes to be addressed at a higher level of the organization, etc. In order to grasp the full significance of the complementary pieces of explanation we need to understand that these questions are not abstract and that their discussion has to take into account deeply grounded historical paths and other ongoing changes. There are resistance and divergent dynamics to consider.

It is first important to consider the historical paths that made the railway system, as it is today (Mumford & Winner, 2010). This network results from big planning programs – the most recent being the TGV program (Fourniau, 1997; Lolive, 1999) – deeply grounded in a positivist vision of progress and modernity. Speed and efficiency are two of the key attribute of this philosophy of spatial and economic development (Fourniau, 2011; Picon, 2001; Studeny, 1995; Troin, 2010). The prevalence of speed-related arguments in the public debate around great project illustrates this point. Since 1945, we have also been observing in France a general trend towards homogenized and optimized standards and procedures across the country

(Finez, 2013a; Mazoyer, 2013; Vatin, 2008). As a result, it became very difficult, according to our interviewees, to experiment locally alternative techniques or organizations modes.

The railway system is a complex but controlled system. It is primarily an engineering determinist structure (“a train schedule does not come with an uncertainty range”). The discourses reflect that the socioeconomic and technical components of the sociotechnical system are very often handled separately (Finez, 2013a). Devices such as the socioeconomic assessment frameworks we mentioned above take the uncertainty socioeconomic assumptions (e.g. the traffic demand or users’ preferences) as exogenous inputs⁹³. Because of the long time-horizons involved and deep uncertainties, climate change does not fit in this type of frameworks. Consequently the complex sociotechnical aspects of climate change (Dessai et al., 2009; Hulme, 2009; Sarewitz & Pielke, 2007) are often ignored, while only the technical determinist part is retained.

Past experiences have a major role in the development of the railway system. Many of the standards and techniques – for design, building, operation – result from an incremental empirical process, while the use of complementary approaches such as modelling techniques, is quite new and still emergent. Feedback from in-house experts after major incidents remains the main driver for change within the company. There is very little room for different forms of knowledge – such as *in silico* climate modelling - especially when they question existing practices⁹⁴.

SNCF experts we interviewed, share a common feeling that the railway network in the region is already quite robust. They trust the in-house expertise to find technical solutions to cope with future problems climate change can create and do not believe it is necessary to question the current basis of the organization because of this phenomenon.

The railway sector is undergoing rapid evolutions and has to adapt to structural changes of its socioeconomic environment. The discourse on climate change is therefore far from being the only challenge to current practices. It has to “compete” with other concerns, sometimes

⁹³ Experts produce these ministerial frameworks at the national level, they make assumptions which are not discussed anymore later.

⁹⁴ We find similar questions in other sectors such as the insurance industry or coastal management. Our understanding of the consequences of a shift from statistic approaches based on historical events, to probabilistic distributions based on numerical simulations is still to be improved.

requesting very divergent responses and often perceived are more salient or urgent by decision-makers.

In France, as in many other old-industrialized countries, networks are aging and face important needs for retrofitting and renewal⁹⁵. In a tight budgetary situation, providing the necessary public resources to enable this huge renewal work is a major financial⁹⁶ and political challenge⁹⁷. The processes of “*émergence*” we described materialize these moments of prioritization. Climate change appears as a second order imperative – not as urgent – or even a risk. Indeed, many actors fear that adaptation would increase the cost of renewal projects which is hardly compatible with a strategy of focusing the available resources on the major priorities. In addition, many of them assign the vulnerability of the network to its age and to its current conditions. Modernizing the network therefore already appears as a major effort contributing to vulnerability reduction.

The liberalization process currently going on in this sector is another key contextual insight to understand the overall situation (Cour des comptes, 2008; Perennes, 2014). Railways have historically been a very monopolistic and closed sector with a very limited number of players. There are now many more actors involved and a greater porosity between transport modes. In order to adapt to this situation SNCF Mobilités communicates about itself as a mobility platform or assembler more than a railway operator⁹⁸. Other heavy trends including the digital revolution or the energy transition shape the evolutions of mobility in this context. An example of this is given by the national debates for the 2018 “mobility package”, starting with the *Assises de la Mobilité* and their 6 priorities: clean mobility, solidarity, safety, intermodality, economic sustainability and digital transformations⁹⁹. In Occitanie, the *Etats généraux du rail et de l’intermodalité*¹⁰⁰ organized in 2016 drew a list of regional priorities that occupy most of the political attention (Figure 4-7).

⁹⁵ See for instance the hearing of SNCF and SNCF Réseau CEOs in the Parliament in March 2016.

⁹⁶ SNCF Réseau debt was approximatively 44 bi€ in 2016.

⁹⁷ There are difficult trade-off regarding resources allocation, with strong political consequences. After years of underinvestment an ambitious retrofitting program is under implementation. In 2015 and 2016 SNCF, along with regional authorities, invested 5 bi€/yr to modernize the railway system. Cf. <https://www.sncf-reseau.fr/fr/a-propos/notre-strategie/moderniser-maintenance> - last accessed, September 2017

⁹⁸ e.g. Guillaume Pepy, SNCF CEO interview: « SNCF job is to become a mobility-assembler ». Le Monde, July 2917. www.lemonde.fr/economie/article/2017/07/01/guillaume-pepy-le-metier-de-la-sncf-est-celui-d-un-assembleur_5154303_3234.html and www.sncf.com/fr/groupe consulté le 14/09/2017 - last accessed, September 2017

⁹⁹ <https://www.assisesdelamobilite.gouv.fr/syntheses> - last accessed June 2018

¹⁰⁰ <https://www.laregion.fr/EGRIM> - last accessed June 2018

structured - with a succession of obligatory steps and dozens of environmental, technical, economic and financial components. They also involve a growing number of stakeholders. However, despite the number of parameters considered and the time and resources devoted to studies, these processes appear to be very standardized and stable. They struggle to integrate emergent trends such as climate change. There is a very little number of really determining criteria that hardly evolve. By construction some variables prevail in the analysis carried out -for example the value of time in socio-economic assessments¹⁰¹.

The rare attempts to bring climate change in the process are very limited. The coast-line vulnerability assessment we presented only came to reinforce a consensual decision not really to open a discussion. Similarly, in the daily operation of the network, the imperatives of security and optimization prevent from dedicating resource to exploratory approaches and experimenting alternative practices ("SNCF has a rationale of excellence but no sense of approximation").

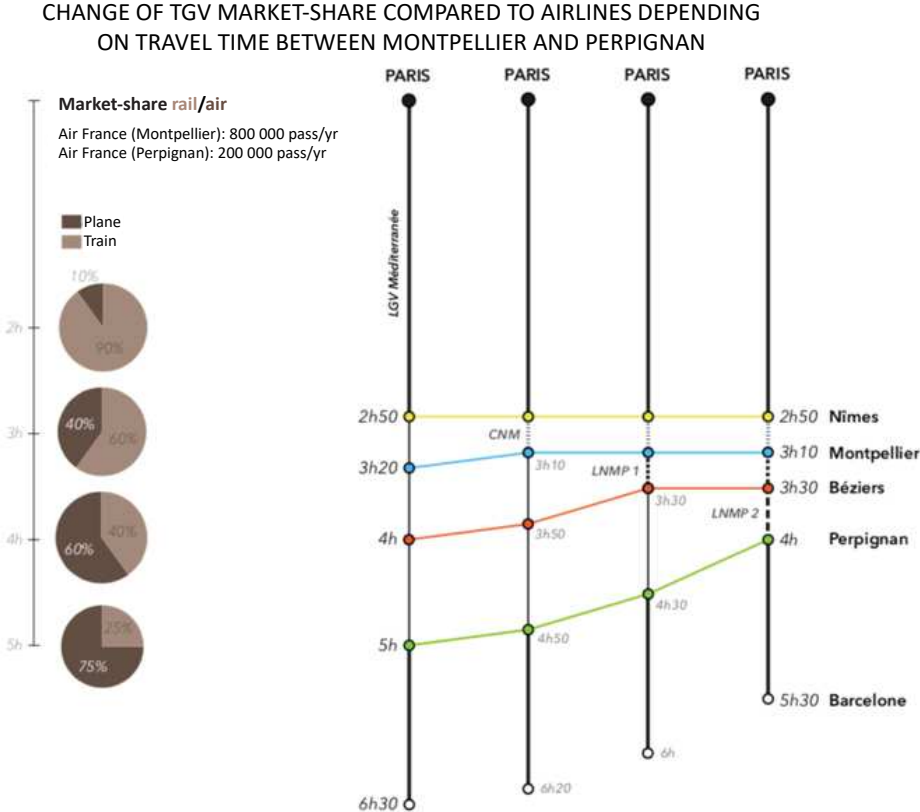
Some actors express divergent views and disagree with this mindset. However, during our inquiry we did not find any "constituency" organized to build and propose alternative approaches. Most of the stakeholders we met did not feel "legitimate" or equipped ("we don't have the resources") to take this role ("it's not our job"). They would apparently have very little room to do so.

Regarding the LNMP project, for instance, users' associations and environmental NGOs defended a priorities ranking different from SNCF's one. For them, the reliability of daily transports and the fight against road congestion were more valuable than trains speed for long-distance travels. They contested the functional choices made by local authorities – which are expressing, according to them, an "outdated vision of progress". They proposed alternative visions of mobility frameworks for the region, based on an increased redundancy and resilience of the system. Climate change takes place in this argument as an additional factor among others without really being discussed. When these actors try to provide alternative arguments and realize complementary studies – e.g. on the relationship between speed and

¹⁰¹ Works conducted until now struggled to derive significant direct correlations - between climate variables and for instance and mobility-needs or provisional maintenance costs (Bruscoli, 2016; Gaudry & Quinet, 2011; Ltd, LLP, & Ecofys, 2013).

the shift from railway to air (Figure 4-8) - these independent, “hand-made” arguments had very little influence in the debate.

Figure 4-8 – Example of diagram produced to support user’s associations’ argument



Source: FNAUT

Some actors in charge of the network operation or maintenance also regret the current lack of anticipation. According to them there are problems already existing today that will become worse because of climate change which becomes an additional reason to find solutions, and be more proactive in changing how things are done. However, beyond a few limited experimentations – for instance testing of innovative vegetation management approaches – these propositions remain peripheral. Maintenance but also traffic management keep with their habits, for example when it comes to deal with a coming flood:

"So far the logic is not to decide on preventive cancellations. Maybe someday [...] but I am not sure that it will become [...] - in any case, it should be a strategic decision at the corporate level" Quote from an interview with SNCF Staff

CONCLUSION OF THE CHAPTER AND FIRST SEQUENCES OF THE STUDY: ADAPTATION AS IT IS PRAGMATICALLY DONE FOR NOW AND CONDITION TO MOVE BEYOND INCREMENTAL OPTIMISATION

Regionally, the interdependencies between railway and climate are very well known. SNCF local executives do not ignore ongoing evolutions and are already adapting to them. However, this adaptation is mostly reactive, autonomous and often implicit: i.e. people do not talk about adaptation to global changes but just react to adjust their practices and respond to the symptoms of perceived modifications in their surrounding environment. According to interviewed actors, it would be difficult to do more or differently. Practices might only change when current ways of doing would become obviously obsolete: “if the track collapses every morning”; “as it works like this we won’t change... and maybe this is the best option”. Those changes would involve both regional and national entities: “maybe someday we will take precaution measures and cancel trains before the incident but such a change in the doctrine can only happen as a national decision”; “we might experiment new techniques, but national experts have to validate the options before we implement them”.

At the end of the day, the *status quo* is prevailing and, as things are currently framed, this appears as a pragmatic response. It is the negotiated outcome of multiple interactions with the complex reality of contemporary organizations.

Adaptation as it is done today at the corporate and regional levels

- Is a new, peripheral factor in a process of constrained optimization, to be included in the dominant “programs” of the company;
 - On the risk side (defensive), seeking to demonstrate that climate change as a disorder is under control and does not endeavor the activity.
 - On the opportunity side (preactive¹⁰²), trying to find synergies with performance improvement and focusing on no regret actions. People conducting this work have to demonstrate why it might be useful, to convince their hierarchy to dedicate resources for recording and analyzing data.
- In order to consider this new constraint, focuses on the relationship between the climate system and current weather, following a vulnerability first approach which may

¹⁰² *Preactivity* being defined as the ability to get ready for predictable changes (while proactivity is the ability provoke desirable changes).

have better chances of success as it starts from the companies' concerns and existing processes. However, it also follows path-dependences and focuses on aspects of climate change that are already visible today. SNCF addresses climate change as the continuity of past and current trends. For the moment, it does not use any climate projection and relationships between railway experts and climate-change specialists are very limited. The objective is first to optimize existing processes by considering manageable weather constraints, not to transform those processes.

- Tends to assume that, in many cases, wait-and-see is the only viable option, both in economics and in strategic terms;
- Is not a matter for interaction between local operations and various sites where the common frame of reference, representations or strategic choices are progressively shaped.

What would that mean to do it differently?

Going beyond this *status quo* would for example mean to consider:

- Anticipating changes that have not been observed yet, especially in the basis of future climate projections;
- Accepting evolutions of traffic management policies that would move away from what SNCF is used to, for instance leading to situations in which the company is not in full control;
- Questioning the current priorities such as speed and efficiency in favor of complementary criteria like robustness, especially in new development projects (Dépoues, 2016);
- Being more proactive and betting on experience, flexibility and open-approaches to search for new solutions early when new problems emerge;
- Valuing in some cases immediate costs for an increased longer-term adaptation, taking time to implement changes which benefits come later, etc.

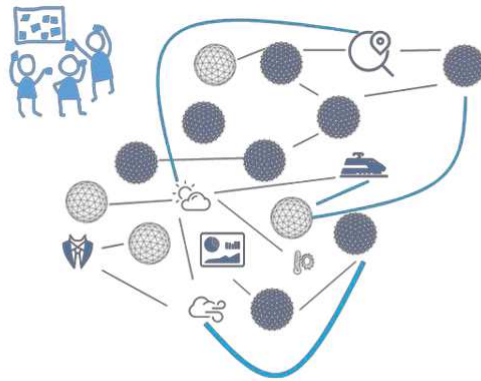
In other words, a more proactive form of adaptation would imply to frame the question differently and to accept evolution in the shared representation of the railway-climate system¹⁰³. It would be a learning process allowing actual transformations (Kates et al., 2012;

¹⁰³ To say it in constructivist terms (Le Moigne, 2007), that could be qualified, after Bateson (Bateson, 1977) as a type two change or as a paradigm shift.

Lonsdale et al., 2015; O'Brien, 2012; Pelling, O'Brien, & Matyas, 2015). We learn from the literature that such processes work through iterations, with double-loop learning. They need to connect a strategic thinking with a grounded approach. In the context of SNCF this implies a stronger and more explicit interaction on this topic between local operations and the national management. Feedback and information flow between SNCF sites and management levels is therefore an essential component of adaptation, yet insufficiently developed. It is the necessary condition for a better articulation between immediate issues and long-term thinking.

In our inquiry material, we have only a few tentative examples of such an interaction which emerges at a local level when SNCF executives face repeated problem with no satisfying solution. We observed that regarding the impact of sea sprays on maintenance costs or vegetation control to limit the risk of fires. In both cases, we have noticed that it really takes time to move from the acknowledgement of powerlessness to build or import original knowledge and try new practices (e.g. scientific cooperation to design and implement a precise survey and experiment geoengineering coastal solutions in the case of sea-sprays, cooperation with fire-departments to test controlled burn to mitigate fire risks). Most of the time, experimentations have to go through a validation procedure involving various degrees of hierarchy. Railway is a heavy and sometimes rigid system, which struggles to adopt flexible, trial-and-error approaches. Security being the first priority is very hard to implement an innovative solution before extensive testing.

In order to better understand this relationship and move in this direction we propose, in the next two chapters to work on the two following questions. How to locally raise and carry the critical questions climate change may carry and identifying who they might actually concern (Chapter 5)? What are the necessary conditions to enable adaptation to become a strategic insight for SNCF long-term vision (Chapter 6)?



“What can be studied is always a relationship or an infinite regress of relationships. Never a ‘thing’.”
Gregory Bateson

Chapter 5 - An experimental workshop to question the implications of an increase in extreme weather events frequency

This chapter presents the results of an experimental workshop designed to investigate the consequences of an increased climate variability on the strategies of SNCF.

I. DESIGNING AN EXPLORATORY WORKSHOP FOR CREATING DELIBERATION SPACES AND MOVE ADAPTATION FORWARD

We saw in the previous chapters of this dissertation that both at an institutional level and within management teams, SNCF is aware of climate change and understands its consequences. Nevertheless, this understanding does not appear to lead to any major transformational change. People working for SNCF draw a clear picture of their company as a sociotechnical system with many structural and conjectural constraints. Any technical or organizational innovation is thus necessarily the negotiated outcome of interactions among multiple legacies and various ongoing changes: “Our network is 150 years old [...] Everything has changed in 150 years [...] the climate has changed, but also the population, the means, the practices, etc.”¹⁰⁴ The company is entangled in a complex socio-economic environment with cross interactions with regulatory bodies, local authorities, other providers of public transportation and users. This creates a complex situation with internal (industrial processes, fixed-circulations schedules¹⁰⁵, etc.) and external (norms, political choices, etc.) constraints.

Railway in France is also a system at the crossroads facing major changes both on the supply (new technologies, connected services, rise of intermodal offers, markets liberalization and new entrants to the market, etc.) and on the demand (evolving mobility preferences, etc.) sides. After years of underinvestment, strategic choices need to be done to renew the network and modernize the service. It is therefore SNCF top priorities¹⁰⁶ to improve dramatically its cost-performance, to succeed in its digital transformation, to develop its customer culture,

¹⁰⁴ Quotes are parts of the workshop discussions (2018-10-30), translated into English.

¹⁰⁵ Ex. “an organization 2 years in advance for train paths, 6 months for schedules “

¹⁰⁶ Cf. <http://www.sncf.com/fr/groupe> - last accessed February 2018

and to improve its relationship with both users and transit authorities. Climate change comes as an additional concern among many parameters of this rapidly changing environment. As a result, the company favors progressive adjustments, incremental and reactive adaptation.

Through anticipation and adaptive management, SNCF could better manage climate risks and take opportunities to offer an adapted and resilient mobility service. Yet, in line with our previous observations (chapter 3) and to the literature (Berkhout, 2012, 2014; Rotter et al., 2016; Surminski, 2013; WBCSD, 2014), a more transformative adaptation to climate change can only happen through a proactive uptake process (Rotter et al., 2016). Such a process requires dedicated deliberation spaces and times to clarify the relevant consequences of climate change in this particular context.

To move further in this direction, we designed and organized an experimental workshop with SNCF in October 2017. This workshop intended to test how effective the opening of an alternative discussion space may be. It was designed to foster exchanges about the impacts of climate change for SNCF and the issues that could be raised, then to identify which discussions could emerge.

1. Workshops' objective and methods

Workshops and focus groups are common research devices to enable group interaction and reveal collective dynamics (Chambers, 2002). They provoke reactions between individual actors; make connections between issues. They make attitudes more apparent and create moments of reflexivity (Blanchard, 2011). Among researches on climate adaptation, workshops are frequently used to explore climate change consequences (Colombert, 2016; Corre, Dandin, L'Hôte, & Besson, 2015; Tissot et al., 2016)¹⁰⁷; to facilitate the dialogue between scientists and decisions makers (Kane et al., 2014; J. Porter & Dessai, 2017) and even to co-design adaptation strategies (Haasnoot et al., 2013). Some of the workshops reported in the literature¹⁰⁸ are action-research devices; they intend to provoke changes in the system

¹⁰⁷ Cf. http://www.gip-ecofor.org/doc/drupal/gicc/Lettre_GICC_numero21_1.pdf - last accessed May 2018

¹⁰⁸ Bertrand et al. (2017) for instance created animation devices to build a common knowledge and overcome the "mismatch between supply and demand for climate knowledge". According to them, "the important thing is that people anticipate environmental situations and transform them into shared images and expectations that enable social action". Malekpour et al. (2016) proposed a model for "a diagnostic intervention in the ongoing process of strategic infrastructure planning, as a way of revealing context-specific impediments [...] tested in water infrastructure planning for one of the world's largest urban renewal areas in Melbourne, Australia". Their goal is "enabling reflexivity within the ongoing planning process [...] about the development of processes and tools that support the widespread adoption and successful implementation of those solutions in the face of wide-ranging impediments". Similarly, Malekpour et al. (2017) tested a strategic planning intervention format as an alternative to predict-then-act approaches, to cope with uncertainties and complexities.

studied. They do so by intervening at particular moments to feed actual decision-making. For instance, (Malekpour, Brown, de Haan, & Wong, 2017) “put forward a planning intervention, which can be plugged into conventional planning processes”. As such, we did not go so far: our workshop served a research purpose and aimed at producing original knowledge through interaction. However, the description we got of how climate change may question the system is an insight potentially very useful to shape and share visions for the future of rail in France.

If we were able to set up a successful workshop, it was because we prepared it through several months of fieldwork and interaction with SNCF teams. SNCF has been a key partner of this research allowing a privileged access to people working all across the organization and to internal working-groups on climate change. Thanks to this cooperation we could develop sustained relationships with several executives and have rolling discussions about how the organization deals with climate change. We met many of the participants before the workshop and we could count on their understanding of the research objectives and process. We also received a strong support from high-level executives in the company who helped us to select the participants and encouraged people to take part to the workshop. This allowed us to gather representatives from various SNCF activities ranging from infrastructure management to a variety of traffic services (Table 5-1).

Table 5-1 - SNCF participants to the workshop

| Representatives of* |
|---|
| SNCF Headquarter (n=4): sustainability and climate officers, normalization and standards |
| SNCF Mobilités (n=3): <i>Intercités (classical national lines), regional sustainability manager, regional communication officer & digitalization project manager</i> |
| SNCF Réseau (n=4): <i>Regional sustainability managers, Engineering department - LNMP and Nîmes-Manduel projects (new High speed line and new railway station)</i> |

Source: Author

**Because of strong internal turnover within SNCF, many of the participants brought experiences coming from more than just one position. Nevertheless, participants regretted the absence of people directly involved in the maintenance.*

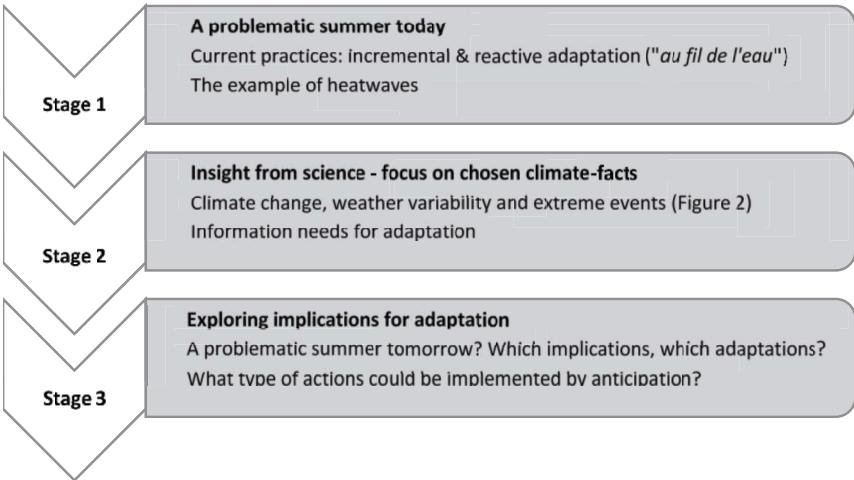
We decided to keep the workshop closed to external stakeholders to allow participants to express themselves freely, though this prevented us to debate questions involving external stakeholders. The workshop was held in SNCF buildings in the regional operations department of Montpellier, previously chosen for our detailed case study (Chapter 4).

During four hours, it offered a space to engage in exploratory discussions on the consequences of climate change for SNCF activities. Following a research protocol agreed with participants, we recorded the whole workshop. Participants also received “participant’s workbooks¹⁰⁹” (cf. appendices) with specific questions and blank spaces to express their ideas and feedback (Blanchard & Vanderlinden, 2012). Nine participants returned their completed workbook. We analyzed the content of these workbooks and the complete transcript of the discussion according to a grounded-approach (Herpin, 2010; Lejeune, 2014), conducting a thematic analysis of our corpuses.

2. An protocol to focus on variability and extremes despite uncertainties

Drawing on our previous interactions with SNCF staff and our knowledge of the company environment, we adjusted the proposed discussion framing and chose how and at which stage to introduce scientific inputs and raised different questions (Figure 5-1). Being able to include a climate-scientist in the research team was also a key ingredient of the experience.

Figure 5-1 - 3 stages of the workshop as it was built and items on the discussion agenda



Source: Author

¹⁰⁹ Participant’s workbook “is a methodological tool that optimizes the time we spend together. This optimization falls into two orders. First by formalizing break times, with writing breaks, we anchor our deliberations better in what each and every one of us brings. Secondly, the participant workbook enables us to collect some data in the form of your writings.” (Blanchard & Vanderlinden, 2012).

We hypothesized that some characteristics of climate change, might be major disruptive factors in spite of not always being immediately mentioned by the actors nor stressed in reference reports on climate change (Cattiaux, 2017a, 2017b; IPCC, 2014c; Jouzel et al., 2014). Those characteristics are an increased climate variability and possible new extreme events and multiple uncertainties. We took the apparent gap between how the company is adapting and those characteristics - recalled at the beginning of the session (Figure 5-2) – as the workshop starting point.

Figure 5-2 - Wrap-up slide on climate science presented during the workshop

Take-home messages

- Talking about climate is talking about all possible weather situations
- The climate is changing and will change even more
- A changing climate enable unprecedented weather situations...
- ...all around the world, including in Languedoc Roussillon
- It especially means more heat waves, longer, more intense ... which may happen at unexpected moments in the year,

*What is extreme today may be normal tomorrow ...
we may wonder what the extremes of tomorrow will look like!*



Source: Jézéquel, translated

Our goal was to draw all the consequences of this increased climate variability and uncertainty for the railway system: technical concerns but also non-technical, for instance consequences regarding the business model or the service delivered.

In a context of deep uncertainty, many authors suggest to favor exploratory approaches of adaptation rather than predict-then-act deterministic procedures (Dessai et al., 2009; Dittrich et al., 2016; Hallegatte, Shah, Brown, Lempert, & Gill, 2012). Formulating questions based on triggering issue, discovering alternative courses of action, testing current practices and planned actions against a variety of futures are among the first steps of such approaches. We subscribed to this type of frameworks. (Wardekker, de Jong, Knoop, & van der Sluijs, 2010) used “wildcards” (i.e. imaginable surprises) to stress test adaptation options for coastal-management. In a similar fashion, we intended to question the current representations and ways of doing. As Malekpour, de Haan, & Brown (2016), we explicitly raised the question “what could go wrong with current SNCF approach and strategy with regards to climate change?”. We wanted the discussion to focus on the organization, its management practices, guidelines and its strategy more than available scientific information and uncertainties. The next sections report our findings.

II. DISCUSSION OUTCOMES: QUESTIONNING THE STATUS-QUO

1. Questions raised by the focus on an increased climate variability, seasonal variation and extremes

Challenging management practices

We chose to discuss climate change with a seasonal approach, focusing on the current management of summer heatwaves and possible future hot seasons. This entry point drove the discussion towards the critical issue of increased inter-annual climate variability and seasonality (Cassou & Cattiaux, 2016; Fischer & Schär, 2009). Changes that were experienced by the workshop participants in the past did open conversations on the limits of current, well established, management practices. For instance, participants involved in the maintenance of the infrastructure rose the issue of vegetation control along the tracks (Dépoues, 2019)¹¹⁰. Up to now, vegetation is managed through a centralized heavy process, relying on a national train operating all around the country to weed the tracks. This train has a very precise working-program planned up to three years in advance. This way of doing can only work if weeds lifecycle is foreseeable and stable enough. With an increase in variability, early or late weed germination and the train might miss the efficient treatment period. Alternative processes, maybe less centralized and more flexible, might therefore be implemented:

“For two years we have not weeded at the right moments. [...] The leaves fall in December and there are droughts in February. [...] So, when we do a treatment in April it's useless. It would be necessary to do it after the rains of June whereas the national trains is planned for April-May, it is too early. [...]. But we cannot program differently. With current industrial process of vegetation control with weeding trains set at the national level, we cannot fine-tune, we cannot do it case by case. Maybe we should work at the regional level to deal with it. The vegetation cannot be managed at the national level anymore with weather hazards and variations in seasonality we perceive, at least in Languedoc Roussillon. [...] It's been three years, that our regional train has to make a second pass because the first was useless. [...] We spread tons of glyphosate, it costs money and we are not very effective in Languedoc Roussillon at the moment.”

This example shows that sometimes, it is when focusing on variability more than trends that climate change really starts questioning current management processes.

¹¹⁰ Cf. last appendix. « Ce que peut nous apprendre le cas de la gestion de la végétation sur l'adaptation au changement climatique pour SNCF ». Dépoues (2018). Publication à venir, Revue Générale des Chemins de Fer.

Questioning management policies and guidelines and raising strategic issues

Summer heatwaves are one of the extreme events with the most serious implications for SNCF activities. They have technical consequences – ex. rails buckling implying to temporarily reduce trains' speed (European Environment Agency, 2014; Ferranti et al., 2017; Jaroszweski et al., 2013). They also have more organizational and human consequences affecting both workers and users comfort and health. They are a potential source of perturbation and crisis. For instance, Dubost describes how, because of unbearable heat onboard during a short traffic interruption in a suburban train near the city of Paris, travelers got off the train causing a prolonged traffic interruption for safety reasons (Abramovici, 2011; Dubost, 2017). Discussing about the possible recurrence of situations that are currently considered as exceptional questioned the ability of current crisis management guidelines to withstand the test of time. Here are some of the questions risen during the workshop:

“It is up to the company to decide if we must have trains running as scheduled despite exceptional conditions? At some point we must be able to answer no. When trains cannot circulate they cannot. I think we need to integrate this parameter in our operations. It's like that. This summer when it was 60°C in the US, planes did not take off. What do you want to do? Is it worth doing research to run engines at 60°C for only a couple of days or it is better not to take off for 3 days? These are all the questions we need to think about.”

“Even in the case of a weather alert we send out the trains - as long as it is only an alert, we send them out. But today we know that for some alerts, we should perhaps consider alternatives.”

“At least on secondary routes we can generalize replacement options. If we know we will be annoyed the whole summer because of heat, rather than waiting for the incident, we could anticipate and implement in advance an alternative bus transport.”

Going in the same direction was the discussion about worst-case events. We did not want the debate to be limited only to imagine “most probable changes.” Narratives of possible future weather situation can “provide complementary, more realistic and more physically consistent representations of what future weather might look like” (Hazeleger et al., 2015). Going in this direction, we proposed an example of high-end but plausible scenario built on the existing literature in climate science (Bador et al., 2017; Berry, Betts, Harrison, & Sanchez-Arcilla, 2017; Dubuisson, 2017; IPCC, 2014c; Jouzel et al., 2014; Quesada, Vautard, Yiou, Hirschi, & Seneviratne, 2012; Stott, Stone, & Allen, 2004). This possible future was made of a succession of several subsequent extremes events in a summer sometimes between 2035 and 2050: a

dry spring, an early but short heatwave in May, a longer even if not extreme heatwave from July to September when the Cevenol¹¹¹ season begins. We chose those events to be representative of various categories of climate evolution: changes in seasonality, changes in duration of heatwaves, and possible conjunction with disruptive climate events.

This exposé did not lead to a precise discussion on the responses to address to these particular cases. Participants more generally wondered what it could mean to cross these thresholds (ex. temperatures up to 50°C in summer becoming realistic (Bador et al., 2017)). It appeared very clearly that this could challenge some of the choices made today and particularly the viability of certain lines. This is particularly salient for lines exposed to climate hazard or dependent on seasonal flows (beach tourism in this region, ski elsewhere): “I wonder if in 2050-2100, the most structuring routes will be the same as today with this heat”. In other words, climate change questions investment policies and strategic choices. In particular, contexts combining an enhanced climate vulnerability and evolving socioeconomic reality may lower the overall relevance of railroads.

“-In case of heat, because of the risk of rails dilation you slow-down from 90 to 60 mph, but doing so, you disturb the whole traffic [...] -Such a deterioration of the performance questions the relevance of this mode of transport”.

“If tomorrow, every summer you cannot take the train for 10, 20 or 30 days because the rails, the catenary or the air conditioning ... it questions the durability of the rail system in general. Maybe there are modes of transportation currently developed that will be more adapted. Adaptation is perhaps just a question of survival of the rail system.”

“There are lines with few customers and very expensive to maintain: should we continue to operate them? We have the case with Intercités routes, for instance in Lozère, with a purely economic perspective, we should not circulate anymore. Maybe that's where we go for tomorrow, if in addition there is more problems because of the weather”.

This discussion ranged from consequences of climate change to the railways installations themselves - which did not appear controversial - to more open-ended questions regarding management practices and policies or strategic investments. Moving from internal management concerns to social issues, participants eventually reached issues that questioned current roles and opened up discussions on responsibilities and governance.

¹¹¹ Cf. note 24

2. Discussing roles distribution, responsibility and governance

The responsibilities of the company were clear only for some of the issues that were raised. For instance, when it comes to vegetation control, there is no ambiguity regarding how to define and address the problem. Changing seasonal patterns becomes a source of inefficiency for those in charge of the maintenance of the network (namely SNCF Réseau and even more precisely the *M&T*¹¹² department for the maintenance planning and regional *Infrapôles* for the implementation). When detected, this inefficiency becomes a salient item on the company agenda. Consistency with its objectives, priorities and performance indicators is pursued. Making this inefficiency visible and measurable is therefore the main lever for climate adaptation. As Network Rail (SNCF Réseau counterparts in the UK, (Network Rail, 2017)) did, SNCF could implement an action plan to monitor the relationships between climatic conditions and maintenance operations. This may allow for the definition of targets to improve the management of these relationships. Emerging adaptation initiatives previously observed (Chapter 3) already go in this direction. They combine new weather indicators in partnership with the national meteorological service and an improved monitoring of the network. Implementing the relevant changes, moving for instance towards decentralized weed-control, is then a classical challenge for change-management. This is also an R&D challenge with a major technical aspect consistent with SNCF innovation strategy (SNCF, 2017b). New IT solutions like smart-network monitoring offer new options for efficiency. Localized, predictive, agile maintenance based on sensor-data could effectively replace systematic centralized planning and could at least partially address this type of climate evolutions (““At the time leaves were falling in October ... it used to be like that. It is not the case anymore, so, [...] we may set up different processes to deal with that, there are plenty of innovations we can use, digital, connected, there is plenty to do”).

For other issues, however, adaptation is not as straightforward. Responsibilities are not as clearly defined. For instance, when climate change challenges crisis management, it opens questions ranging from acceptability of preventive train cancellations to availability and

¹¹² “Maintenance operations, surveillance of railway installations, organization, work site supply chains, implementation of works ... 24/7 Maintenance & Works staff ensure the maintenance and modernization of the railway network. [...] To guarantee a high level of performance, innovation and safety, Maintenance & Works defines priority renewal projects, especially within the framework of the Network Modernisation Plan. It also organises maintenance actions tailored as closely as possible to railway needs”: routine maintenance works, special maintenance works including renewal of the railway and grouped worked. <https://www.sncf-reseau.fr/en/about/our-business/maintenance-works> - last accessed February 2018

systematization of alternative options (ex. buses) or messages sent to users¹¹³. Who is responsible for addressing these questions remains unclear, because of their multiple consequences in terms of service quality, efficiency, image of the company (we talked about SNCF perception in the media, especially in the new social media era¹¹⁴), but also in terms of public security. Mobility being a public service and railways being critical socio-economic infrastructures, such consequences go beyond SNCF itself. These questions involve many stakeholders both within SNCF and among public authorities. This part of the discussion on climate change impacts lead to a debate around costs, risks and responsibilities: “in the dialogue with traffic authorities, as soon as it comes to responsibilities and costs issues, discussions become like a ping pong game. Everyone is putting the responsibility on the others. We need to clarify who is in charge of what.”

SNCF Mobilités is often pointed as an easily identifiable culprit. It is on the front line, interacting on a daily basis with users of rails and directly blamed in case of disruption (“we are still the company that is quickly pointed out”; “in customers’ mind today, if we are forced to close a line, even because of a climate emergency, SNCF is still responsible”). However, the company does not necessarily control all the levers to address the issue. As a mobility provider, it has first to deal with shorter time horizons: it operates with the existing infrastructure and in case of crisis has to follow SNCF Réseau instructions (SNCF, 2016b)¹¹⁵. This may situation will most likely be complexified by the opening of the rail transportation market: “In an opened-market, it just has to respond to the requirements of the authority in charge of the mobility policy¹¹⁶”. SNCF Réseau, as a long-life assets manager, is more long-term oriented (CEDD, 2015) – and thus is a less visible potential “culprit”. Yet, because of its natural monopoly on the infrastructure, it remains the unique and legitimate interlocutor for public authorities. Finally, public authorities have a duty to take care of public security¹¹⁷. They

¹¹³ How to integrate this issue of adaptation into the information delivered to passengers? Is it a State responsibility or should it be delegated to SNCF? Are passengers ready to postpone their planned trips? “A train-user books his ticket months in advance or even buy an annual transit pass. This means that from his perspective the trip is already promised, it is due. When there is an interruption it's intolerable because he perceived it as a broken contract”.

¹¹⁴ “Customer's expectations are changing, becoming even more demanding and visible with social medias. In case of a crisis, cancelling a train may be very impacting for the company image. At the end of the day, whatever the initial cause, the message broadcasted is that “SNCF trains are not circulating”.”

¹¹⁵ “SNCF Réseau is in charge, as Infrastructure Manager, of the management of operations related to the return to a nominal railway production on the National Rail Network” (translated from (SNCF, 2016)

¹¹⁶ As noted, it is already the case in urban areas “Keolis is not defining the mobility Policy of Bordeaux Metropolis, it just operates the service”

¹¹⁷ Décret n° 2017-1071 du 24 mai 2017 relatif aux attributions du ministre d'Etat, ministre de la transition écologique et solidaire, cf. <https://www.ecologique-solidaire.gouv.fr/direction-generale-des-infrastructures-des-transport-et-mer-dgitm> – last accessed February 2018

also enforce free-competition rules defined at the EU level for liberalized part of the service (freight, high-speed lines, international lines and soon regional traffic). Moreover, they design and financially support public mobility policies. Since the 2016 law¹¹⁸, there are two important public levels of governance regarding railway transport: the national State and Regional councils¹¹⁹. The national State is the traffic authority for Intercités services, i.e. middle-distance trains operating classical lines¹²⁰. Regional councils are the traffic authorities for regional trains (TER). These public actors can make contrasted political choices. They might for instance bet on rail to insure a fair and reliable access to low carbon, high capacity mobility solutions or they might rely on competition between modes to increase the cost-performance and flexibility of options available to users (Table 5-2). Resources constraints but also political visions – coming out democratic debates - may intervene in such a decision.

Table 5-2 - Two contrasted regional mobility policy options for adaptation

| | Typology of main costs | Distribution of benefits | Institutional framework | Notes and comments |
|--|--|---|---|--|
| <p>(1) Going for rail</p> <p>Political decision to reinforce the relevance of railway for an adapted transport solution at the regional scale: technical robustness and systemic redundancies to cope with a wide variety of possible future weather conditions.</p> | <p>Investments costs to strengthen and develop the infrastructure</p> <p>Operating costs to maintain and operate secondary lines which are not self-financed</p> <p>Coordination costs for an efficient management of the whole system</p> | <p>Little immediate cash-flow but an increased social-benefits in terms of long-term security, reliability of service and territorial fairness* + reliability as an added value for freight**</p> | <p>Public investment; implementation and coordination by the infrastructure manager (SNCF Réseau).</p> <p>→ Regulated market with precise specifications for mobility operators' responses to call for tenders</p> | <p>Historical players</p> <p>Implies a redefinition of performance criteria</p> <p>Possibly not the most cost-efficient</p> <p>Financing issues – resource constraints</p> <p>Coordination skills are critical</p> |
| <p>(2) Multimodality and flexibility</p> <p>No <i>a priori</i> preference for one mode but focus on cost-performance, agility and flexibility between various mobility options, including rail and road: real-time management, ability to efficiently deal with incidents and quick recovery.</p> | <p>R&D investments to create and scale-up new mobility solutions (including new services, skill and more efficient management techniques)</p> <p>Information costs to optimize management (e.g. just-in-time transport capacity, predictive maintenance)</p> | <p>Rapid increase in cost-efficiency; economically optimized mobility service</p> | <p>Increased cost-performance that can give a competitive advantage to a mobility provider</p> <p>→ Incentives for a competition driven innovation & performance. Autonomous adaptation as a differentiation strategy for mobility providers.</p> | <p>Possibly new players (including companies coming from other sectors such as digital companies)</p> <p>Uncontrolled externalities (e.g. data privacy, environmental impacts.)</p> <p>Possible coordination costs between operators – risk of maladaptation</p> |

Source: Author

* In a recent work, the French Ministry of Ecology showed that the socio-economic consequences are one of the most significant costs following an interruption in traffic because of a weather-related incident. In the real-life case when a main train-service between two regional cities in Brittany the cost exceed 2M€. (CGDD, 2017)

** c.f. for instance scenarios studied by the logistics company DHL in which reliability becomes a major competitive advantage in a world by an increased climate variability (Dépoues, 2016; DHL, 2012)

¹¹⁸ Loi n°2015-991 du 7 août 2015 portant nouvelle organisation territoriale de la République (Loi NOTRe)

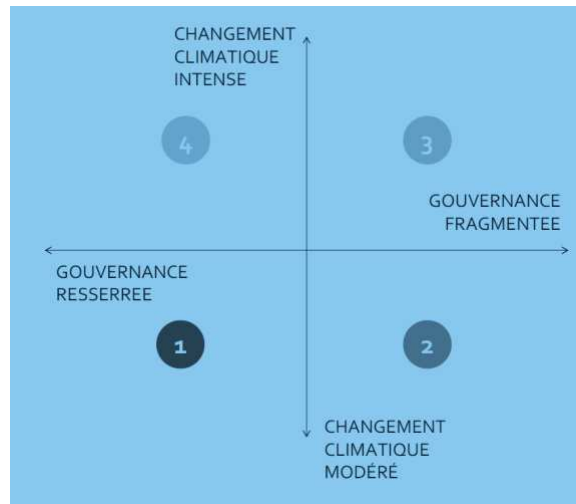
¹¹⁹ Metropolitan France is divided into 13 administrative regions

¹²⁰ « Trains d'équilibre du territoire »

Box 5-1 - Adaptation governance an issue previously identified at SNCF

It is interesting to note that, in its very first attempt to address adaptation we described at the beginning of chapter 3 (DRAIL project) SNCF had already identified governance (regulation, level of competition) as one of the trickiest questions. In the outcomes of this project, we could read among priorities for adaptation to "identify all the interdependencies, bring out a shared vision between the stakeholders, strive for the authorities to adopt a clear governance of the rights, duties and responsibilities of each - especially in case of climate crisis ". The degree of coordination (fragmented vs. tight governance) was even proposed, with the intensity of climate change, as one of the two key variables to build an adaptation strategy (Figure 5-3).

Figure 5-3 - Key parameters to build adaptation scenarios



Source: SNCF, DRAIL prospective workshop

Taking into account those heterogeneous contexts and constraints, discussion around roles and responsibilities is critical for designing and implementing an efficient adaptation strategy (Preston et al., 2011): "a recent study shows that demarcations of responsibilities are often lacking in adaptation policy documents". As noticed in (European Environment Agency, 2014, p. 14), "the responsibility for adaptation action in the transport sector is often not clear. [...] in the event that adaptation related to transport would happen only spontaneously, conflicting and ineffective strategies could follow" (Table 5-3)¹²¹.

¹²¹ Governance of adaptation is a topic increasingly addressed in the literature. Huitema et al. proposed a general framework to analyze or design governance systems according to a typology of options among which decision makers have to choose. The categories of this typology are: problem choices, level choices, timing choices, choices concerning modes of governance and instruments, norms and principles choices and eventually implementation and enforcement choices (Huitema et al., 2016).

Table 5-3 - Different adaptation interests of transport stakeholders

| Actors | Likely primary interest in transport | Existing and potential adaptation approaches |
|--|---|---|
| Governments (acting for society as a whole) | <ul style="list-style-type: none"> • Ensure a well-functioning transport system as the backbone for economic activities and movement of people. | <ul style="list-style-type: none"> • Manage or support to ensure a stable transport system also under climate change and extreme weather events; • strategies, action plans, mainstreaming into other policies like Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), spatial planning, emergency plans, urban renewal etc.; • ensure security through access to emergency aid in crisis situations. |
| Private and public users | <ul style="list-style-type: none"> • Need reliable, affordable transport for the exchange of goods; • commuting to work, study, daily life issues; • leisure and business trips. | <ul style="list-style-type: none"> • Switch to another provider; • switch to another mode; • access services without transport by ICT, telecommunication, etc.; • change their travel plans. |
| Private and public providers — service operation | <ul style="list-style-type: none"> • Business continuity by providing transport services; • provide transport services as a basic service for society. | <ul style="list-style-type: none"> • Adapt operation procedures; • request climate-proof infrastructures and vehicles/equipment; • change to other infrastructure and equipment providers if that is an option; • accept interruptions if the related costs are lower for the company than adapting (cost-benefit analysis for the company). |
| Private and public providers — infrastructure | <ul style="list-style-type: none"> • Business continuity by providing transport infrastructures to operators; • provide transport infrastructures to operators to ensure a well-functioning transport system. | <ul style="list-style-type: none"> • Proper maintenance of the infrastructure; • making infrastructure climate-resilient; • provide alternative routes (redundancies), if the related costs are lower for the company than adapting (cost-benefit analysis for the company); • otherwise accept interruptions and repair the affected infrastructure after a disaster; • insure against potential damages. |
| Providers — vehicles, aeroplanes, ships, trains, equipment | <ul style="list-style-type: none"> • Business continuity by providing vehicles and equipment to operators. | <ul style="list-style-type: none"> • Proper maintenance of the equipment, trains, etc.; • making equipment, trains, etc. climate-resilient (based on cost-benefit analyses for the company); • develop/provide climate-proof equipment according to the request of their clients (operators). |

Source: (European Environment Agency, 2014, p. 15)

“Transport activity is the result of bringing together resources of quite a different nature: appropriate infrastructure, equipment, vehicles, trains, aeroplanes and ships need to be provided. Service providers put together these resources to make transport services available for different needs, thereby using different transport modes: rail, road, aviation, inland water or maritime shipping. Regulators at the various administrative levels provide the basic rules to facilitate operations to run smoothly, efficiently and with minimum impacts. Finally, the numerous users make their choices and thereby shape transport demand. Most stakeholders may only have a partial perspective of the system they manage or use. They might also have different interests in transport. It is expected that, without overall strategies, the main stakeholders will react autonomously to the challenges of climate change. Given the broad challenges of climate change and the strong interconnectivity inside the transport sector and with other sectors and areas of society, such a fragmented approach seems unlikely to be efficient. It challenges the necessary consistency and coherence across the sector and system to address long-term challenges”. (ibid)

This rapid overview of actor's relationships shows that the conditions may exist for a constructive dialogue on climate adaptation, at least between public authorities and SNCF Réseau ("Being the unique manager of the Infrastructure, SNCF Réseau will perhaps remain as the good interlocutor. It is also responsible for what happens on its network"). Mobility providers for their part can choose to remain silent or to share information with the authorities. Among participants to the workshop, both options were defended. SNCF Mobilités has the legitimacy of experience but the dialogue may become more difficult in a competitive setting:

"We are still in a situation of monopoly, but soon we will not be the only ones on the market. If we raise this topic but our new competitors do not, our clients will think that there are people able to manage it more efficiently than we do. At the end of the day, which legitimacy will we have to talk about these issues more than any other?"

"I still think that we must not remain totally silent. Precisely because of this new market situation. It would be too easy for traffic authorities to blame us for not alerting them. The new entrants encountering problems will explain that they are legacy of the past. As we know the risks we may gain from being irreproachable and transparent in the information we deliver to authorities."

3. A variety of potential adaptation postures

Throughout these discussions, participants did not hesitate to consider a wide spectrum of adaptation options. They went quite far in questioning the implications of climate change, behind the usual veil of institutional postures. Without any representatives of public authorities, we could not fully compare everyone's viewpoints, but even within SNCF, adaptation strategies can be very different depending on actor's constraints and interests:

- From an asset manager perspective, adaptation means in the first place to improve the infrastructure – making it more robust or more resilient - to assure it will be able to cope with climate changes. The issue at stake is to make sure that railway as a mobility option will survive in the coming years.
- From a mobility-policy perspective, adaptation is about making the relevant investments and prioritize choices to assure durable and qualitative services to users. Favored routes and transport techniques are considered variables in this equation, sometimes as favored modes. This is consistent with ongoing evolutions that drive historical players such as SNCF Mobilités to redefine their identity from a railway

company to mobility-services providers: “Our partners only consider the railway option. We have to say that SNCF is now an intermodal company. [...] There is a pedagogical aspect to make our customers understand that global warming can change how we can fulfill our mission. And our mission is not to operate railroads; it is to carry people, to offer mobility services.” Their challenge is to meet policy-makers requirements in the most cost-efficient and satisfying way: “In some places, the most adapted train line may be a bus line [...]”.

- From a commercial perspective (e.g. for TGV operating high-speed lines which are not subsidized as regional lines are) considering climate change means adapting the company value proposition¹²² (managing risks and seizing opportunities) to keep or improve a competitive advantage over other transport alternative. Adaptation therefore becomes part of an efficient marketing strategy wondering how customers’ expectations will evolve regarding e.g. heat-comfort, top seasonal destinations or travel-priorities (will speed remain as important compared to reliability with more weather hazards especially for freight?). As one participant said, “there are other companies entering the market both for travelers and freight, and [...] if Veolia trains are better air-conditioned, then more people will choose them, the comfort will become a criterion of competition.”

This description shows how, even within a “single” company such as SNCF Mobilités, several attitudes are possible and rational. Various economic configurations live together. Depending on the context, adaptation may be beneficial simultaneously, or not, to the interest of the state owned SNCF and to the interest of private operators¹²³. It very strongly depends on the overall market structure, which is different from one service to another and rapidly evolving. Roggero et al. argued on the role of “the conceptual toolbox of institutional economics” to improve the governance of adaptation, taking into account this variety of market settings (Roggero, Bisaro, & Villamayor-Tomas, 2017; Roggero & Thiel, 2017). According to them different “coordination and cooperation problems emerge from the way actors interact to achieve adaptation”. These are relevant questions both from the companies’ perspective and for maximizing collective benefits of adaptation.

¹²² i.e. what it offers to its customers, the promise of benefits to be delivered to users.

¹²³ On the public-private debate on adaptation, cf. (Duit & Galaz, 2008; Klein, Juhola, & Landauer, 2017; Mees, Driessen, & Runhaar, 2012; Tompkins & Eakin, 2012).

For instance, regarding TER, the current liberalization phase makes any long-term planning very difficult. A participant testified: "I lived the opening of market for freight, in the beginning the competitors did not talk about societal problems, it is only about the economics, the price, how to manage costs, how to go faster. [...] Our competitors will be much more concentrated on market shares than on climate issues". However, with time, this type of configurations may evolve: - towards an oligopoly in which adaptation may become a collective problem addressed through sectoral agreements¹²⁴, or -towards monopolistic competition in which adaptation becomes part of a differentiation strategy (fostering adaptation as an innovation policy). The situation is already different for TGV or Fret SNCF (freight) which are commercial services engaged in an intermodal competition (against planes, coaches, trucks, etc.). In this context, adaptation can participate to the redefinition of the benefits offered by SNCF to its customers: focusing for instance on user's comfort for TGV or reliability for the freight¹²⁵.

CONCLUSION OF THE CHAPTER: A SUCCESSFUL WORKSHOP GIVING FLESH TO BROADER QUESTIONS

Railway services are part of a social contract and SNCF is a major actor of French mobility. It is a very well-known organization with which users have an "affective" relationship (Opinion Way pour Trainline, 2018; Regniault, 2017). As a result, when we present climate change as a potential game-changer, debates go far beyond technical adjustments or internal reorganization. Very quickly, they move towards bigger social questions regarding risk culture, mobility and travel expectations and habits (for work, for holidays¹²⁶).

"Can we imagine to adapt daily transport plans? -It raises the question of working hours because people take the train too to go to work. -If tomorrow we have days with +8°C people will not work between 10:00 and 16:00, so there will be natural evolutions that will affect mobility-demand."

"When you think that school holidays begin on the same day for everyone and so you have 15M people heading to train stations, it's an aberration in terms of transport organization".

¹²⁴ A participant who worked for the water industry before described this type of configuration between major companies in this sector.

¹²⁵ Conducting a foresight exercise, DHL, the logistics company imagined a scenario in which vulnerability mitigation and resilience of transports become more important than speed and efficiency maximization because of more numerous extreme weather events (DHL, 2012).

¹²⁶ For school holidays, France is divided in zones/regions made to handle the holiday rush better. A national schedule sets every year holiday's periods. These fixed dates are key determinant of train- passengers flows (what we call "grands departs"). For instance see, http://www.sncf.com/ressources/cp_27_-_grands_departs_2017.pdf - last accessed May 2018

At the end of the day, there is no unequivocal adaptation response to these wicked problems but a plurality of possible attitudes. This included the acknowledgement that foreseeing change is not sufficient to act. Costs distribution and technological challenges must be factored in, and sometimes prevent anticipatory adaptation. "Wait and see," is thus an option, accepting to suffer the consequences. For some key factors such as SNCF Mobilités or traffic authorities, many alternative strategic choices are still open-ended.

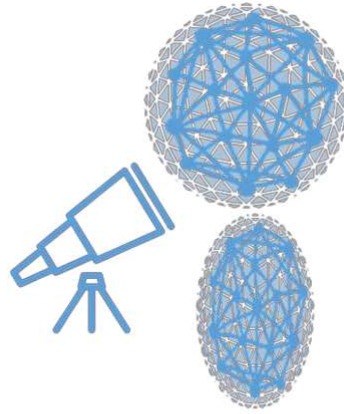
SNCF is facing a dual challenge: adapting its activities to maintain a viable service but also taking part to the adaptation of society more broadly. To what extent this is SNCF's responsibility is open for discussion and may depend on which branch of the company we are talking about. One could defend that as the historic, national player SNCF may have a strategic interest to be proactive and contribute to the adaptation of the economy and society.

This discussion needs to keep going, involving more stakeholders. The original interaction experimented here was successful in giving flesh to theoretical questions about adaptation. What do we really want to adapt: a mode of transportation, a mobility service, a company? For participants, this is not an abstract discussion anymore. As expressed in their workbooks, many participants in the room had this discussion together for the very first time (e.g. "I knew, 4 or 5 of the participants, I appreciated such occasions to meet and talk [...] especially since SNCF Mobilités and SNCF Réseau are two different companies"; "What I appreciated was to get this transversal view thanks to the diversity of participants"). The workshop offered them a deliberative space to start thinking about this issue while providing a unique insight on the complexity of envisioning adaptation under deep and plural uncertainties.

Table 5-4 - Synthetic mapping of adaptation issues as expressed during the workshop

| Questioning management practices | Questioning management guidelines | Questioning strategic choices | Questioning societal habits |
|---|--|---|---|
| <p>Ex. vegetation control</p> <p>→ New technologies, procedures changes (ex. decentralization of weeding)</p> | <p>Ex. crisis management</p> <p>→ New cancelling policy, substitution options, changes in users communication</p> | <p>Ex. investment decisions & prioritizations</p> <p>→ Reconsidering routes viability, permanent mode switch, favoring strategic redundancies</p> | <p>Ex. work and holidays organization</p> <p>→ Working and travelling differently, accepting to lower expectations (ex. losing in speed for security/reliability)</p> |
| An internal issue | | | A societal issue |
| <p>Clear roles and responsibility distribution.</p> | <p>Issues of public security + infrastructure availability: a discussion to set up between SNCF Réseau and public authorities?</p> | <p>-Mobility as a public service: designing mobility policies; role of regional and national traffic authorities (SNCF Mobilités – TER/Intercités: service-provider implementing public requirement)</p> <p>-Mobility as a commercial service, TGV or Fret: commercial services, adaptation as an added-value proposition</p> | <p>A broad societal issue in which SNCF might play a role, for instance doing pedagogy with train-users, participating in a collective dialogue on the necessary evolutions of the “contract” between users, authorities and mobility providers</p> |

Source: Author



*“Le chemin de fer sera le moyen de transport du
21^{ème} siècle, s'il parvient à survivre au 20^{ème} siècle”
Louis Armand*

Chapter 6 - Economics for adaptation as a strategic insight

"There is no doubt that, in less than ten years, the question of adaptation will be integral to SNCF's strategy, as it will have to be for all companies that believe in their long-term survival." (Dubost, 2017)¹²⁷

In this chapter, we focus on the "strategic dimension" of adaptation – less directly observed during our fieldwork but repeatedly mentioned by the actors ("we should anticipate") and in the conclusions of the previous chapters (talking about strategic will in Chapter 3, proactive adaptation in Chapter 4 and strategic interest to be proactive in Chapter 5). Strategy is a tricky word, often referring to a *panoramic* story (Latour, 2005, p. 198), an ex-post rationalization (H. Laroche, 2006; H. Laroche & Nioche, 2015) with very little grasp on the reality. Normally, strategy is conceived as a clear and stable discourse, reaffirming the core identity of the organization and setting the course for its future. Yet, comparing how SNCF is currently adapting (Chapter 3 and Chapter 4) and the questions raised by climate change when considered its full complexity (Chapter 5), this stability seems seriously undermined. The company will have to consider potential transformations and to anticipate coming evolutions (Kates et al., 2012; Lonsdale et al., 2015; O'Brien, 2012; Pelling et al., 2015)¹²⁸. Climate adaptation reopens the black box of representations of the organization and its future. Our intention in this final chapter is to reconnect these storylines with the paths we have been following during our inquiry. If climate change challenges the relationships between short and long term, between inside and outside we should wonder: Where and when does that actually happen? Who is actually doing something, and how?

I. STRATEGIC FORESIGHT AT SNCF: WHERE AND WHEN?

1. *A short history of long term thinking in SNCF*

"How can a company, which is necessarily focused on the short term (for SNCF, ensuring the safety and comfort of four million passengers every day), reflect and act to take climate

¹²⁷ Christian Dubost was the SNCF sustainability director between 2014 and 2018.

¹²⁸ Indeed, reactive autonomous adaptation does not always end well. Taking action too late may be insufficient to cope with potentially rapid changes. Adjustment only, may create lock-ins in configurations maladapted to a more variable or extreme climate regime: "Humans have the unique ability to anticipate future stresses, and are thus capable of taking proactive adaptation measures to lessen the perceived negative impacts from these future events". (Engle, 2011).

change into consideration? This is the heart of the matter: effective adaptation of the planet and of the French territory requires spending time and especially money to plan for the future. In a world in crisis, this is not the least of our difficulties.” (Dubost, 2017)

Drawing on science and technology to control and shape future is a common attitude for industrialized western societies¹²⁹ (Cazes, 1986; Chateauraynaud, 2013; Lesourne, 1966). Socioeconomic actors have been concerned with foresight, future studies, and long-term strategies for decades. In a rapidly changing environment, it is a matter of survival for them: "lasting businesses are very afraid of one thing: death. The fact of taking a look at the future takes away this perspective” (Durance & Monti, 2017).

Providing a complete history of how big French companies in general or even just SNCF deal with the future go far beyond the scope of this dissertation. However, we can sketch a rough periodization, starting from 1945.

Just after WWII, the administration of the French economy was highly centralized in particular through the role played by the High Commissioner for the Plan (Massé, 1965). SNCF was an essential instrument of this planning process regarding transports but also spatial planning and social policies¹³⁰. Starting in the 70s, we observed a general trend directed toward an increased volatility, uncertainty, complexity and ambiguity. Some companies experienced actual turning points; for instance the oil shocks changed the game for energy producers in the 70s (Hatchuel & Moisdon, 1997). For others, such as national railways, evolution came more progressively.

Decision-makers and researchers worked together to develop frameworks and tools to deal with these changes and preserve the capacity for action. A dynamic foresight community, sometimes called *Ecole française de prospective*, emerged around individuals such as Gaston Berger, Pierre Racine, Bertrand de Jouvenel or Jacques Lesourne (Berger, 1957; De Jouvenel H., 2004; Durance, 2014; Godet, 2007). This school of thoughts had a deep influence on both public administrations and major businesses, among which EDF (national electricity producer) and SNCF. For SNCF this was a period of rapid technological change and developments.

¹²⁹ As Jacques Lesourne already noted 50 years ago:” for several centuries, Western civilization has been a gigantic attempt to control man's destiny. This attempt was first manifested by the development of physical sciences, then by that of biological sciences, and it was these developments which, in terms of applications, gave birth to industrial technology and modern medicine. For a little more than half a century, and by the most different ways, the attempt has been extended to the human sciences, economics, psychology, sociology”. (Lesourne, 1966)

¹³⁰ 480 000 people worked for SNCF in 1948. Source : <https://ressources.data.sncf.com/explore/dataset/effectifs-disponibles-sncf-depuis-1851/?sort=date> – last accessed May 2018

Together with new pricing approaches, the TGV program embodied and performed a vision of progress made of speed and rationalization (Finez, 2013a; Fourniau, 1997, 2011; Picon, 2001).

Foresight took roots at SNCF with the creation in 1966 of the Research division, also very influenced by operational research, economics and systemic analysis. This division - 130 experts in 1970 (Guibert, 2008) - had a complex history but remained very close and well connected to SNCF top-management until the end of the 90s (Berlioz & Biais, 2010; Lesourne, 2001). It produced several major pieces of work on topics ranging from Europeanization to major technological breakthroughs.

Today, what used to be long-term issues have become immediate challenges for SNCF. The next steps of the liberalization process, the huge debt of SNCF Réseau, the energy transition have to be handled now to ensure that railway will remain a viable option in the future (SNCF, 2013, 2017c, 2017b; SNCF Réseau, 2018b). Focusing on “modernization”, “digitalization”, “performance” or “user experience” SNCF goal’s is to get ready to operate in the coming world. The discourse about innovation or even open innovation is very illustrative. It is no longer time to prepare well designed 'plans' but to demonstrate that SNCF is still on track (SNCF, 2013, 2017c; SNCF Réseau, 2018b). There is no more powerful research division, close to the board, but distributed skills to incentivize innovation everywhere in the company.

The relationship that an organization has with the future is contextual and reflects its current representation of the world. It goes with a specific type of strategic thinking. SNCF is currently living a critical moment: the legacy from the past are still with it – the infrastructure, but also the social model, the debt, etc. – but it is increasingly challenged by burning present issues - traffic management, network retrofitting, etc. – and the future is already here – new market conditions, digitalization, etc. François Bourse, quoting Gaston Berger, talks about a “thick present”. Climate adaptation has to find its way through these trends yet: the speed and nature of change are critical obstacles.

2. Climate change: the issue of novelty and speed

Our brief overview of historic foresight studies reveals that in SNCF, long-term issues are prepared well in advance (Finez, 2013a; Lesourne, 2001).

“Given the rigidity resulting from the size, the main technologies, regulations and the structure, the time that separates the reflection from the action at SNCF is necessarily long, which is sometimes frustrating”. (Lesourne, 2001)

SNCF is familiar with faraway horizons – engineering works are made to last for more than 100 years, rolling stock are designed to operate during 30 to 40 years, etc. Studies have been exploring issues regarding open-competition, new technologies or even the impact of railways on the environment for more than 30 years. Some of the current top executives have been in the company for several years and had the time to become familiar with those topics. It would therefore be incorrect to assert that SNCF top-management does not think about long-term issues. However, the long-term at SNCF takes time¹³¹. As noted by Lesourne or Berlioz & Biais, the board of the company is “literally absorbed by unexpected events in daily traffic management” (Berlioz & Biais, 2010); “contrary to EDF [French electric utility company] top management, SNCF executives cannot step-back from everyday problems” (Lesourne, 2001). As a result, structural changes and strategic trends need to be progressively prepared and implemented. The sense of urgency coming from an emergent trend is hardly felt.

Even if climate change has been around for quite some time now, it has been identified as an urgent issue only recently. Compared to the well-structured and prepared ongoing socioeconomic transformations it is still an emerging trend (Mondon, 2017). The recent IPCC 5th Assessment report (2014) of the COP21 in Paris (2015) were decisive moments but they only happened a few years ago.

In addition, climate change has long been perceived as an exogenous phenomenon, apparently distant and different from changes the company is used to deal with. In 1970, former CEO of SNCF, Roger Guibert quoted weather conditions as one of the variables that do not normally affect railway operations (“it is relatively indifferent to the weather”). When the weather disturbs the traffic, the situation is “exceptional” and therefore out of the scope of corporate strategy (Guibert, 1970).

In SNCF, there are few existing spaces and canals to deploy the problematic implications and emerging issues of such an emergent and rapid phenomenon. The complete intersement

¹³¹ This is also what we noted with LNMP high-speed line project (Chapter 4) for which discussions began in the early 90s for a project that could be completed sometimes around 2030s and be operational for more than 100 years.

chain has to be rebuilt from problematization to mobilization (Callon, 1996)¹³². Scientific knowledge on climate change alone is incapable to transform the specificities of climate change in a relevant insights for SNCF decision-making. It is hardly performative (Akrich, Callon, & Latour, 2006; Callon et al., 2001). This issue needs sponsors and spokespersons to exist, it needs to find allies to take it full place in SNCF strategy.

II. SUSTAINABLE DEVELOPMENT FOR ADAPTATION: A TWOFOLD CHALLENGE

1. *Picking up the intersement thread*

During our inquiry, we identified those who made the first steps to bring the topic in. They are mainly people involved in the sustainability policy of the company (being the 3D or the cluster DD in the Synapse network). The connection between sustainable development and adaptation to climate change seems meaningful for at least three reasons:

- *Systematic thinking about action consequences.* A critical dimension of sustainable development is to systematically anticipate and take into account the future consequences of our actions: “it is no longer possible to do as we did before, we must now think about the consequences of the present actions” (Rumpala, 2010). In order to do so, sustainability officers, intervene for instance in great projects to guarantee that long term social and environmental issues are well addressed. In this context, they are legitimate to raise the issue of adaptation to future climate conditions.
- *Managing the relationships with external stakeholders.* The sustainability department of SNCF is also a Public Relation department, with its director directly reporting to SNCF general secretary. SNCF discourse about being a sustainable mobility option is a major element of its relationship to the government and local authorities. On one hand, SNCF actions on adaptation become consubstantial to SNCF social responsibility. Indeed, as we have previously seen (Chapter 5) SNCF may play a critical role in the broader climate adaptation of French economy. On the other hand, the company adaptation policy is also a risks management policy. As described in Cochran et al., being able to

¹³² Callon discerns “four moments” in the processes of translation, from problematization to intersement, enrolment (successful intersement) and mobilization. In the translation from knowledge on impacts to adaptation to climate change, we are still in the very first phase. The nature of the problem itself it still being defined. Actors have not yet agreed on adaptation as an ‘obligatory passage point’. Some of them are trying to enroll other in this process but things are barely shuddering.

communicate about its adaptive capacity may become a necessity for companies to reassure investors and insurers (ARCC, 2017; Cochran et al., 2017; EBRD, 2018):

“There is mounting anxiety in the financial sector about physical climate risks for financed counterparties and how these risks may influence future performance. It is highly likely that, in the years to come, businesses will be required to provide more information to financial players about their exposure and vulnerability to climate risk, as well as their capacity to manage such hazards”. (Cochran et al., 2017)

- *In house mobilization.* Convinced about what is at stake, people working in the sustainability department strive to carry the issue within the company itself. Organizing workshops, conveying the scientific information, meeting people, they are the spokespersons for adaptation, playing a critical role in socializing adaptation as a strategic insight for the company. They are the one drawing connections between people involved in adaptation in so many places within the organization. The Synapse working group on adaptation presented in chapter 3 is a good example of device set up to improve knowledge sharing and connections on adaptation.

However, playing these three roles is far from easy. To make things hold together, promoters of adaptation have to meet a twofold challenge: demonstrating how adaptation is contributing to current SNCF priorities, how this objective can converge with other changes (2) and formulating how and why adaptation is also a specific issue able to challenge current choices (3).

2. Demonstrating how adaptation is contributing to current SNCF priorities

The first challenge is about being pragmatic and ensuring that adaptation will be audible. As previous projects failures – such as D-RAIL (Chapter 3) – revealed, it is not a good tactic to present climate change as an evident concern, independently for SNCF strategy. It is much more effective to find ways to articulate this challenge with ongoing evolutions, to build synergies. This is exactly what the sustainability department has been doing during the last few years. Improving weather monitoring and optimizing how SNCF is able to integrate climate variables in its operations go in this direction. The goal is there to prove how adaptation can

contribute to the economic performance of the organization. According to this first perspective, adaptation is an element of stability, strengthening the current strategy.

Illustration through the case of BREHAT

The database BREHAT, that we came across at different stages of our inquiry, has appeared as a critical piece of this process. Adaptation promoters try to create a new use of this existing and shared tool to make climate impacts objective and comparable with more classical performance drivers.

BREHAT is only one of the databases existing in the company, however we heard about it many times, both nationally and regionally. BREHAT provides records of the positions and times of incidents and allows computing statistics of regularity and determining ex-post which entity was accountable for an incident. The last officer who had to manage each incident has to fill in several fields (Figure 6-1): the type of incident and the affected traffic, the place where it happens (as a section between two kilometer posts), a beginning date and time, who he or she is and what was the last action implemented before closing the case. Regarding the cause, around 30 options are available and complemented with the type of resources affected, and the structure involved (e.g. TGV, TER, Réseau, external, etc.). A “comment” field allows to add relevant complementary information (but is often left empty).

Figure 6-1 - Screenshot of an incident record in BREHAT

| Type Incident | Lieu | Date début | PR de début |
|-----------------------------------|--|------------------|---------------|
| Circ. impliquée | | Date fin | PR de fin |
| Circade sur la voie ou aux abords | Sur VP | 27-09-2017 22:52 | SALSES 00 |
| PK441 - 27012017 | | 28-01-2017 04:54 | RIVESALTES BV |
| Date Dernière MAJ incident | Dernier poste intervenu sur l'incident | | |
| 30-01-2017 08:16 | LR OTD EIC LR 2 | | |
| 10 8 238 100 | | | |

| Type défaillance | Type ressource | Ressource | Structure |
|------------------|-------------------------|-----------|-----------|
| Intempéries | Voie courante ou abords | PK411 | Externe |

COMMENTAIRE

-GID-
 29710224
 2017 Alerte radio émise par ADC 480383 suite à prise en charge sans motif.
 04h00 : SN

 Sables - 22:55 - Inondation PN 411 PK 450,193 Sables.
 Etat des lieux.
 ADC480383 arrêté par prise en charge - émet l'alerte radio. Reconnaît son train et constate que le pn 411 pk 450,193 est inondé.
 Liste des événements
 22:57 - IRC- Liste de train composée : 375431 arrêté à PLN va être utilisé pour reconstruire la voie. 0217 (su) à NK avec 137 personnes. 3037 (su) à BS avec 60 personnes. 0219 (uni) parti de MPL (39 personnes + compte à faire dans le Tgv). Pas de voyageur PSIR.
 23:28 - IRC- 480383 fait un essai de train.
 23:45 - IRC- 480383 a compté 3 accouplements défectueux, a rebrit les accouplements et a effectué un essai de train. Le CDT est sur place depuis 23h24 mais ne peut effectuer une visite de la voie tant que le 480383 n'est pas parti.
 23:47 - IRC- 0219: 80 personnes en tout. Recherche de bus en cours au cas où via Effia : 0 bus
 00:05 - DDCG- Le DFI va demander au CDT s'il n'est pas possible de circuler sur la voie 2.
 00:09 - DDCG- Le CDT est en train d'autoriser le passage à VL 40 sur voie 2.
 00:12 - DDCG- Le TER 870451 va être expédié à CS de Sables à Perpignan. Procédure de descente à CS de Sables et Rivesaltes en cours.
 00:16 - IRC- 480383 s'est remis en marche. Le CDT visite la voie 1.
 00:18 - IRC- Le CDT interdit la circulation voie 1.
 00:28 - IRC- Le CDT avise que la voie 1 est inondée et se trouve à un niveau plus bas que la voie 2. Toutes les circulations drouleront à contre sens sur voie 2 de Sables à Perpignan.
 03:17 - IRC- 2937 service normal voie 2.
 06:10 - IRC- 4044 service normal voie 1.

Source: SNCF

The weather is one of the proposed causes. However, many incidents have more than one cause or result from a causal chain affected by weather but not recorded as such. The level of

details provided and the way of describing the situation can vary a lot from one user to another. As a result, it is very tricky to compute statistics out of this database. Many people claim for improving this tool in order to integrate new dimensions but this is not its mainspring. However, in the absence of better alternative BREHAT remains the base requested to gather information about how the weather affects the railway traffic.

In Montpellier, SNCF Réseau regional sustainability officer regularly asks his colleague in charge of managing BREHAT to extract relevant data in order to confirm or infirm perceived trends and try to detect correlations. In 2010 for instance, with lots of fires experienced in summer, weather has been associated with twice as much incidents as average in the region (in total 300/22 000 incidents).

With a more formalized approach, the Carbone 4 study (cf. Chapter 3), also relies on BREHAT to compute correlations between hazards and types of incidents on the Transilien network. The consultant kept 150 000 records out of 460 000 to conduct an in-depth analysis of 10 pairs {incident-hazard}. By cross-analysis with Météo-France data (observations and projections) they computed indicators such as {number of travelers' pass-out - maximum temperature} or {cumulated delays-rainfall}: "The study identified and explained currently weather-sensitive points within the Transilien network and helped to prioritize which were most at risk given the future climatic evolutions". They conclude on the need for "adaptations or additions to the nomenclature of the BREHAT database to better reflect the events due to weather hazards" and improvement "of the weather indicators provided in the France weather history". Data reprocessing, cross correlations to include multi-causality and elements such as the age of the infrastructure or previous maintenance performed, still appear as technical challenges for this type of analysis. However, according to the experts who conducted the analysis, it already has an operational benefit to improve performance management.

SNCF in-house experts also mentioned BREHAT during the discussion of the SYNAPSE group. They noticed the ambiguity of a tool ("a trap for external consultants") which hides the actual complexity of the railway system. The person in charge of consolidating damage costs for insurance claim exposed the difficulty to use this tool to do so.

We generally do not monitor what does not change. Consequently, up to now, SNCF did not formally monitor the climate. Discussions around BREHAT show that things are changing. It

became increasingly relevant to gather information on this issue, to be able to attribute more precisely responsibilities, to build capacity on this issue in order to be able to address coming challenges.

3. Formulating how and why adaptation is also a specific and challenging issue

The second challenge is about playing a role of watchtower and considering what does not fit well in the scope of current priorities. It is the responsibility of adaptation spokespersons to ensure that there is enough room within the company and enough slack in the processes to deploy and discuss all the possible consequences of climate change. Taking time to raise and debate these questions can lead to significant changes in long-term strategy. As conceptualized by the literature on wicked problems, addressing this kind of questions often leads to the adoption of an iterative, learning, adaptive approach (ADEME, 2013c; IPCC, 2014c; UKCIP, 2012). This second challenge is much harder to meet, as proposed solutions might be conflictual with the current dominant pathways. However, keeping this “dialogical” tension alive is critical for a company like SNCF to be ready to deal with possible disruptive rapid and unexpected changes. There is a growing consensus, that companies successful over long periods of time are those maintaining a subtle balance between stability and agility, continuity and change, exploration and exploitation (Aghina, de Smet, & Weerda, 2015; Chateauraynaud, 2013; Duit & Galaz, 2008; Dumez, 2009; Durance & Monti, 2017). They are those which learnt to deal with the unexpected and renew their model without losing their identity (Bloch & Lamothe, 2014) .

Building adaptive capacity

The considerations developed above are close to those contained in the literature about adaptive capacity (Adger & Vincent, 2005; Engle, 2011; Folke et al., 2002; Ford & King, 2015; Gallopín, 2006; Rudberg, Wallgren, & Swartling, 2012; Smit & Wandel, 2006; Staber & Sydow, 2002). Adaptive capacity is defined as “the inherent characteristics of institutions that empower social actors to respond to short and long-term impacts either through planned measures or through allowing and encouraging creative responses from society both ex ante and ex post” (Gupta et al., 2010).

Existing frameworks can help to identify the levers of action to strengthen its adaptive capacity. Gupta et al. for example propose an “adaptive capacity wheel” with six dimensions to promote adaptive capacity of institutions. Their fundamental story line is that “institutions that promote adaptive capacity are those institutions that (1) encourage the involvement of a variety of perspectives, actors and solutions; (2) enable social actors to continuously learn and improve their institutions; (3) allow and motivate social actors to adjust their behavior; (4) can mobilize leadership qualities; (5) can mobilize resources for implementing adaptation measures; and (6) support principles of fair governance” (Gupta et al., 2010). These types of frameworks can be very useful heuristic tools as they incentivize to take into account apparent paradoxes and driving tensions. Pelling et al. describe adaptive capacity as “relation spaces within that cut across the formal organizational structure for learning and adaptation, and which relate individual to social learning, [They] argue that the relational attributes of organizations and policy regimes are central to adaptive capacity, enabling robust responses not only to unknown shocks and trends associated with climate change, but also the interpenetrating uncertainties of economic, social and political change. These spaces allow individual or subgroups within organizations to experiment, imitate, communicate, learn and reflect on their actions in ways that can surpass formal processes within policy and organizational settings. This approach offers a potential method for measuring adaptive capacity that focuses on process rather than output, enabling proactive adaptation” (Pelling, High, Dearing, & Smith, 2008). According to Roggero et al., learning is probably the most efficient adaptation narrative to engage with private organizations. It is “the entry point for private adaptation [...] unpacking analyses that currently link perceptions and knowledge issues directly to adaptation, and explore the institutional mechanisms at work” (Roggero et al., 2017).

However, a focus on adaptive capacity should not make lose sight of the fact that adaptation is also a governance and a political issue. Adapting mobility systems goes beyond SNCF ability to be resilient as an organization. As we have seen in the previous chapter it involves private and public choices about visions for the future.

III. ECONOMICS TO CATALYSE THIS PROCESS: HOW?

“Speaking of organization in its own language” (Latour, 2013, p. 381)

People in charge of sustainable development struggle to promote adaptation both within the organization and in their relationships with external stakeholders because of competing priorities¹³³. These other strategic priorities of the company – debt, cost-performance, investment needs, and major business-risks – are generally expressed in economic terms. This observation, led to the hypothesis we made at the beginning of this research, according to which, being able to rephrase the adaptation challenge in economic terms may improve the visibility of such issue. During our inquiry, we heard demands for such economic inputs, especially coming from experts working on adaptation with a technical perspective and looking for arguments to convince their hierarchy about the importance of this issue.

Our goal has been to understand and describe the adaptation issue to be able to formulate the most relevant economic questions. Now, we have a clearer understanding of the relationships within the organization, of how the information flows, which type of discourses and devices need to be mobilized for a topic to exist, we should nevertheless be even more careful in formulating them on an economical form. Indeed, one-size-fits-all methodologies or ready-to-use tools, developed in external contexts¹³⁴, with no direct connection to the organization, have very limited chances of success. In addition, economics in such an organization can cover a wide range of realities: from socioeconomic evaluations to financial analysis or decision-making tools (such as CBA) to assess different options of an engineering project. Once again, we first have to find where and how and by whom, economics is actually practiced in this specific context.

In order to do so, we relied on a rich literature which highlights the need to provide an historical perspective and to contextualize the use of economics for decision-making. We also interviewed people in charge of economics research at SNCF and socioeconomic analysis at SNCF Réseau and in the French administration.

¹³³ It is interesting to note that we find in France questions similar to what has been described in other countries, such as Germany (Rotter et al., 2016).

¹³⁴ Who developed and carry the analysis is an especially critical point: only a few actors with their own methodologies are recognized as legitimate to provide figure in the discussions.

1. Economics at SNCF

The history of economic calculation and the history of railways are strongly related. Many concepts such as return to scale or approaches like differentiated pricing or discounting, appeared with the development of railway networks over the nineteenth century (Doganova, 2014; Etner, 1987; T. M. Porter, 1996; Soraya Boudia, 2014). Scholars analyzed this moment as the installation of a technical rationality at the heart of major political choices. State engineers, especially from the *Corps des Ponts et Chaussées* – promoted the ideal of depoliticized investment choices maximizing public interests (Dehornoy, 2011).

In the 1960s, we entered a period of economization that saw the emergence of a market-oriented approach in railway management. Finez describes it as a “convergence between France’s traditionally State-controlled railway sector and the model of a commercial enterprise” (Finez, 2013a). This evolution took place in a broader context characterized by a growing audience for marginalist theories, external and internal changes (evolution of markets and regulations, new executives, etc.). The creation of the R&D department (Guibert, 2008; Lesourne, 2001) and the TGV program embodied this new mindset.

In the beginning of the 90s the liberalization process – strongly influenced by the EU – started, deeply rooted in liberal economic theories (Dehornoy, 2011; Perennes, 2014). Since then, most scholars noted a growing skepticism towards economic analysis for which they proposed complementary explanations. First, big public investment programs ended (at least temporary); most of the French metropolis are now highly interconnected and there is no more public resource for additional projects. Many of the projects still in the pipeline are public private partnerships in which the financial analysis becomes more important than socioeconomic assessments. Others are more difficult to justify economically and economic evaluations are often ignored when they are not consistent with political preferences (“we prefer to break the thermometer”) (Dehornoy, 2011; Lesourne, 2001). In addition, classical analysis struggles to take into account a growing diversity of issues and externalities (including the environment, security, health, etc.) (Godard, 2004a). To address this problem the use of multi-criteria analysis (MCA) has grown. There are also attempts to improve the economic frameworks to enable a greater consideration of externalities (France Stratégie, 2014, 2016; Gollier et al., 2011; Quinet et al., 2013), but these evolutions struggle to improve the

reputation of economic analysis as they reveal methodological difficulties, they make the analysis more complex and they regularly reduce ROIs¹³⁵. As a result, people become more sceptic about the capacity of economics – which increasingly become a “black-box” – to account for public interest. Classical economic analysis tends to overemphasize some factors – such as speed – over others which are less socially relevant (Crozet, 2004). It has become much more difficult to provide a consensual definition of what is “general interest”. With an increasing number of stakeholders and sometimes divergent priorities, there is no common metric anymore (Godard, 2004a).

For each of these periods, we can find a corresponding vision of the organization itself. Far from being stable, the ideas about what are SNCF identity, goals, markets, etc. have greatly changed over time. Just after WWII, “while the ideology of planning is at its high, SNCF is considered as ‘a homogeneous entity’ [...] an effective public service based on a triptych: monopoly of exploitation, public control of the enterprise and social status of workers. At the turn of the years 1950-1960, under the influence of a movement of engineers-neoliberal economists and an increasingly organized lobby, the preponderance of rail falters” (Finez & Quessette, 2018). The idea of competition between modes - first rail vs. road, later vs. air-transport – surfaced and rail had to prove its benefit, in term of spatial planning for instance. In the 90s even the concepts changed, we moved from transports (an infrastructures-centered notion) to mobility (a user’s-centered notion) and this accompanied the formal separation between the asset owner and the asset manager. All other these periods, the definition of what is a public service evolved, the power balance between actors changed transforming the perception and use of economics.

Finally, yet importantly, we should note to complete this rapid overview that economics have historically played a more active role at the interface between SNCF and public choices than for the management of the company itself – with the possible exception of the TGV program, strongly influenced by the *Research division*. We explicitly find reference to the economic theory regarding debates on the market structure or major investments. However, for daily operations and smaller projects a budget approach prevails with no systematic formal comparison between the costs and expected benefits of options. We asked the question of the role of economic analysis during almost all our interviews with SNCF staff and it became

¹³⁵ Internalizing costs by constructions make the projects more costly and so less profitable.

rather clear than this is not the prevailing culture among SNCF managers. It is even difficult to collect cost-figures - people compiling insurance-requests after major climate-events for instance struggle to do so. The design of the existing information-system for recording incidents feedback is not optimized for this use. Cumulative delays – expressed in minutes – are most of the time preferred to euros as a performance indicator. Even introducing an economic chapter in technical studies is a relatively new practice.

2. Economics for adaptation

Any attempt to introduce adaptation economics at SNCF has to consider this global picture. According to (Oberlack & Neumärker, 2013), adaptation economics is commonly concerned with assessment of benefits and costs of adaptation, strategies for efficient adaptation, the role of markets and governments as well as policy instruments to incentivize adaptation. In addition, these authors introduce relevant questions for an institutional economics¹³⁶ approach to address challenges such as multi-level governance systems, individual and social learning processes, fairness and justice of adaptation, power and legitimacy of action or preconditions for autonomous adaptation. Indeed, there is a growing and increasingly mature literature focusing on these research questions (Econadapt Consortium, 2015; IPCC, 2014c)¹³⁷. However, as we have understood all along this inquiry the questions are not so clearly defined in a real-life setting. Furthermore, as we saw, not all the approaches developed are directly relevant or easily audible in this specific context.

For instance, arguments relying on the global cost of climate change and comparing it to the cost of adaptation (AFA, 2015; Michaelides et al., 2014; ONERC, 2011; UNEP, 2016) have limited resonance. Indeed, the issue is not convincing SNCF managers that adaptation is an important issue but finding ways to connect it with strategic concerns and to ensure that decision makers take ownership of this topic. Our analysis brings us to the conclusion that there is no strong demand for socio-economic analysis to justify adapted political or strategical choices either. Attempts to introduce climate-related risks in evaluations frameworks creates

¹³⁶ (New) institutional economics (Coase, R., 1934, 1960) focuses on social rules, institution and norms – such as property rights, responsibilities distribution, transaction costs - that underlie economic activity. Recent research in this field identified questions of interest to improve governance frameworks for adaptation (Huiteima et al., 2016; Roggero et al., 2017).

¹³⁷ <http://econadapt.eu/> - last accessed May 2018

methodological difficulties that weaken the approach. Moreover, as we have already mentioned, socioeconomic evaluation is not as important as it used to be for decision-making.

In contrast, economics might be particularly useful to tackle the two challenges described in the first section of this chapter: mainstreaming adaptation in investment decisions and take into account the risks and opportunities that come with uncertainty and volatility in strategic positioning. It can help to maintain the necessary balance between optimization and exploration by valuing both.

There are many methods and tools developed to move in this direction. Among them, decision making under deep uncertainty (DMDU) tools go beyond the limits of classical cost-benefit analysis in a context of deep climate uncertainty (Hallegatte, 2006; Hallegatte et al., 2012; Watkiss & Hunt, 2013). They aim at prioritizing adaptation options but also at displaying possible future for the decision-makers to compare alternative choices (Dittrich et al., 2016; Ranger, 2011; Walker et al., 2013; Watkiss & Hunt, 2013). DMDU tools propose to formulate questions based on trigger issues (e.g. When do train users switch to cars in case of high summer temperature? What characteristics of unprecedented event might disturb current plans: date of an early heatwave, type of conjunction of weather events, etc.?). Then they invite to discover alternative courses of actions based on uncertainties, to assess adaptation options against this diversity of possible futures. In a nutshell, they propose to move from a unique definition of the optimal choice to a richer definition of satisfying options, valuing not only the cost-benefit ratio but also the robustness and flexibility of choices. Models from institutional economics can also be very relevant to questions of costs and benefits distribution and relevant governance frameworks to provide the right incentives (Huitema et al., 2016; Oberlack & Neumärker, 2013; Roggero, 2013). Indeed, as revealed by the workshop we organized in Montpellier, the trickiest adaptation issues are governance issues regarding for instance the relationship between SNCF and traffic authorities. Attributing responsibilities, sharing costs, defining the collective level of accepted risks are among the major issues raised by the coming changes in climate. Moreover, these questions take different forms depending on the market section operated; they are not the same for SNCF Réseau, TGV or TER. *Playing* with economic models allows to test the effect of various design of governance processes in order to identify the most significant variables (for example in terms of transaction or implementation costs) and to test possible configurations.

All these approaches offer heuristics to frame trade-off and explore possible futures. They can contribute to build and value adaptive capacity for SNCF and the society. The time dedicated to such studies, the occasion to gather executives around a table (literally) to discuss the results and the representations they propose may embody the type of experimental framework that foster exploration of salient questions, such as those that emerged during our inquiry:

Relevant research questions for economics

First, economics can provide relevant and consistent socioeconomic data to feed strategic foresight. For now, it has been very difficult – both for SNCF and traffic authorities - to conduct forward-looking studies as we have almost no information at all on the possible evolution of major variables such as the mobility demand under contrasted climate scenarios. Macroeconomic modeling but also experimental economics¹³⁸ (for example to assess changes in user's behaviors with different climate conditions) might help to fill this gap.

More operationally, economic research can bring complementary insights to decision-makers in project appraisal processes, including modernization programs, investments in new infrastructures and R&D initiatives. While there are huge needs for investments and important resource constraints it might be relevant to compare alternative options considering short term cost-efficiency but also option-value of robustness or flexibility. Economics offer this broad perspective and allows to go beyond yearly budget perspective despite uncertainties. In doing so, it is however crucial to consider substitution effects by conducting assessments on a portfolio basis. For the infrastructure manager for instance, this means implementing a comprehensive asset-management approach¹³⁹ (CEDD, 2015; Meyer et al., 2010; Tacnet et al., 2016).

As we saw in the previous chapter, mobility operators, infrastructure managers of public authorities may favor very different forms of adaptation depending on their own interests. For example, SNCF Réseau will see adaptation through the robustness of its core-asset while mobility operators might also consider non-rail options. Depending on political priorities, public authorities may privilege the cost-efficiency of the service, its reliability or other

¹³⁸ Experimental economics designs experimental devices for empirical studies. Regarding adaptation we find for instance researches studying the expectations, preferences and behavior related to several adaptation options (Rulleau & Rey-Valette, 2013).

¹³⁹ In order to avoid situations in which increasing the robustness of a section with a better adapted option decreases the robustness of the system even it in capturing the budget and preventing other critical work down the line.

benefits (such as a contribution to a low carbon economy). Economics can provide inputs to the negotiation between actors in order to reach economically sound collective decisions.

The implementation of the decision further needs to consider how the costs and benefits are distributed among actors: will the mobility provider or the infrastructure manager be able to price the benefit of an adaptation action or should it be publicly funded? We came across examples in which SNCF Réseau would be the one bearing the extra-cost of adapting the infrastructure while not being able to value the extra-benefits¹⁴⁰. In such cases, adaptation would not just happen which would not be socially optimal.

Similarly, on the costs side, economics can help to assess which actor would implement it at the lower cost. Information costs, coordination costs, innovation and experimentation costs might be major variables of the equation. These are classical questions for specific branches of economic sciences – such as innovation economics (Guellec, 2009) which deals with incentives for firms to innovate, the efficiency (and imperfections) of market, value of information and the relationships between private and social benefits of innovation. In a context of liberalization, while relationships between players are totally to redefine, these seem particularly rich research topics. For instance, if the regional mobility market becomes - as it probably will - an oligopoly, would it be better to: (i) organize cooperation between operators for a coordinated response to climate change, allowing, for example, better circulation and better sharing of information between operators in the same region and feedback? ; (ii) or to encourage the development of differentiation strategies based on the company's ability to meet these challenges and the expectations better than its competitors?

Economics as science of governance

Crozet wrote that evolution in the way we practice economics can contribute to “renew the maieutic of collective choices” (Crozet, 2004). As such, economics is first defined as a science of governance¹⁴¹, unfolding interests and motivations of various economic actors (Calame & Lalucq, 2009)¹⁴². Its mission is to raise questions and provide insights for the discussion. We argue that a function of “authorized Itching powders” (Dehornoy, 2011) might be the most

¹⁴⁰ For instance, when the extra-cost is higher than the operating loss of disruption. In particular cases, when the line is not self-profitable it might even be economically better for the infrastructure manager to be able to close it after a weather-related incident.

¹⁴¹ Governance being described, following Calame, as the “construction of collective places to elucidate the issues at stake”.

¹⁴² “The great advantage of the term “economy” is that it carries the term “nomos”, the law, the rule. [...] economics is therefore also a branch of governance”.

useful and relevant use of economics in the context we have studied. Far from replacing a passionate discussion about what really matters by a cold and abstract calculation, economic sciences materialize, make visible, the dependencies and attachments between actors (Latour, 2013). “The whole practice of formalizing economics is to make possible the local renegotiations” (p 472). In order to do so, the construction of devices to measure, compute, represent and discuss matters more than the final result that comes out the analysis: “no economics, no economy” (Callon, 2013; Callon & Muniesa, 2009). This process can reveal misunderstandings, trade-off and tensions reminding that adaptation is a hot topic which implies political and strategic choices: what are the acceptable risks and the valuable opportunities, who intervenes, who bears the responsibility, what are the preferred adaptation options?

3. Conditions to make it happen, not just about economics

There is no lack of tools or methods to handle these questions. However, there are, up to now, very few examples of the use of such tools in France (Girard, Pulido-Velazquez, Rinaudo, Pagé, & Caballero, 2015) and very little evidence of a demand from decision-makers for such approaches. We defend that the major challenge is to support the uptake of these approaches, to integrate them in consistent political and strategic narratives

On the technical side there is no doubt that there are, both within SNCF (especially in the Engineering and Projects (I&P) department of SNCF Réseau) and among the States experts, people with the necessary skills to implement such approaches. If there was a sufficient demand and the necessary resources, they could propose to adapt and test approaches already used elsewhere¹⁴³. Both within SNCF and in public choices, using performance indicators in decision-making is still an emerging practice; we can hope it is still plastic enough to integrate such considerations (or fear it is not yet mature enough) .

Beyond the calculation itself, this would require a communication effort to present the results and demonstrate which additional pieces of knowledge they bring. Even if it would not be immediate, such experiments can contribute to shape the representation of climate related issues. But, to be perceived as salient, credible and legitimate (Cash et al., 2003), this type of

¹⁴³ With probably an important first step to gather and consolidate the necessary cost-data which are not yet easily accessible.

studies cannot be carried out by anyone. They have to be commissioned by decision-makers themselves and integrated in the relevant decision processes (such as investment committees or public debates and budget allocations).

Figures and stories

Another key conclusion coming out of our inquiry is that economics is far from being the only justification regime employed in the company. At the interface between SNCF and its stakeholders the “regime of market is today the main backbone [...], but to varying degrees depending on the sub-markets considered”(Finez, 2013a). The “regime of civic world” is for instance very salient as well when talking about the role of railways as a public service (and questions such as tariff equalization) (Amblard et al., 2005; Boltanski & Thévenot, 1991). Within internal management processes, as mentioned above, economic rationalization is just emergent. As a result, economics has to take place in a broader set of approaches to support a vision of adaptation (Godard, 2004).

Other heuristics and communication tools may crucially complement economics. Climate projections for instance, may be used as “sources of insight into complex system behavior, and aids to critical thinking within robust decision frameworks” (Dessai & Hulme, 2004; Weaver et al., 2013). High end climate scenario especially bring insightful elements to challenge current pathways and choices (Berry et al., 2017), and to identify triggers points (Haasnoot et al., 2013). Visualization tools are another key element of this toolbox.

There are plenty of well-designed tools and methods available¹⁴⁴ and potentially very useful to build on, depending on the interlocutor and specific situation. However, none of these techniques can work as a standalone element. All require to be conceived as pieces of a broader framework (Trutnevyte et al., 2016). They can be plugged into conventional planning or project processes (for instance through workshops¹⁴⁵ or critical notes) or be used occasionally (for instance through autonomous studies or research projects).

The existence but, first and foremost, the connectivity of those tools and spaces that contribute to increase the organization adaptability by exploring the field of possibilities is the

¹⁴⁴ Cf. <https://econadapt-toolbox.eu/>; <http://www.mediation-project.eu/platform/toolbox/toolbox.html> or <http://www.deepuncertainty.org/> - last accessed July 2018

¹⁴⁵ Malekpour et al. for instance experienced such exploratory thinking approaches – building on climate projection used as heuristic tools and robust-decision frameworks - in the water sector in Australia (Malekpour et al., 2017; Malekpour, de Haan, & Brown, 2016) .

prerequisite for a proactive adaptation. It is about energizing the actual and collective practice of future thinking (“prospective”) within the organization by taking time, mobilizing people, dedicating resources to explore topics such as the long term evolution of mobility demand because of climate change (as done by other similar industries (Dépoues, 2016; DHL, 2012)), the evolution of users preferences (for instance regarding comfort standards) or the evolution of the positioning of the company towards local authorities¹⁴⁶. Foresight studies about the consequences of climate change are neither extrapolation of past trends nor groundless fictions. They can rely on the growing scientific understanding of the climate system, social vulnerabilities and how they interact.

Beyond rational scenarios this should progressively build a strong narrative (Vanderlinden, 2015), able to “grab [the] attention and curiosity” of actors [...] containing novelty and surprise in directions where the ideas and visions need to be stretched” (Rasmussen, 2005). The challenge is to manage to combine formal scientific and economic knowledge with the existing knowledge and experience of the context. Our interactions with SNCF have shown how individual experiment and personal expertise is essential in the operation of the railway system. Even top-management very often has a field-experience in the past. Incident feedbacks, experienced situations are the true substance of the internal knowledge. Hence the necessity of embodying the substance of scientific knowledge not only in virtual situations but also in actual cases. The “flesh and floods” of proposed scenarios is critical:

“Scenarios are flexible means to integrate disparate ideas, thoughts and feelings into holistic images, providing the context and meaning of possible futures. The application of narrative scenarios in engineering, development of socio-technical systems or communities provides an important link between general ideas and specification of technical system requirements. They focus on how people use systems through context-related storytelling rather than abstract descriptions of requirements.” (Rasmussen, 2005).

CONCLUSION OF THE CHAPTER: IT IS POSSIBLE TO SET UP THE RIGHT CONDITIONS TO MOVE FURTHER ON ADAPTATION AND ECONOMICS CAN HELP

We have seen in this final chapter that SNCF has a long history of long term thinking and planning. However, the current situation (more open and complex) and the speed and

¹⁴⁶ We can for example think to scenarios to explore such as a future in which SNCF Mobilités becomes a Regions’ partner for resilience, through specific skills with high added value such as increased capacity to manage crisis, to deploy forms of adaptive maintenance or the ability to support and advise regions in their investment and service choices. Such added value will not be deployed from day to day, and requires learning and anticipated investments.

novelty of climate change make it difficult for the organization to integrate this topic in its strategic vision. Such an integration is a long interestment process, which needs active sponsors and a plurality of complementary devices. The challenge is to guarantee there is enough space within the organization and in the public debate to reflect on the concrete consequences of the ongoing changes and gather people around them. While there is no lack of tools and methodological frameworks to initiate this reflection, their use is still limited. However, as some specific examples show (as the case of vegetation management, cf. appendices) it is not impossible to set up the right conditions for a more exploratory approach.

From a reflexive perspective, as a researcher writing a PhD thesis in economics, we arrive at the end of this dissertation charged with more research questions for economists than answers from economics. Indeed, we chose to dedicate most of our time to gather information and to understand the system we were interested in, in order to formulate relevant questions. We understood that the first step was to install the devices to actually measure, monitor, compute and set up discussions about what genuinely counts. Is not this precisely the mainspring of economics?

We might keep in mind that economics is first an empirical discipline in charge of valuing, assessing, tracing what can be valued and propose ways to mobilize and organize “passionate interests” (Latour, 2013; Latour & Lepinay, 2009). Economics is also a governance science (Calame & Lalucq, 2009). It can help to move adaptation outside its niche, to make it a political concern. We defend that in the case of adaptation, and contrary to previous situations through History, we do not need economics as a way of “pursuing objectivity” (T. M. Porter, 1996). We need it to urge people to make objections. Indeed, adaptation has to be connected with “hotter” topics. There are for instance lively economic discussions about the role of rail in low-carbon mobility systems or about the future of public services and how to manage them (ex.(Bigo, 2016; Bonnafous, 2017; Crozet, 2017; F. Laroche, 2018; Zembri & Libourel, 2017)). Adaptation can and should be part of those debates.



"Up to now the economizers have only performed the world; now the task is to describe it!" Bruno Latour

General conclusion

The objective of this thesis has been to explore how a large organization which has been operating for decades with stable climatic conditions, is today tackling the changes in climate described by science. It has aimed both at analyzing the specific case of SNCF – how this particular company is dealing with current and future consequences of this global phenomenon – and at testing the value of a particular empirical and inductive approach to get a better understanding of the issues at stake and provide meaningful insights for adaptation.

Economics is the answer but what is the question?

The climate and railway infrastructures are two complex systems. Investigating how they interact and how we represent their coevolution is a therefore a tricky task. We saw that, from their perspective, socioeconomic actors tend to see climate change as an exogenous factor, poorly connected to their most direct and pressing concerns. Most adaptation observed for now is reactive, focusing on no-regret adjustments to multiple changes.

The first challenge is therefore to make the implicit and potential relationships between the railway system and climate change more visible, to report about well-identified connections but also about less apparent interdependencies. In other words, it is to reorganize the relationships within an enriched sociotechnical system, now including new dimensions: elements – weather and climate - which used to be seen as external from the perspective of an organization like SNCF and future changes that we can, to some extent, anticipate thanks to scientific projections.

We find here what environmental economics is classically concerned with: internalizing environmental factors and considering long-term issues in today's economic decisions. In order to address those questions, economics usually use models, i.e. simplified representations of the reality, and deductive methods to test different options (Barde & Pearce, 2013; Figuière, Boidin, & Diemer, 2018; Nordhaus, 1994; Smith, 2011; Stern, 2006). However, regarding adaptation of infrastructure, the problem as it is most often stated is still too vague for an efficient economical uptake. What should we compute? The global cost of adaptation for the company compared to the cost of avoided impacts or the cost-benefit ratio of specific adaptation options? The option value of waiting? To what horizon, for which

impact? There are plenty of researches to address this type of questions (e.g. (de Perthuis, Hallegatte, & Lecocq, 2010; Dittrich et al., 2016; Markandya, Galarraga, & Sainz de Murieta, 2014)) but, from what we observed, they did not appear salient enough to offer operational answers to the stakeholders of a specific adaptation case as SNCF.

In order to provide a better understanding of the situation and dedicate the necessary time to formulate meaningful questions in context, we have unconventionally proposed to conduct an inquiry following the principles of the Actor-Network Theory. Very often, economics studies are deductive processes intending at testing working hypothesis using models or controlled experiments. We decided here to work along with an inductive approach, to provide the more relevant description of the reality in order to make the most relevant and salient modelling choices: i.e. to understand which questions we want economics to address and which variables and relationships are the most meaningful to work with. This approach also allowed us to understand how to make people interested by the research thanks to economics.

Indeed, we defend that, to move forward with adaptation – i.e. to take full consideration of the consequences and take action in spite of uncertainties and controversies – we need new representations of the whole system, seen not as an interface between an autonomous climate and an autonomous infrastructure but as a common assemblage of various heterogeneous and interconnected components. Our inquiry aimed at opening the black boxes of preconceived representations to draft such new models. Indeed, behind the image of climate change as a homogeneous object, reified through IPCC reports, we find a diversity of worldviews carried by a multidisciplinary scientific practice working on the multiples aspects of a truly complex phenomenon. Similarly, there is no such organization “with clearly defined borders and a complete, well-rounded identity that had been inserted inside a set much larger in size” (Latour, 2013, p. 414) but a plurality of interconnected actors with their own passions, interests, needs, etc. What we had to do was to find the attachment points, to reveal the relevant connections between all the actors composing those systems in order to find ways to interest them to the issue of climate adaptation (Akrich et al., 1988; Latour, 1995).

In order to do so, we have successively explored several sites, first to see how scientists and people working for SNCF are perceiving and understanding the consequences of climate change and which form of adaptation they promote. We have tried to report both on explicit

views on adaptation and on implicit reactions to ongoing changes. Then, we set up a process to test which complementary relationships would emerge when focusing on alternative properties of climate change such as an increased variability and new climate extremes. By doing so, we both reported about adaptation as it happens for now (i) and the questions that climate change may raise if we try to move beyond the current status quo (ii).

Summary of the findings

The first site we surveyed (Chapter 2), i.e. the scientific literature about climate change and adaptation, revealed a very rich, diverse and multifaceted science. We found a strong consensus to portray climate change as a phenomenon that questions the climate stability experienced in recent centuries. Based on this consensus many scientists are committed to produce policy relevant research and to provide information capable of fostering adaptation actions. However, these actions are not happening as efficiently as expected. Essential properties of climate change - including issues of scale, unprecedented speed, uncertainties, and high stakes impacts - make the interface between knowledge and decision problematic. Depending on how one perceives those properties, adaptation can take very different forms. According to a growing number of scholars, we are facing a wicked situation which calls for an iterative, learning and maybe transformative form of adaptation. However, this reading is not consensual, many ambiguities remain how to deal with this knowledge, especially when it relates to anticipated, future changes.

When we looked more in depth at the transport sector, we observed an ongoing and diverse uptake process, initially focusing on technical aspects, and now encompassing socioeconomic dimensions. Very often centered on weather-vulnerability, many current initiatives converge towards a non-regret, incremental approach of adaptation. Regarding infrastructure, we found a significant number of institutional and sectoral attempts to get familiar with this topic, especially in Europe. Indeed, infrastructures are critical components of contemporary economies and are directly exposed to climate change. However, the level of maturity can be very different from one organization to another. A growing number of authors identify knowledge management and the clarification of governance as key issues to progress on adaptation.

There are multiple perspectives to describe the impact of climate change with different focuses and coexisting views on what adaptation should be. The approach presenting adaptation as an iterative, learning process to address climate change as a wicked problem, is very promising but not consensually shared by actors.

At SNCF (Chapter 3), we found traces of a first significant attempt to address the adaptation challenge in 2011 through a transversal project but with limited success. This project revealed that it can be difficult to interest people - including the top management - within the company to this emergent issue. Adaptation can hardly be a centralized, “one shot” process.

The timid contribution of SNCF to the National adaptation plan has highlighted the difficulties of the adaptation exercise. Identifying the norms and standards potentially affected by climate change for instance is complicated. The railway system is complex, with thousands of formal and informal procedures, some defined at the EU level. Reviewing them is a heavy and demanding effort. Similarly, the vulnerability of the infrastructure is quite well known by railway experts but has never been consolidated in a comprehensive assessment. Conducting such an assessment would be possible but would demand a large amount of resources that the company chose to dedicate to topics that appear as more salient.

Based on this observation SNCF Sustainability Department has tried another approach, centered on an improved management of the relationships between railways operations and the weather in order to get ready to adjust as efficiently as possible to changes and so to keep control. SNCF adaptation policy contributes therefore both to a risk management and to performance optimization. According to this corporate discourse, adaptation is also a possible driver for technical and organizational innovations. A plurality of bottom-up adaptation initiatives, coming from sectoral experts through the organization, share this performance-centered approach. However, beyond those people strongly committed to the topic, the consequences of climate change remain a concern but not a strategic priority for the company.

When paying deeper attention to SNCF daily operations (Chapter 4), we found that locally, the interdependencies between railway and climate are experienced daily. SNCF local executives do not ignore ongoing evolutions and are already adapting. However, this adaptation is mostly reactive, autonomous and often implicit. Our interviewees do talk about adaptation to global

changes, they just react to adjust their practices and respond to the multiple visible modifications in their environment.

In an organization such as SNCF, there are traces of initiatives directed to adaptation in many places. Most of the time, adaptation measures remain actions to keep control on the system, manage risks and optimize its performance. They are still not trivial. People and places involved in adaptation are not always well connected. There is especially little interaction on climate issues between short-term concerns and long-term strategic thinking, between on-field operational problems and structuring choices of the company. Interviewed stakeholders seem relatively confident in their collective ability to deal with the consequences of climate change, especially through technical solutions. Nonetheless, we have only very limited evidence that the most transformative aspects of climate change are actually considered.

We made the hypothesis that additional properties of climate change less mentioned by actors may lead to transformations that are more disruptive for the organization. We organized an experimental workshop to test an exploratory approach to question the implications of an increased weather variability and unprecedented extreme events (Chapter 5). Our goal was to draw all the possible consequences of climate change through “what could go wrong if” questions. The process shifted the focus on complementary adaptation challenges from daily management practices (e.g. on vegetation management, maintenance planning), to corporate policies (e.g. train cancellation policies) and strategic choices (e.g. long-term investments). The workshop also revealed that who should tackle the challenges and how often remained unclear. It raised fundamental governance questions regarding risk and responsibilities distribution. As the discussion progressed, it moved from SNCF-centered topics towards bigger social concerns regarding risk culture, mobility and travel expectations and habits. We showed that there was no one-best adaptation response but a plurality of possible attitudes more or less interesting regarding which entity was considering them. Even within a single organization like SNCF, adaptation may mean different things from the perspective an asset manager, for branches operating commercial services in an open market (like TGV or freight SNCF) or for branches operating services in the process of being liberalized (like regional traffic in France currently). Which adaptation is better from a societal perspective is still an open-interrogation.

Socioeconomic actors will happily ignore the implications of the scientific information on climate impacts until the very moment in which these impacts will hit them. At that moment, it will be too late for adaptation. To bring their attention on this issue, to make it relevant for them, it is necessary to find strategies of interest that reveal how hot the topic can be, why it is a truly strategic and political issue. The challenges evolve from adjusting to progressive changes to dealing with a context of uncertainty, potential unprecedented events and possible breakthroughs.

In the final chapter of this dissertation (Chapter 6), we wondered how to reconnect those observations to more general reflections about strategic decisions and the long term. Long-term thinking exists at SNCF, but structuring topics takes time to emerge and percolate in the organization. Climate change still appears as a relatively new and external issue. We observed throughout our inquiry how some people, within the organization were working to mainstream the topic among SNCF concerns. We explained how these people actually face a two-fold challenge. On the one hand, they struggle to demonstrate how adaptation may be aligned with SNCF's current priorities. On the other hand, they need to preserve enough room for an open and prospective thinking about the possible "out of the box" implications of climate change. The issue at stake is to encourage the organization to take in consideration the necessary transformations. Promoters of adaptation need consistent arguments to meet those challenges. We have defended that economics can significantly contribute to offer such insights provided that we are able to formulate the relevant questions.

Adaptation is not just about managing risks and performance to guarantee business continuity in spite of changes in climate but also about considering the necessary transformations that an organization can partially anticipate, reinventing itself in a world significantly different because of climate change. Adaptation is a strategic bet. The challenge for its promoters is therefore not only to design clear adaptation pathways but also to provide room for developing adaptive capacity through exploration, learning and experimentation. Valuing this aspect in economic terms and dedicating enough resources to such socioeconomic foresight is a critical challenge today.

The emerging narrative built to present SNCF as a competitive and innovative firm in the liberalized market defines the "performance" in a way that is too narrow to properly include adaptation. Addressing adaptation is also paying attention to complementary dimensions that

contribute to a certain vision of what is an adapted economy. There is more than one possible form of adaptation and this vision has to be defined and discussed. For example, a robust railway network with redundant routes and efficient coordination mechanisms might be one option. A totally different alternative might be a multimodal, very flexible mobility system accepting disruption but betting on strong crisis management abilities to limit damages and recover quickly. The costs but also who bear them and who are the main beneficiaries vary a lot from one approach to another. The skills and institutional arrangements to implement one option or the other are also very different, public authorities and the infrastructure managers being the main players in the first option while private mobility providers take up in the second one. We see through this rough example that adaptation cannot be addressed only at the project level, it is a systemic concern and comes with many interrelated costs and benefits which call for a collective negotiation of adaptation choices. The current approach limited to experts and specific technical problems prevent this necessary politization both within the company and in the public debate. Economics serves adaptation when it contributes to unlock this situation.

Outlooks and future researches

Based on these concluding remarks we identify complementary research paths to build on this work:

There is first an urgent need to challenge current uptake of the consequences of climate change on socioeconomic systems and to provide sound examples of plausible scenarios that exceed current models' boundaries. Action-research can contribute to foster adaptive capacity through collective exploratory foresight exercises. We could for instance organize workshops as the one we held in Montpellier (Chapter 5) but embedded in real-life decision processes - as it has already been done in other sectors (Malekpour et al., 2017) – and open to other actors than SNCF. This is an interdisciplinary task as it implies to articulate climate inputs about physical changes with socioeconomic models (e.g. new projection of mobility-needs) to describe possible consequences of these changes and adaptations.

Adapting capacity and flexibility appeared as essential components to move from exploration to actual consideration of this situation of deep uncertainty and variability. However, we observed that they might be difficult to justify within the current management frameworks

focused on short-term cost-efficiency. Building robust performance evaluation models able to consider alternative criteria is still an ongoing task for researchers in management science. The issue at stake is to be able to value long-term adaptation benefits of current investments in actions such as learning or experiments with poor immediate returns. Adaptation of mobility systems being also a matter of public policies, this is a challenge for political science (or sociology of public action) as well, especially in a context of “managerialization” of public policies (Aggeri & Labatut, 2014; Bezes & Musselin, 2015; Lascoumes & Simard, 2011).

Finally, we identified the evolution and clarification of risks and responsibilities distribution as a critical issue for adaptation. Analyzing multiple options of distribution and their impact for different actors – including in terms of social-costs and benefits – is an emerging research topic. It is even more relevant in sectors – such as transportation – which are currently experiencing strong evolutions in regulation and market configuration. We therefore follow Oberlack and Neumärker when they say that institutional economics “can contribute to the evolving agenda of climate adaptation” and provide meaningful inputs to address these questions (Oberlack & Neumärker, 2013).

Any of these further analyses would be of little use if they do not feed a debatable vision of the infrastructure we need in a world with climate change. As long as there is no actor or constituency taking these outlooks as central features of a project and narrative, the *status quo* is likely to remain unchallenged. Because of the way things are arranged – as the future is seen, as performance is measured, as costs and responsibilities are distributed - waiting seems to be the privileged option. Climate change is still perceived as an exogenous, distant and elusive phenomenon. This is a paradox since we have started to experience its consequences. However, we still need to connect the dots between our ambitions for the future and in which conditions they will have to be achieved. We need to make sense of climate projections and vulnerability assessments, to reveal underlying interdependencies and to elucidate which of them are critical for a system – being SNCF or a regional mobility system – to operate in this world. In order to do so, science is probably not the only relevant practice – design or art for instance might be very helpful as well.

The term “adaptation” is misleading because organizations are adaptive by nature; they progressively evolve to adjust to their environment. Their essence is to manage the tension between constraints, resources and their *raison d’être*. Climate change comes with a wave of

disruptive changes that can blow away all the well-known terms of this equation. The adaptation challenge is therefore to accept that there might be no “normal” anymore (*no new normal*). This would lead to put back into play what was firmly stabilized: identity, cultures (for instance engineers’ culture), and definition of excellence or progress. Compromises which had been negotiated no longer hold. Nevertheless, for one of the first times, we can anticipate these evolutions and get prepared providing we also accept that the information we have has specific properties. It is not at all a prolongation of past trends; it is not a fiction or a future guess either. It is a probabilistic ensemble of documented projections based on a rich (even incomplete) understanding of the mechanisms at work. This might constitute, for many actors, a cognitive break¹⁴⁷. Drawing the consequences of this break requires new skills, attitudes and representations¹⁴⁸.

In order to achieve that, we will probably need, even before adaptation specialists or climate services, people able to shoulder, embody and make visible the consequences of the risks and opportunities associated with these “outside-the-box challenges”. We will also need people able to demonstrate – through their experience – that it is possible to tackle such challenges with an adapted mindset. As such, climate change generalizes a context which a few actors in charge of “major risks” or “radical innovation” have already known for a while (Godard, Henry, Lagadec, & Michel-Kerjan, 2002; Lagadec, 1981; Taleb, 2008). The experience of these former risks shows how difficult it could be to accept them¹⁴⁹ (Lagadec, 2015).

The priority is therefore to learn how to deal with uncertainty and variability, to experiment and to explore; not to develop new tools or to look for the perfect information. Economics can play a role to perform this task, along with other types of heuristics. The pitfalls to avoid is to produce analyses that make the topic even colder and more distant or abstract. Economics should rather contribute to display controversies, to make interests and tensions visible and debatable. We believe that this is the main added-value of an inductive approach as the one we intend to implement with this project: to put flesh on the bones of the topic, to describe and understand how the issue makes sense for specific actors, how these actors talk

¹⁴⁷ For SNCF it is even a double-leap: first moving from a strict budgetary approach to actual economic-based risk management practices then introducing deep-uncertainty in its risk management.

¹⁴⁸ Providing a reflexive look at the process might be a mission for the science of adaptation Swart are calling for (Swart et al., 2014).

¹⁴⁹ “The fundamental issue: our Cartesian and administrative cultures, made of exact science and concrete jurisprudence, demanding stable universes and without extreme phenomena, have a lot of trouble with uncertainty, volatility and chaotic phenomenon” Patrick Lagadec

about the challenge, to find who is actually concerned, which characters will play and tell the story of adaptation.

What SNCF tells us about adaptation of infrastructure

It is less about “stand[ing] on the shoulders [of previous studies] than, challenged and challenging, run[ning] by their side” (Geertz, 1994)

We saw all along our inquiry that SNCF was a very specific company. Nevertheless, it also shares many properties with other socioeconomics organizations and, under certain aspects (economization, liberalization (Finez, 2013a)) it even becomes less and less specific. Some of the challenges that SNCF is facing today are quite similar to the challenges faced by others infrastructure managers and operators, especially in Europe. Asset management objectives, financial constraints, digitalization, etc. are common trends in the sector. It is therefore not surprising, that our observations on SNCF adaptation are consistent with what is globally described in other comparable organizations (Berkhout, 2014; European Environment Agency, 2014). We have for instance seen how Network Rail in the UK went through the same steps as SNCF Réseau to improve its understanding of the relationships between the weather and railways and to be able to manage it and anticipate future changes (Network Rail, 2017). We are therefore convinced that some of our results might be meaningful beyond the specific example of SNCF. They can feed more general works on adaptation of infrastructure, they can provide robust inputs for broader reviews or assessments as well as elements for comparisons.

Some of the “patterns” we have identified (e.g. the novelty of climate change for this type of organization, the current focus on performance) may also have a heuristic value for further research intending at analyzing how, old, large, technical firms are dealing with global changes. Following Lewis & Ritchie, we can talk about “inferential generalization” not targeting a form of representativeness but transferability between congruent contexts:

"Inferential generalization in social research must similarly be a matter of judgement, and the role of the researcher is to provide the 'thick description' of the researched context and the phenomena found (views, processes, experiences etc.) which will allow others to assess their transferability to another setting". (Lewis & Ritchie, 2003, p. 268)

We for instance showed how an opposition commonly discussed in the literature such as the incremental-transformative debate has indeed a materiality on the field and an actual potential to set up meaningful discussions. It helps to understand that in an organization such as SNCF, adaptation is a twofold stake: a concern for technical experts to get prepared to manage coming changes and a challenge for decision-makers to anticipate transformative changes. Other common assertions such as “adaptation is local” or “adaptation is urgent” do not always fit well real-life situations (Preston et al., 2015). Indeed, railway systems are multi-scale: a climate-related incident might be very local and have implications hundreds of kilometers away. The local-global distinction makes little sense as the circulation of information between SNCF as a world-group with financial constraints and its regional facilities is a critical component both to set up an efficient iterative learning process and to make the issue salient enough for a consistent strategy. Regarding urgency, it must be kept in perspective with the urgency of common concerns of each specific organization. SNCF deals with minutes of delay and has to catch up years of underinvestment in maintenance. In this context the urgency of adaptation is hardly understood. Climate change is rather seen as an emerging and unfamiliar topic¹⁵⁰. Similarly, for economic heuristics, we have for instance seen that in the context we studied, a focus on aggregated costs and benefits of adaptation are of lesser use than a detailed work on costs distribution and coordination mechanisms.

“The Only Generalization Is: There Is No Generalization” (Lincoln & Guba, 2004)

Consistently with our initial methodological choices, we did not look for generalization. The case of SNCF has an “ideographic value” (Larsson 2009), it tells something by itself and contributes to the broader understanding of larger collectives in which SNCF is embedded, the French economy in particular. All along our study, we were reminded of the major role SNCF has today in the French economy – it transports people, but it is also a major contributor to land use planning and development, an actor of social and employment policies, etc. The organization, considered in all its complexity, is both directly affected and directly involved in many choices that drive contemporary socioeconomic evolutions and shape our development model.

¹⁵⁰ By contrast, other companies (for instance electricity transmission utilities, (Dépoues, 2017a)) might be more familiar with deep-uncertainties and volatility but perceive 2030 as a very close horizon.

Some of the questions raised go far beyond the company's scope. An inquiry as the one we have conducted, contributes to create the condition to set up the necessary discussion to build a common world out of interrelated pathways, decisions, visions (Duit & Galaz, 2008; Ostrom, 2015; Soubeyran & Lolive, 2007; Stengers, 2003).

"[...] The inquiry which alone can furnish knowledge as a precondition of public judgments must be contemporary and quotidian." (Zask, 2015)

At the end of the day, the only generalization we can hope is a greater diffusion of such inductive, pragmatic, empirical methods. We intimately believe that it had a great value for us, and hopefully for the partners of this project and the readers of this dissertation, to better understand the issue at stake here, bring meaningful insight to the discussion and identify relevant research questions. We still need many more attempts, experiments, on different cases to prove about its effectiveness and efficiency and show how complementary it is to more classical economics approaches. The world – including climate – is changing, elucidation has always to be continued, and description always has to start over.

References

- Abramovici, M. (2011). Attention, un client peut en cacher un autre » Gérer les clients en situation perturbée. *Gérer & Comprendre*, 105(3), 71. <http://doi.org/10.3917/geco.105.0071>
- ADEME. (2013a). Elaboration and implementation of a local adaptation strategy or action plan.
- ADEME. (2013b). Etude prospective sur les impacts du changement climatique pour le bâtiment à l'horizon 2030 à 2050.
- ADEME. (2013c). Objectif Climat : méthode de suivi-évaluation des politiques d'adaptation au changement climatique.
- ADEME. (2015). Programme thèse ADEME : Appel à candidatures.
- ADEME, & Météo-France. (2011). *France Changement climatique au 20ème siècle en Languedoc-Roussillon*.
- Adger, N., Arnell, N., & Tompkins, E. (2005). *Successful adaptation to climate change. Global environmental change* (Vol. 15).
- Adger, N., & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, 337(4), 399–410. <http://doi.org/10.1016/j.crte.2004.11.004>
- AEE. (2014). National adaptation policy processes in European countries.
- AFA. (2015). *Risques Climatiques : quel impact sur l'assurance contre les aléas naturels à l'horizon 2040 ?*
- Aggeri, F., & Labatut, J. (2014). Les métamorphoses de l'instrumentation gestionnaire. In C. Halpern, P. Lascoumes, P. Le Galès, & Centre d'études européennes (Paris) (Eds.), *L'instrumentation de l'action publique controverses, résistances, effets* (pp. 63–94). PARIS: SciencesPo, les Presses.
- Aghina, W., de Smet, A., & Weerda, K. (2015). Agility: It rhymes with stability. *McKinsey Quarterly*, (December), 1–7.
- Akrich, M., Callon, M., & Latour, B. (1988). A quoi tient le succès des innovations ? 1 : L'art de

- l'intéressement; 2 : Le choix des porte-parole. *Gérer et Comprendre. Annales Des Mines*, (11 & 12), 4–17 & 14–29.
- Akrich, M., Callon, M., & Latour, B. (2006). *Sociologie de la traduction: textes fondateurs*. Presses des Mines.
- Alstom. (2011). Généralités sur les contraintes exercées par les éléments climatiques sur le matériel roulant, Le point de vue d'Alstom. *Revue Générale Des Chemins de Fer*, (211).
- Amblard, H., Bernoux, P., Herreros, G., & Livian, Y. (2005). *Les nouvelles approches sociologiques des organisations*. Éditions du Seuil.
- American Meteorological Society. (2016). *Bulletin of the American Meteorological Society (BAMS)*.
- Amilton, C., Bonneuil, C., & Gemenne, F. (2015). *The Anthropocene and the Global Environmental Crisis. Thememorynetwork.Net*.
- Amoaning-Yankson, S., & Amekudzi-Kennedy, A. (2017). Transportation System Resilience Opportunities to Expand from Principally Technical to Sociotechnical Approaches. *Transportation Research Record: Journal of the Transportation Research Board*, 2604(2604), 28–36. <http://doi.org/10.3141/2604-04>
- Andreewsky, E., Delorme, R., Association européenne du programme Modélisation de la complexité., Association pour la pensée complexe (France), Association française de science des systèmes cybernétiques, cognitifs et techniques., & Impr. Corlet numérique). (2006). *Seconde cybernétique et complexité : rencontres avec Heinz von Foerster*. L'Harmattan.
- Aparicio, Á. (2017). Transport adaptation policies in Europe: From incremental actions to long-term visions. In *Transportation Research Procedia* (Vol. 25, pp. 3533–3541). <http://doi.org/10.1016/j.trpro.2017.05.277>
- Aparicio, Á. (2018). The Changing Context of Transport Research. *Publicly Funded Transport Research in the PR China, Japan, and Korea*, 31–53.
- Arafer. (2016). *La mise en œuvre de la réforme ferroviaire : état des lieux du régulateur*.
- ARCC. (2017). *Understanding the value of the Adaptation Reporting Power process to the*

reporting organisations involved.

- Armatte, M. (2011). L'économiste dans la Cité: ingénierie et expertise. *Nouvelles Perspectives En Sciences Sociales*, 6(2), 97. <http://doi.org/10.7202/1005772ar>
- Armstrong, J., & Preston, J. (2010). Rail in the Context of Climate Change: Strengths, Weaknesses, Opportunities and Threats. *12th World Conference for Transportation Research*, 1–15.
- Armstrong, J., Preston, J., & Hood, I. (2016). Adapting railways to provide resilience and sustainability. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability*, 169(2), 1–10. <http://doi.org/10.1017/CBO9781107415324.004>
- Auxiette, J. (2013). *Un nouveau destin pour le service public ferroviaire Français: les propositions des régions.*
- Bachelard, G. (2013). *Le nouvel esprit scientifique.* Presses universitaires de France.
- Bador, M., Terray, L., Boé, J., Somot, S., Alias, A., Gibelin, A. L., & Dubuisson, B. (2017). Future summer mega-heatwave and record-breaking temperatures in a warmer France climate. *Environmental Research Letters*, 12(7). <http://doi.org/10.1088/1748-9326/aa751c>
- Baker, C. J., Chapman, L., Quinn, A., & Dobney, K. (2010). Climate change and the railway industry: a review. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 224(3), 519–528. <http://doi.org/10.1243/09544062JMES1558>
- Barde, J.-P., & Pearce, D. W. (2013). *Valuing the environment: Six case studies.* *Valuing the Environment: Six Case Studies* (Vol. 6). Routledge. <http://doi.org/10.4324/9781315066301>
- Bateson, G. (1977). *Vers une écologie de l'esprit.* Seuil.
- Beau, R., & Larrère, C. (2015). Penser l'Anthropocène. In Fondation de l'écologie politique (Ed.), *Colloque international, Paris, Collège de France, "Penser l'Anthropocène "*.
- Beck, U., & Latour, B. (2004). *La société du risque : sur la voie d'une autre modernité.* Flammarion.

- Becker, H. S., & Richards, P. (2007). *Writing for Social Scientists: How to Start and Finish Your Thesis, Book, or Article*. <http://doi.org/10.7208/chicago/9780226041377.001.0001>
- Berger, G. (1957). Sciences humaines et prévision. *La Revue Des Deux Mondes*, 3, 417–426. <http://doi.org/10.1111/j.1746-8361.1961.tb00432.x>
- Berkhout, F. (2012). Adaptation to climate change by organizations. *Wiley Interdisciplinary Reviews-Climate Change*, 3(1), 91–106. <http://doi.org/10.1002/wcc.154>
- Berkhout, F. (2014). Adaptation to climate change by business organisations. In J. P. Palutikof (Ed.), *Applied studies in climate adaptation* (pp. 415–421).
- Berlioz, C., & Biais, J. (2010). La prospective à la SNCF. In F. Roubelat, M. Godet, J. Thepot, & A. E. Saab (Eds.), *Décision, prospective, auto-organisation : mélanges en l'honneur de Jacques Lesourne* (Dunod, p. 504).
- Bernheim, A. (2003). Évolution récente de la maintenance du matériel roulant à la SNCF (1972-2002). *Revue d'histoire Des Chemins de Fer*, 28–29, 28–29.
- Berry, P., Betts, R., Harrison, P., & Sanchez-Arcilla, A. (2017). *High-End Climate Change in Europe*.
- Bezes, P., & Musselin, C. (2015). Le New Public Management: entre rationalisation et marchandisation? In Laurie Boussaguet; Sophie Jacquot; & Pauline Ravinet (Eds.), *Une "French Touch" dans l'analyse des politiques publiques?* (pp. 125–152). Presses de la Fondation nationale des sciences politiques.
- Bigo, A. (2016). *Comment atteindre le facteur 4 dans les transports ? Analyse comparée de scénarios de prospectives à 2050*.
- Blanchard, A. (2011). *Reflexive Interdisciplinarity - Supporting the dialogue on the role of science for climate change*". Dissertation, University of Bergen and the University of Versailles - Saint-Quentin-en-Yvelines.
- Blanchard, A., & Vanderlinden, J.-P. (2012). Interdisciplinarité et outils réflexifs : vers une approche globale des trames vertes urbaines. *VertigO*, (Hors-série 12). <http://doi.org/10.4000/vertigo.11798>
- Bloch, A., & Lamothe, I. (2014). *L'éternité en héritage. Enquête sur les secrets de la résilience*

des organisations (Descartes & Cie.).

Blok, A., Nakazora, M., & Winthereik, B. R. (2016). Infrastructuring Environments. *Science as Culture*, 25(1), 1–22. <http://doi.org/10.1080/09505431.2015.1081500>

BMVI. (2013). *Impacts of Climate Change on Waterways and Navigation in Germany*. <http://doi.org/10.15414/raae.2013.16.02.24-39>

Boltanski, L., & Thévenot, L. (1991). *De la Justification: les Economies de la Grandeur*, Gallimard.

Bonnafous, A. (2017). Le rapport Duron fait des économies, le rapport Spinetta fait de l'économie. *TI&M, Transports, Infrastructures & Mobilité*, (508), 16–20.

Boston Consulting Group. (2015). The 2015 European Railway Performance Index. *Boston Consulting Group*, 17.

Bowden, G. (1995). Coming of Age in STS: Some Methodological Musings. In S. Jasanoff, G. E. Markle, J. C. Peterson, & T. Pinch (Eds.), *Handbook of science and technology studies*, 3 (pp. 2–17). SAGE Publications.

Briley, L., Daniel Brown, Kalafatis, S. E., Laura Briley, Brows, D., & Kalafatis, S. E. (2015). Overcoming barriers during the co-production of climate information for decision-making. *Climate Risk Management*.

Bruscoli, D. (2016). *Incorporating weather conditions into railway infrastructure cost functions*.

Cai, Y., Lenton, T. M., & Lontzek, T. S. (2016). Risk of multiple interacting tipping points should encourage rapid CO₂ emission reduction. *Nature Climate Change*, 6(5), 520–525. <http://doi.org/10.1038/nclimate2964>

Calame, P., & Lalucq, A. (2009). *Essai sur l'oeconomie*. Charles Léopold Mayer.

Callon, M. (1996). Some elements of a sociology of translation: domestication of the scallops and the fisherman of Saint Briec Bay. *Power Action and Belief a New Sociology of Knowledge Sociological Review Monograph 32*, 110, 196–233.

Callon, M. (2013). *Sociologie des agencements marchands*. Presses des Mines-Transvalor.

Callon, M., Lascoumes, P., & Barthe, Y. (2001). *Agir dans un monde incertain. Essai sur la*

- démocratie technique*. PARIS: Le Seuil. <http://doi.org/10.3917/dio.207.0130>
- Callon, M., & Muniesa, F. (2009). La performativité des sciences économiques. (PUF, pp. 303–338). PARIS. <http://doi.org/10.3917/puf.stein.2013.01.0281>
- Capo-Canellas, V., Collin, Y., Des Esgaylw, M., Foucaud, T., Karoutchi, R., Keller, F., ... Raoul, D. (2014). *Infrastructures de transport : sélectionner rigoureusement, financement durablement*.
- Carmen Lemos, M., Kirchhoff, C., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, 2(11), 789.
- Carmen Lemos, M., & Rood, R. B. (2010). Climate projections and their impact on policy and practice, 1(5), 670–682.
- Carrozza, C. (2015). Democratizing Expertise and Environmental Governance: Different Approaches to the Politics of Science and their Relevance for Policy Analysis. *Journal of Environmental Policy and Planning*, 17(1), 108–126. <http://doi.org/10.1080/1523908X.2014.914894>
- Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., ... Gustin, D. H. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), 8086–8091. <http://doi.org/10.1073/pnas.1231332100>
- Cassou, C., & Cattiaux, J. (2016). Disruption of the European climate seasonal clock in a warming world. *Nature Climate Change*, (April), 1–6. <http://doi.org/10.1038/nclimate2969>
- Castells, M. (1996). *The rise of the network society: volume i: the information age: economy, society, and culture*. Recherche (Vol. 61). <http://doi.org/10.2307/1252090>
- Cattiaux, J. (2017a). Cours Changement climatique - ENM.
- Cattiaux, J. (2017b). Quel temps fera-t-il dans 59 ans ?
- Cavagné, B., Charpin, J., Cornu, G., Dagbert, M., Delli, K., Duron, P., ... Simian, B. (2018). *Rapport du Conseil d'Orientation des Infrastructures - Mobilités du quotidien: répondre aux urgences et préparer l'avenir*.

- Cazes, B. (1986). *Histoire des futurs : les figures de l'avenir de Saint Augustin au XXI^e siècle. Histoire des futurs*. L'Harmattan.
- CEDD. (2015). *La gestion des infrastructures de réseaux*.
- CEN-CENELEC. (2016). CEN-CENELEC Guide 32: guide for addressing climate change in standards. Brussels.
- Ceppi, P., Brient, F., Zelinka, M. D., & Hartmann, D. L. (2017). Cloud feedback mechanisms and their representation in global climate models. *Wiley Interdisciplinary Reviews: Climate Change*, 8(4), e465. <http://doi.org/10.1002/wcc.465>
- CER, UIC, EIM, UNIFE, UITP, UIP, & ERFTC. (2012). *Climate Change & Standardisation A Sector Position Paper*. Bru.
- CEREMA. (2014). *Réforme du système ferroviaire français : Éléments de décryptage de la loi de 2014*.
- CEREMA. (2015a). PNACC, volet infrastructures et systèmes de transport, action 1 – Adaptation des infrastructures et systèmes de transport au changement climatique.
- CEREMA. (2015b). *PNACC, volet infrastructures et systèmes de transport , action 3 Impacts potentiels du changement climatique sur les infrastructures, systèmes et services de transport, recueil de concepts*.
- CEREMA. (2017). Étude de la vulnérabilité des réseaux de transport au changement climatique : Étude de cas appliquée aux réseaux de transport Marseillais. In *Séminaire DGITM « Adaptation des infrastructures et réseaux de transport au changement climatique »*. Paris: Furmanek, Nicolas Vedovati, Bertrand.
- CGDD. (2017). *Indisponibilité d'une infrastructure de transports, mesurer et réduire les coûts*. PARIS.
- CGEDD. Evaluation du plan national d'adaptation au changement climatique (2015). CGEDD.
- Chambers, R. (2002). Participatory workshops. A source of 21 sets of ideas and activities. *London, England: Earthscan.*, 220 p. <http://doi.org/10.1108/et.2002.00444had.006>
- Chapman, L., & Bell, S. J. (2018). High-Resolution Monitoring of Weather Impacts on

- Infrastructure Networks using the Internet of Things. *EARLY ONLINE RELEASE*.
<http://doi.org/10.1175/BAMS-D-17-0214>
- Chappin, E. J. L., & van der Lei, T. (2014). Adaptation of interconnected infrastructures to climate change: A socio-technical systems perspective. *Utilities Policy*, *31*, 10–17.
<http://doi.org/10.1016/j.jup.2014.07.003>
- Charmaz, K. (2006). *Constructing grounded theory: a practical guide through qualitative analysis*. (SAGE Publications, Ed.), *Book* (Vol. 10).
<http://doi.org/10.1016/j.lisr.2007.11.003>
- Chateauraynaud, F. (2013). Regard analytique sur l'activité visionnaire. *Du Risque à La Menace. Penser La Catastrophe*, 287–309.
- Chavaillaz, Y. (2016, May 18). *La vitesse du changement climatique et ses implications sur la perception des générations futures*. Paris Saclay.
- Chinowsky, P., Helman, J., Gulati, S., Neumann, J., & Martinich, J. (2016). Impacts of climate change on operation of the US rail network. *Transport Policy*, (May), 1–9.
<http://doi.org/10.1016/j.tranpol.2017.05.007>
- Coase, R., H. (1934). The Nature of the Firm. *Economica*, *4*(440), 440–446.
- Coase, R., H. (1960). The problem of social cost. *The Journal of Law and Economics*, *49*(1), 1–44. <http://doi.org/10.1086/466560>
- Cochran, I., Dépoues, V., Hubert, R., & Nicol, M. (2017). Corporate adaptation plans or the pressure of finance. In B. Laville, A. Euzen, & S. Thiébault (Eds.), *Adapting to Climate Change: a question for our societies* (CNRS Editi). Paris.
- Colombert, M. (2016). *ADAPTATIO Rapport Final*.
- Commission Mobilité 21. (2013). *Pour un schéma national de mobilité durable*.
- Conklin, J. (2005). *Dialogue Mapping: Building Shared Understanding of Wicked Problems - Chapter 1*. CogNexus Institute. Wiley. <http://doi.org/10.1097/NNA.0b013e3181b9228f>
- Consortium Projet RISC. (2017). *Projet RISC. Résilience Immobilière Solidaire et Concertée*.
- Corre, L., Dandin, P., L'Hôte, D., & Besson, F. (2015). The VIADUC project: innovation in climate

- adaptation through service design. *Advances in Science and Research*, 12(1), 199–205.
<http://doi.org/10.5194/asr-12-199-2015>
- Cour des comptes. (2008). *Le réseau ferroviaire : une réforme inachevée, une stratégie incertaine*.
- Cour des Comptes. (2017). *L'Etat Actionnaire: Rapport public thématique*.
- Coutard, O. (2002). *Governance of Large Technical Systems*. (O. Coutard, Ed.). Routledge.
- Couture, M. (2003). La recherche qualitative : introduction à la théorisation ancrée. *Interactions*, 7(2), 127–133.
- Crozet, Y. (2004). Calcul économique et démocratie: des certitudes technocratiques au tâtonnement politique. *Cahiers d'économie Politique*, 2(47), 155–172.
<http://doi.org/10.3917/cep.047.0155>
- Crozet, Y. (2017). Where high-speed rail is relevant. The French case study. In B. L. P. Henríquez & E. Deakin (Eds.), *High-Speed Rail and Sustainability* (pp. 66–81). Routledge.
- da Cunha, C., & Vanderlinden, J.-P. (2014). Adaptation aux changements globaux. Quel apport de la transdisciplinarité ?, (1), 277–282.
- Dahan, A., & Guillemot, H. (2015). Les relations entre science et politique dans le régime climatique : à la recherche d'un nouveau modèle d'expertise ? *Natures Sciences Sociétés*, 23, S6–S18. <http://doi.org/10.1051/nss/2015014>
- Damas, J., Gazeau, B., Lucas, V., Putallaz, Y., Ramette, Y., & Thauvette, A. (2017). *À la reconquête de la robustesse des services ferroviaires*.
- Dankel, D. J., Vaage, N. S., & Van der Sluijs, J. P. (2017). Post-Normal science in practice. *Futures*, 91(May), 1–4. <http://doi.org/10.1016/j.futures.2017.05.009>
- Daudier, M. (2017). 14ème Forum international de la météo et du climat : un colloque « Adaptation des infrastructures et des réseaux aux changements climatiques ». *La Météorologie*, (98), 14–20.
- David Tàbara, J., Frantzeskaki, N., Hölscher, K., Pedde, S., Kok, K., Lamperti, F., ... Berry, P. (2018). Positive tipping points in a rapidly warming world. *Current Opinion in*

Environmental Sustainability, 31, 120–129.
<http://doi.org/10.1016/J.COSUST.2018.01.012>

de Haan, F. J., Rogers, B. C., Brown, R. R., & Deletic, A. (2016). Many roads to Rome: The emergence of pathways from patterns of change through exploratory modelling of sustainability transitions. *Environmental Modelling and Software*, 85, 279–292.
<http://doi.org/10.1016/j.envsoft.2016.05.019>

De Jouvenel H. (2004). Invitation à la prospective. *Futuribles*, 90.

de Perthuis, C., Hallegatte, S., & Lecocq, F. (2010). *Economie de l'adaptation au changement climatique*.

de Sardan, O. (1995). La politique du terrain. *Enquête*, (1), 71–109.
<http://doi.org/10.4000/enquete.263>

DEFRA. (2013). The economics of climate resilience Buildings and infrastructures theme : strategic Road and rail.

Dehornoy, J. (2011). La politique des transports suit-elle les recommandations des économistes ? *Tracés*, (#11), 199–211. <http://doi.org/10.4000/traces.5331>

Dépoues, V. (2016). *Modernisation du système ferroviaire français et changement climatique Oser penser des transformations profondes pour des réseaux robustes et adaptés*. Paris.

Dépoues, V. (2017a). “Adaptation des réseaux aux changements climatiques : comment poser la question ?” : contribution au Colloque du 14e Forum International de la Météo et du Climat.

Dépoues, V. (2017b). ECCA 2017. (Session 11). 9.2 Energy and Transport Infrastructure under Climate Change: Adaptation, Mitigation and Resilience. “Adaptation of the French railway system: climate change as a strategic driver of decision making?” Glasgow.

Dépoues, V. (2017c). Organisational uptake of scientific information about climate change by infrastructure managers: the case of adaptation of the French railway company. *Climatic Change*, 143(3–4), 473–486. <http://doi.org/10.1007/s10584-017-2016-y>

Dépoues, V. (2019). Ce que peut nous apprendre le cas de la gestion de la végétation sur l'adaptation au changement climatique pour SNCF. *Revue Générale Des Chemins de Fer*,

(to be pub.

- Dépoues, V., Giguët, S., Jézéquel, A., & Quilcaille, Y. (2015). Témoignage de quatre étudiants engagés pour la réussite de la COP 21. *Natures Sciences Sociétés*, 23, S122–S125. <http://doi.org/10.1051/nss/2015024>
- Dépoues, V., Granger, F., & Leguet, B. (2018). *Se situer dans la transition énergétique : un impératif pour toutes les entreprises. Une démarche co-construite avec la Compagnie des Alpes*.
- Dépoues, V., & Hainaut, H. (2018). Infrastructures de transport et objectifs climatiques. *TEC*, (236), 52–53. http://doi.org/10.3726/92136_388
- Dépoues, V., & Masera, C. (2013). Devenons médiateurs du savoir. *L'Éléphant*. Paris.
- Dépoues, V., Vanderlinden, J.-P., & Venturini, T. (2018). *Entre dire et faire : discours scientifique sur le changement climatique et adaptation du système ferroviaire français (pending)*.
- Dépoues, V., Vanderlinden, J.-P., Venturini, T., & Jézéquel, A. (2018). An experimental workshop to question the implications of an increase in extreme weather events frequency on the organization of French railways system (pending), 1–18.
- der Vleuten, E. (2004). Infrastructures and societal change: a view from the large technical systems field. *Technology Analysis & Strategic Management*, 16(3), 395–414.
- Dessai, S., & Hulme, M. (2004). Does climate adaptation policy need probabilities? *Climate Policy*, 4(January 2013), 107–128. <http://doi.org/10.1080/14693062.2004.9685515>
- Dessai, S., Hulme, M., Lempert, R. J., Pielke, R., Dessai, S., & Hulme, M. (2009). Climate prediction: a limit to adaptation. Adapting to climate change: thresholds, values, governance. In *Adapting to climate change: thresholds, values, governance*. (pp. 64–78). <http://doi.org/http://dx.doi.org/10.1017/CBO9780511596667.006>
- Dessai, S., & Van der Sluijs, J. P. (2007). *Uncertainty and Climate Change Adaptation - a Scoping Study*. *Sustainable Development*.
- Dewey, J. (1940). Logic: The Theory of Inquiry. *The Philosophical Review*, 49(2), 259. <http://doi.org/10.2307/2180803>

- DHL. (2012). *Delivering Tomorrow. Logistics 2050 A Scenario Study*.
- Diemer, A. (2004). Et si l'économie était bien une science morale! In Arnaud Diemer (dir) (Ed.), *Enseigner l'économie* (p. 348). Paris: L'Harmattan.
- DirMed. (2017). Analyse de risque réseau DIR Med. In J.-P. LEGRAND (Ed.), *Séminaire DGITM « Adaptation des infrastructures et réseaux de transport au changement climatique »*.
- Dittrich, R., Wreford, A., & Moran, D. (2016). A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward? *Ecological Economics*. <http://doi.org/10.1016/j.ecolecon.2015.12.006>
- Dobbs, R., Pohl, H., Lin, D.-Y., Mischke, J., Mischke, N., Hexter, J., ... Nanavatty, R. (2013). Infrastructure productivity: How to save \$1 trillion a year.
- Dobney, K., Baker, C. J., Quinn, A., & Chapman, L. (2009). Quantifying the effects of high summer temperatures due to climate change on buckling and rail related delays in south-east United Kingdom. *Meteorological Applications*, 16(2), 245–251. <http://doi.org/10.1002/met.114>
- Doganova, L. (2014). Décompter le futur. *Sociétés Contemporaines*, 93(1), 67. <http://doi.org/10.3917/soco.093.0067>
- Doll, C., Trinks, C., Sedlacek, N., Pelikan, V., Comes, T., & Schultmann, F. (2014). Adapting rail and road networks to weather extremes: case studies for southern Germany and Austria, 72(1), 63–85. <http://doi.org/10.1007/s11069-013-0969-3>
- Dubost, C. (2017). SNCF: face to face with climate change. In B. Laville, A. Euzen, & S. Thiébault (Eds.), *Adapting to Climate Change: a question for our societies* (CNRS Editi).
- Dubuisson, M. B. and L. T. and J. B. and S. S. and A. A. and A.-L. G. and B. (2017). Future summer mega-heatwave and record-breaking temperatures in a warmer France climate. *Environmental Research Letters*, 12(7), 74025. <http://doi.org/10.1088/1748-9326/aa751c>
- Duit, A., & Galaz, V. (2008). Governance and Complexity—Emerging Issues for Governance Theory. *Governance*, 21(3), 311–335. <http://doi.org/10.1111/j.1468-0491.2008.00402.x>
- Dumez, H. (2009). Identité, performance et pérennité organisationnelle. *Revue Française de*

- Gestion*, 35(192), 91–94. <http://doi.org/10.3166/rfg.192.91-94>
- Durance, P. (2014). *La Prospective stratégique en action* (Odile Jaco).
- Durance, P., & Monti, R. (2017). *Le Long Terme comme horizon : Système d'anticipation et métamorphose des organisations* (Odile Jaco). Paris.
- EBRD. (2018). *Advancing TCFD Guidance on Physical Climate Risks and Opportunities*.
- Econadapt Consortium. (2015). The Costs and Benefits of Adaptation: Results from the ECONADAPT project.
- Edwards, P. N. (2003). Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems. In *Modernity and technology*, 1. (pp. 185–226). <http://doi.org/0262633108>
- Edwards, P. N. (2010). *A vast machine: Computer models, climate data, and the politics of global warming*. Mit Press.
- Eisenack, K., Moser, S. C., Hoffmann, E., Klein, R., Oberlack, C., Pechan, A., ... Termeer, C. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change*, 4(10), 867–872. <http://doi.org/10.1038/nclimate2350>
- Eisenack, K., & Paschen, M. (2016). Adapting long-lived infrastructure to uncertain and transient change, 1–19.
- Eisenack, K., & Stecker, R. (2012). A framework for analyzing climate change adaptations as actions. *Mitigation and Adaptation Strategies for Global Change*, 17(3), 243–260. <http://doi.org/10.1007/s11027-011-9323-9>
- Engle, N. L. (2011). Adaptive capacity and its assessment. *Global Environmental Change*, 21(2), 647–656. <http://doi.org/10.1016/j.gloenvcha.2011.01.019>
- EPE, & ONERC. (2014). *Les entreprises et l'adaptation au changement climatique*.
- Etner, F. (1987). *Histoire du calcul économique en France*. (Economica, Ed.).
- Eurocontrol. (2014). Adapting Aviation to a Changing Climate Key Climate Change Risks for Aviation.
- European Commission : CORDIS. (2010). *Final Report Summary - MACOSPOL (Mapping*

controversies on science for politics).

European Commission. (2011). *Guidelines for Project Managers: Making vulnerable investments climate resilient.*

European Commission. (2012). *Methodologies for climate proofing investments and measures under cohesion and regional policy and the common agricultural policy.*

European Commission. (2013a). *Adapting infrastructures to climate change.*

European Commission. (2013b). *The EU Strategy on adaptation to climate change.*

European Commission. (2014). *Climate Change and Major Projects.*

European Commission. (2015). *Resilience of large investments and critical infrastructures in Europe to climate change.* (G. Forzieri, B. Alessandra, M. A. Marin Herrera, F. Batista e Silva, C. Lavallo, & L. Feyen, Eds.). JRC. <http://doi.org/10.2788/232049>

European Environment Agency. (2014). *Adaptation of transport to climate change in Europe: challenges and options across transport modes and stakeholders.*

European Environment Agency. (2017a). *Climate change, impacts and vulnerability in Europe 2016.*

European Environment Agency. (2017b). *Climate change adaptation and disaster risk reduction in Europe. Enhancing coherence of the knowledge base, policies and practices.* <http://doi.org/10.1007/s13398-014-0173-7.2>

Felt, U., Fouché, R., Miller, C., & Smith-Doerr, L. (2016). *The handbook of science and technology studies.*

Ferranti, E., Chapman, L., Lee, S., Jaroszweski, D., & Lowe, C. (2017). The hottest July day on the railway network : insights and thoughts. <http://doi.org/10.1002/met.1681>

Figuière, C., Boidin, B., & Diemer, A. (2018). *Économie politique du développement durable.* DE BOECK SUP.

Finez, J. (2013a). Aux origines de la préoccupation marchande à la SNCF (1960-2011). *La Nouvelle Revue Du Travail*, 2.

Finez, J. (2013b). Les économistes font-ils l'économie ferroviaire ? *Revue Française de Socio-*

Économie, 11(1), 15. <http://doi.org/10.3917/rfse.011.0015>

Finez, J., & Quessette, L. (2018). Faut-il libéraliser la SNCF ? *La Vie Des Idées*, 11–13.

Fischer, E. M., & Schär, C. (2009). Future changes in daily summer temperature variability: Driving processes and role for temperature extremes. *Climate Dynamics*, 33(7–8), 917–935. <http://doi.org/10.1007/s00382-008-0473-8>

Fitoussi, J.-P., & Laurent, E. (2008). *La nouvelle écologie politique : économie et développement humain*. Seuil.

Flagg, J. A., & Kirchhoff, C. (2018). Context matters: Context-related drivers of and barriers to climate information use. *Climate Risk Management*, (September 2017), 1–10. <http://doi.org/10.1016/j.crm.2018.01.003>

FNAUT-Mobilettre. (2016). *Actes du colloque « Rail 2020 »*. PARIS.

Folke, C., Carpenter R, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *Ambio*, 31(5), 437–40.

Ford, J. D., & King, D. (2015). A framework for examining adaptation readiness. *Mitigation and Adaptation Strategies for Global Change*, 20(4), 505–526. <http://doi.org/10.1007/s11027-013-9505-8>

Fourniau, J.-M. (1997). TGV : du programme de recherche au grand projet industriel.

Fourniau, J.-M. (2011). La politique des grandes vitesses en France : la trajectoire d'un grand projet à l'épreuve du territoire.

France Stratégie. (2014). L'évaluation socio-économique des projets de transport. *Actes Du Colloque*.

France Stratégie. (2016). L'évaluation socioéconomique des risques naturels et sanitaires. In *L'évaluation socioéconomique des investissements publics*.

Friese, S. (2015). ATLAS.ti for Mac - User Manual, 1–11. <http://doi.org/10.13140/RG.2.1.3512.6640>

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures*, 25(7), 739–

755. [http://doi.org/10.1016/0016-3287\(93\)90022-L](http://doi.org/10.1016/0016-3287(93)90022-L)
- Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*, 16(3), 293–303. <http://doi.org/10.1016/j.gloenvcha.2006.02.004>
- Gawel, E., Lehmann, P., Strunz, S., & Heuson, C. (2016). Public Choice barriers to efficient climate adaptation – theoretical insights and lessons learned from German flood disasters. *Journal of Institutional Economics*, 1–27. <http://doi.org/10.1017/S1744137416000163>
- Geertz, C. (1994). Thick Description: toward an interpretive theory of culture. *Readings in the Philosophy of Social Science*, 21.
- Gersonius, B., Ashley, R., Pathirana, A., & Zevenbergen, C. (2013). Climate change uncertainty: building flexibility into water and flood risk infrastructure. *Climatic Change*, 116(2), 411–423. <http://doi.org/10.1007/s10584-012-0494-5>
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: the dynamics of science and research in contemporary societies* (Sage).
- GICC. (2012). *Rapport final SAO POLO*.
- Girard, C., Pulido-Velazquez, M., Rinaudo, J.-D., Pagé, C., & Caballero, Y. (2015). Integrating top–down and bottom–up approaches to design global change adaptation at the river basin scale. *Global Environmental Change*, 34, 132–146. <http://doi.org/10.1016/j.gloenvcha.2015.07.002>
- Glaser, B. G., & Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research. Observations* (Vol. 1). <http://doi.org/10.2307/2575405>
- Godard, O. (2004a). Autour des conflits à dimension environnementale Évaluation économique et coordination dans un monde complexe. *Les Cahiers d'économie Politique*, 47("Les économistes et la démocratie-qu'à-t-on appris depuis schumpeter?"), 127–153.
- Godard, O. (2004b). De la pluralité des ordres - Les problèmes d'environnement et de développement durable à la lumière de la théorie de la justification. *Geographie*

- Economie Societe*, 6(3), 303–330. <http://doi.org/10.3166/ges.6.303-330>
- Godard, O. (2010). Cette ambiguë adaptation au changement climatique. *Natures Sciences Société*, 18(3), 287–297.
- Godard, O., Henry, C., Lagadec, P., & Michel-Kerjan, E. (2002). *Traité des nouveaux risques* (Gallimard).
- Godet, M. (2007). *Manuel de prospective stratégique* (Dunod).
- Gollier, C., Baumstark, L., Fery, P., Auverlot, D., Raynard, C., Fery, P., ... Raynard, C. (2011). *Le calcul du risque dans les investissements publics*.
- Gonzva, M., & Gautier, P. E. (2014). Résilience des systèmes de transport guidé: du risque de vents traversiers vers le risque hydrologique. In *2nd international symposium railway geotechnical engineering-GEORAIL* (pp. 407–416).
- Gras, A. (1993). *Les macro-systèmes techniques. Que sais-je ?* Presses universitaires de France.
- Gregori, P. (2017). Climate Change Transport Benchmark (unpublished work).
- Gueguen, H., Jarrige, F. *, Le Courant, S., & Paloque-Berges, C. (2017). Appel à contributions (n° 35) : Infrastructures – Tracés. *Revue de sciences humaines*.
- Guellec, D. (2009). *Économie de l'innovation*. Éditions La Découverte.
- Guesnerie, R. (2001). Leçon inaugurale au collège de France. L'Etat et le marché : constructions savantes et pensée spontanée. *Revue d'économie Politique*, 111(6), 797–814.
- Guibert, R. (1970). *la S.N.C.F cette inconnue* (Revue TRAN).
- Guibert, R. (2008). Le service de la recherche de SNCF vu par Roget Guibert. *Revue d'histoire Des Chemins de Fer*, (39), 33–43.
- Guillemot, H. (2007). Les modèles numériques du climat. In La Découverte. (Ed.), *Les modèles du futur* (pp. 91–112). La Découverte.
- Guivarch, C. (2017). *Incertitudes et inerties au cœur de la question climatique : Explorations numériques en économie du changement climatique*. Université Paris-Est.

- Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., ... Bergsma, E. (2010). The Adaptive Capacity Wheel: A method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science and Policy*, 13(6), 459–471. <http://doi.org/10.1016/j.envsci.2010.05.006>
- Haas, A. (2015). Crowding at the frontier: boundary spanners, gatekeepers and knowledge brokers. *Journal of Knowledge Management*, 19(5), 1029–1047. <http://doi.org/10.1108/JKM-01-2015-0036>
- Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, 23(2), 485–498. <http://doi.org/10.1016/j.gloenvcha.2012.12.006>
- Hackett, E. J., Amsterdamska, O., Lynch, M., & Wacjman, J. (2008). *The Handbook of Science and Technology Studies*.
- Hallegatte, S. (2006). A Cost-Benefit Analysis of the New Orleans Flood Protection System. *Post-Print*, 12975(12975), 1–18.
- Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change, 19(2), 240–247.
- Hallegatte, S., Shah, A., Brown, C., Lempert, R. J., & Gill, S. (2012). Investment Decision Making Under Deep Uncertainty: Application to Climate Change. *Policy Research Working Paper*, (6193), 41. <http://doi.org/doi:10.1596/1813-9450-6193>
- Hatchuel, A., & Moisdon, J.-C. (1997). Modèles d'aide à la décision ou modèles d'organisation ? le cas de la théorie de la décision et des investissements pétroliers. In Seli Arslan (Ed.), *Du mode d'existence des outils de gestion* (Seli Arslan, p. 286). PARIS.
- Hawkins, E., & Sutton, R. (2009). The Potential to Narrow Uncertainty in Regional Climate Predictions.
- Hazeleger, W., van den Hurk, B. J. J. M., Min, E., van Oldenborgh, G.-J., Petersen, A. C., Stainforth, D. A., ... Smith, L. A. (2015). Tales of future weather. *Nature Climate Change*, 5(2), 107–113. <http://doi.org/10.1038/nclimate2450>
- Henry, C. (2013). Incertitude scientifique et incertitude fabriquée, 64(4), 589–598.
- Herpin, N. (2010). Barney G. Glaser, Anselm Strauss, La découverte de la théorie ancrée.

Stratégies pour la recherche qualitative. *Lectures*.

- Herring, S. C., Christidis, N., Hoell, A., Kossin, J. P., Schreck III, C. J., & Stott, P. A. (2018). Explaining Extreme Events of 2016 From a Climate Perspective. *Special Supplement to the Bulletin of the American Meteorological Society*, 99(1), 166.
- Hess, D. (2001). Ethnography and the Development of Science and Technology Studies. In P. Atkinson, A. Coffey, S. Delamont, J. Lofland, & L. Lofland (Eds.), *Handbook of Ethnography*.
- Hollesen, J., Matthiesen, H., Møller, A. B., & Elberling, B. (2015). Permafrost thawing in organic Arctic soils accelerated by ground heat production. *Nature Climate Change*, 5(6), 574–578. <http://doi.org/10.1038/nclimate2590>
- Hughes, T. P. (1993). *Networks of power, Electrification in Western Society 1880-1930* (JHU Press).
- Huiteima, D., Adger, N., Berkhout, F., Massey, E., Mazmanian, D., Munaretto, S., ... Termeer, C. (2016). The governance of adaptation: Choices, reasons, and effects. Introduction to the special feature. *Ecology and Society*, 21(3). <http://doi.org/10.5751/ES-08797-210337>
- Hulme, M. (2009). *Why We Disagree about Climate Change* (Cambridge). Cambridge. <http://doi.org/10.1017/CBO9780511841200>
- I4CE. (2018). *COP23 : The Paris Agreement warms up before the big 2018 game*.
- IFT Research Reports, & OECD. (2016). *Adapting Transport to Climate Change and Extreme Weather: Implications for Infrastructure Owners and Network Managers*. Paris. <http://doi.org/10.1787/9789282108079-en>
- Ingénieurs Canada. (2011). Protocole d'ingénierie du CVIIP pour l'évaluation de la vulnérabilité des infrastructures et l'adaptation au changement climatique.
- IPCC. Climate Change 2013 & 2014: Contributions of the working groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014).
- IPCC. (2014b). Climate Change 2014 Synthesis Report Summary Chapter for Policymakers. *Ippc*, 31. <http://doi.org/10.1017/CBO9781107415324>

- IPCC. (2014c). Working Group II Contribution to the IPCC Fifth Assessment Report, Climate Change 2014: Impacts, Adaptation and Vulnerability. *Ipcc, AR5(2014)*.
- Isoard, S., & Prutsh, A. (2014). *National adaptation policy processes in European countries*.
- Jacques, G. (2016). Les épisodes cévenols : Un aperçu historique. *La Météorologie*, 8(93), 50. <http://doi.org/10.4267/2042/59941>
- Jacquet, P., Pachauri, R. K., & Tubiana, L. (2009). *Regards sur la Terre 2009 : La gouvernance du développement durable*. Presses de Sciences po.
- Jaroszweski, D., Baker, C., Chapman, L., & Quinn, A. (2013). The impact of cc on transports: current progress and future requirements.
- Jaroszweski, D., Chapman, L., & Petts, J. (2010). Assessing the potential impact of climate change on transportation: the need for an interdisciplinary approach. *Journal of Transport Geography*, 18, 331–335.
- Jaroszweski, D., Quinn, A., Baker, C., Hooper, E., Kochsiek, J., Schultz, S., & Silla, A. (2014). *Guidebook for Enhancing Resilience of European Rail Transport in Extreme Weather Events (MOWE-IT Project)*.
- Jasanoff, S. (editor). (2004). *States of Knowledge: the Co- Production of Science and Social Order*. Routledge.
- Jézéquel, A., Cattiaux, J., Naveau, P., Radanovics, S., Ribes, A., Vautard, R., ... Yiou, P. (2018). Trends of atmospheric circulation during singular hot days in Europe. *Environmental Research Letters*, 13. <http://doi.org/10.1088/1748-9326/aab5da>
- Jézéquel, A., Dépoues, V., Guillemot, H., Trolliet, M., Vanderlinden, J.-P., & Yiou, P. (2017). *Behind the veil of extreme event attribution*.
- Jiricka, A., Formayer, H., Schmidt, A., Völler, S., Leitner, M., Fischer, T. B., & Wachter, T. F. (2016). Consideration of climate change impacts and adaptation in EIA practice - Perspectives of actors in Austria and Germany. *Environmental Impact Assessment Review*, 57, 78–88. <http://doi.org/10.1016/j.eiar.2015.11.010>
- Jitex. (2011). Monographie - Adaptation au changement climatique.

- Jollivet, M. (1992). *Sciences de la nature, sciences de la société*. (M. Jollivet, Ed.). CNRS Éditions. <http://doi.org/10.4000/books.editions-cnrs.4154>
- Jon Barnett, Saffron O'Neill, Barnett, J., & O'Neill, S. (2010). Maladaptation. *Global Environmental Change*, 20(2), 211–213.
- Jonas, H. (1992). *Le Principe responsabilité : une éthique pour la civilisation technologique*. Passages (Éditions du Cerf) (Vol. 2^e). Flammarion. http://doi.org/EB_AA_JONA/P
- Jouzel, J., Ouzeau, G., Déqué, M., Jouini, M., Planton, S., & Vautard, R. (2014). *Le climat de la France au 21^{ème} siècle. Volume 4 - Scénarios régionalisés*.
- Jouzel, J., Planton, S., Cazenave, A., Douez, O., Laborie, V., Petit, V., & Sergent, P. (2015). *Le climat de la France au 21^{ème} siècle. Volume 5 - Changement climatique et niveau de la mer : de la planète aux côtes françaises* (Vol. 5). Paris: Direction de l'information légale et administrative.
- Jude, S. R., Drew, G. H., Pollard, S. J. T., Rocks, S. A., Jenkinson, K., & Lamb, R. (2017). Delivering organisational adaptation through legislative mechanisms: Evidence from the Adaptation Reporting Power (Climate Change Act 2008). *Science of the Total Environment*, 574, 858–871. <http://doi.org/10.1016/j.scitotenv.2016.09.104>
- Kane, I. O., & Vanderlinden, J.-P. (2015). L'utilisation du concept polysémique de résilience : une analyse empirique en zone côtière. *Vertigo*, (Hors-série 23). <http://doi.org/10.4000/vertigo.16661>
- Kane, I. O., Vanderlinden, J.-P., Baztan, J., Touili, N., & Claus, S. (2014). Communicating risk through a DSS: A coastal risk centred empirical analysis. *Coastal Engineering*, 87, 240–248. <http://doi.org/10.1016/j.coastaleng.2014.01.007>
- Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, 109(19), 7156–7161. <http://doi.org/10.1073/pnas.1115521109>
- Kellermann, P., Bubeck, P., Kundela, G., Dosio, A., & Thielen, A. (2016). Frequency Analysis of Critical Meteorological Conditions in a Changing Climate—Assessing Future Implications for Railway Transportation in Austria. *Climate*, 4(2), 25.

<http://doi.org/10.3390/cli4020025>

Kiel, J., Petiet, P., Nieuwenhuis, A., Peters, T., & Van Ruiten, K. (2016). A Decision Support System for the Resilience of Critical Transport Infrastructure to Extreme Weather Events. *Transportation Research Procedia*, 14, 68–77.

<http://doi.org/10.1016/j.trpro.2016.05.042>

Kiem, A. S., & Austin, E. K. (2013). Disconnect between science and end-users as a barrier to climate change adaptation. *Climate Research*, 58(1), 29–41.

<http://doi.org/10.3354/cr01181>

Kirchhoff, C., Carmen Lemos, M., & Dessai, S. (2013). Actionable knowledge for environmental decision making: broadening the usability of climate science, 38(1), 393–414.

<http://doi.org/10.1146/annurev-environ-022112-112828>

Klein, J., Juhola, S., & Landauer, M. (2017). Local authorities and the engagement of private actors in climate change adaptation. *Environment and Planning C: Politics and Space*, 35(6), 1055–1074. <http://doi.org/10.1177/0263774X16680819>

Kønig, N., Børsen, T., & Emmeche, C. (2017). The ethos of post-normal science. *Futures*, 91, 12–24. <http://doi.org/10.1016/j.futures.2016.12.004>

Krauss, W., Schäfer, M. S., & von Storch, H. (2012). Post-Normal Climate Science. *Nature and Culture*, 7(2), 121–132. <http://doi.org/10.3167/nc.2012.070201>

Kwakkel, J. H., Walker, W. E., & Marchau, V. A. (2010). Adaptive Airport Strategic Planning. *European Journal of Transport and Infrastructure Research*, 10(3), 249–273.

Kwiatkowski, K. P., & Chinowsky, P. (2017). Climate change adaptation as an organizational system in transportation infrastructure organizations: Identifying processes and institutional elements. *Transport Policy*, 60, 47–53. <http://doi.org/10.1016/j.tranpol.2017.08.006>

Lagadec, P. (1981). *Le risque technologique majeur : politique, risque, et processus de développement*.

Lagadec, P. (2015). *Le Continent des imprévus – Journal de bord des temps chaotiques*. Manitoba.

- Laroche, F. (2018). *Dix ans après la libéralisation du marché européen de fret ferroviaire : quel bilan et quels enseignements pour la France.*
- Laroche, H. (2006). La production d'intelligibilité dans les rapports officiels : le cas de la canicule.
- Laroche, H., & Nioche, J.-P. (2015). L'approche cognitive de la stratégie d'entreprise. *Revue Française de Gestion*, 41(253), 97–120. <http://doi.org/10.3166/RFG.160.81-108>
- Lascoumes, P., & Simard, L. (2011). L'action publique au prisme de ses instruments. *Revue Française de Science Politique*, 61(1), 5. <http://doi.org/10.3917/rfsp.611.0005>
- Latour, B. (1987). Les "vues" de l'esprit. *Réseaux*, 5, 79–96. <http://doi.org/10.3406/reso.1987.1322>
- Latour, B. (1993). Le « pédofil » de Boa Vista – montage photo-philosophique. *Petites Leçons de Sociologie Des Sciences*, 171–225.
- Latour, B. (1995). Moderniser ou écologiser: A la recherche de la "Septieme" Cité. *Ecologie Politique.*
- Latour, B. (1999). *Politiques de la nature. Comment faire entrer les sciences en démocratie.* *Revue française de sociologie* (Vol. 41).
- Latour, B. (2005). *Reassembling the social : an introduction to actor-network-theory.* Oxford University Press.
- Latour, B. (2006). *Reassembling the Social. Politica y Sociedad* (Vol. 43). <http://doi.org/10.1163/156913308X336453>
- Latour, B. (2010). An Attempt at a "Compositionist Manifesto". *New Literary History*, 41(3), 471–490. <http://doi.org/10.1353/nlh.2010.0022>
- Latour, B. (2013). *An inquiry into modes of existence : an anthropology of the moderns.* Harvard University Press.
- Latour, B. (2015). *Face à Gaïa : huit conférences sur le nouveau régime climatique.* La Découverte.
- Latour, B., & Lepinay, V. A. (2009). *The Science of Passionate Interests : An Introduction to*

- Gabriel Tarde ' s Economic Anthropology. Psychologie Schweizerische Zeitschrift Für Psychologie Und Ihre Anwendungen. Prickly Paradigm Press.*
- Latour, B., & Woolgar, S. (1988). *La Vie de laboratoire. La production des faits scientifiques*. La Découverte.
- Latzko-Toth, G. (2009). *L'étude de cas en sociologie des sciences et des techniques. Notes de recherche du CIRST*.
- Law, J. (1992). Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity. *Systems Practice*, 5(4), 379–393. <http://doi.org/10.1007/BF01059830>
- Law, J., & Urry, J. (2004). Enacting the Social. *Economy and Society*, 33(3), 390–410. <http://doi.org/10.1080/0308514042000225716>
- Le Maître, H. (2015). *Méthodes de prise en compte du risque dans le calcul socio-économique Méthode et application*.
- Le Moigne, J.-L. (2007). *Les épistémologies constructivistes* (PUF). PUF.
- Leguet, B., & Dépoues, V. (2018). Grands projets d' infrastructure : rendre systématiquement compte de la prise en compte du climat. *VARIANCES*.
- Lejeune, C. (2014). *Manuel d'analyse qualitative Analyser sans compter ni classer*. De Boeck Supérieur.
- Lempert, R. J., Nakicenovic, N., Sarewitz, D., & Schesinger, M. (2004). Characterizing climate-change uncertainties for decision-makers, 65(1), 1–9.
- Lepousez, V. (2018). Gérer les impacts du changement climatique sur les infrastructures : exemple des aéroports en période de fortes chaleurs. Paris: Carbone 4.
- Leseur, A. (2015). *Quels mécanismes de financement innovant pour les mesures d'adaptation aux impacts du changement climatique dans les pays développés ? Premier tour d'horizon des principales possibilités*.
- Lesourne, J. (1966). *Du bon usage de l'étude économique dans l'entreprise* (Dunod).
- Lesourne, J. (2001). Snf : les aiguillages du changement. In J. Lesourne (Ed.), *Prospective stratégique d'entreprise* (Dunot, p. 424).

- Lewis, J., & Ritchie, J. (2003). Generalising from Qualitative Research. In *Qualitative Research Practice: A Guide for Social Science Students and Researchers* (p. 336). <http://doi.org/March 10, 2016>
- Lincoln, Y. S., & Guba, E. G. (2004). The Only Generalization Is: There Is No Generalization. In R. Gomm, M. Hammersley, & P. Foster (Eds.), *Case Study Method* (pp. 27–44). SAGE Publications. <http://doi.org/10.4135/9780857024367.d6>
- Lindgren, J., Johnsson, D. K., & Carlsson-Kanyama, A. (2009). Climate adaptation of railways: lessons from Sweden, *9*(2), 164–181.
- Lippmann, W., & Latour, B. (2008). *Le public fantôme*. Demopolis.
- Lolive, J. (1999). *Les contestations du TGV Méditerranée: Projet, controverse et espace public*.
- Lonsdale, K., Pringle, P., & Turner, B. (2015). *Transformational adaptation: what it is, why it matters and what is needed*. UK Climate Impacts Programme. UK Climate Impacts Programme.
- Lorino, P. (2014). Philippe Lorino Une formation à l' enquête, 47–54.
- Love, G., Soares, A., & Püempel, H. (2010). Climate change, climate variability and transportation. *Procedia Environmental Sciences*, *1*, 130–145.
- MacKenzie, D. (1992). Economic and Sociological Explanations of Technological Change. In R. Coombs, P. Saviiotti, & V. Walsh (Eds.), *Technological Change and Company Strategies: Economic and Sociological Perspectives* (pp. 25–48). London: Academic Pres.
- Magnan, A. (2010). Questions de recherche autour de l'adaptation au changement climatique. *Natures Sciences Sociétés*, *18*(3), 329–333. <http://doi.org/10.1051/nss/2010041>
- Magnan, A., Schipper, E. L. F., Burkett, M., Bharwani, S., Burton, I., Eriksen, S., ... Ziervogel. (2016). Addressing the risk of maladaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *7*(5), 646–665.
- Malekpour, S., Brown, R. R., de Haan, F. J., & Wong, T. H. F. (2017). Preparing for disruptions: A diagnostic strategic planning intervention for sustainable development. *Cities*, *63*, 58–69. <http://doi.org/10.1016/j.cities.2016.12.016>

- Malekpour, S., de Haan, F. J., & Brown, R. R. (2016). A methodology to enable exploratory thinking in strategic planning. *Technological Forecasting and Social Change*, *105*, 192–202. <http://doi.org/10.1016/j.techfore.2016.01.012>
- Markandya, A., Galarraga, I., & Sainz de Murieta, E. (2014). *Routledge handbook of the economics of climate change adaptation*. (Routledge, Ed.), *Routledge International Handbooks*. Routledge.
- Massé, P. (1965). Le plan ou l'anti-hasard. *Collection Idées*.
- Mattei, G. (2012). Conclusions : Sur le management à l'épreuve de la complexité et du paradoxe ou les avatars du management scientifique et technocratique. *Humanisme et Entreprise*, *307(2)*, 17. <http://doi.org/10.3917/hume.307.0017>
- Mattsson, L. G., & Jenelius, E. (2015). Vulnerability and resilience of transport systems - A discussion of recent research. *Transportation Research Part A: Policy and Practice*, *81*, 16–34. <http://doi.org/10.1016/j.tra.2015.06.002>
- Mayntz, R., & Hughes, T. P. (1988). *The Development of Large Technical Systems*. Campus Verlag.
- Mazoyer, H. (2013). Réformer l'administration par le savoir économique. *Genèses*, *n° 93(4)*, 29–52.
- McNeall, D., Halloran, P. R., Good, P., & Betts, R. A. (2011, September). Analyzing abrupt and nonlinear climate changes and their impacts. *Wiley Interdisciplinary Reviews: Climate Change*. <http://doi.org/10.1002/wcc.130>
- MEDDTL-DGEC. (2011). Plan national d'adaptation au changement climatique : 2011-2015.
- MEDTL. (2011). *Schéma national des infrastructures de transport*.
- Mees, H., Driessen, P., & Runhaar, H. (2012). Who governs climate adaptation adaptation? Exploring the scope for public and private responsibilities. *Journal of Environmental Policy & Planning*, *14(3)*, 305–330.
- Ménard, C. (2018). ORGANISATION, économie.
- Meyer, M. D., Amekudzi, A., & O'Har, J. P. (2010). Transportation Asset Management Systems

- and Climate Change: An adaptive systems management approach. *Transportation Research Record: Journal of the Transportation Research Board*, (2160), 12–20.
- Michaelides, S., Leviäkangas, P., Doll, C., & Heyndrickx, C. (2014). Foreward: EU-funded projects on extreme and high-impact weather challenging European transport systems. *Natural Hazards*, 72(1), 5–22.
- Mondon, S. (2017). Défis environnementaux émergents: L'adaptation au changement climatique sera-t-elle encore une option pour les sociétés à l'horizon 2030 ? *Prospective et Stratégie*, 8(1), 38–39.
- Morin, E. (1967). De la méthode : une démarche multidimensionnelle. In *Commune en France: la métamorphose de Plodémet* (Fayard, pp. 278–287). Paris.
- Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, 107(51), 22026–22031. <http://doi.org/10.1073/pnas.1007887107>
- Mumford, L., & Winner, L. (2010). *Technics and civilization*. The University of Chicago Press.
- Nassopoulos, H., Salagnac, J.-L., Leseur, A., & Meunier, G. (2014). Projet ADAPTATIO Analyse de projets de recherche portant sur l'adaptation au changement climatique en milieu urbain.
- NCCARF, & RMIT. (2013). *Climate change adaptation guidelines for ports*. <http://doi.org/978-1-921609-83-1>
- Network Rail. (2015). *Climate Change Adaptation Report*.
- Network Rail. (2017). *Network Rail Weather Resilience and Climate Change Adaptation Strategy 2017-2019*.
- NOAA. (2018). *State of the Climate: Global Climate Report for Annual 2017*.
- Nordhaus, W. D. (1994). *Managing the global commons: the economics of climate change*. MIT Press.
- Nowotny, H., Scott, O., & Gibbons, M. (2001). *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Polity.

- O'Brien, K. (2012). Global environmental change II: From adaptation to deliberate transformation. *Progress in Human Geography*, 36(5), 667–676. <http://doi.org/10.1177/0309132511425767>
- O'Brien, K. (2016). Climate change and social transformations: is it time for a quantum leap? *Wiley Interdisciplinary Reviews: Climate Change*, 7(5), 618–626. <http://doi.org/10.1002/wcc.413>
- Oberlack, C., & Eisenack, K. (2018). Archetypical barriers to adapting water governance in river basins to climate change. *Journal of Institutional Economics*, 14(3), 527–555. <http://doi.org/10.1017/S1744137417000509>
- Oberlack, C., & Neumärker, B. (2013). *A Diagnostic Approach to the Institutional Analysis of Climate Adaptation* (Constitutional Economics Network No. No. 01-2013 A). Freiburg.
- OECD. (2015, July). Climate Change Risks and Adaptation: Linking Policy and Economics.
- ONERC. (2011). *Changement climatique : Coûts des impacts et pistes d'adaptation*. La documentation française.
- ONERC. (2018). *Vers un 2e plan d'adaptation au changement climatique pour la France enjeux et recommandations*.
- Opinion Way pour Trainline. (2018). Les Français et l'ouverture à la concurrence du secteur ferroviaire.
- Oslakovic, I. S., ter Maat, H., Hartmann, A., & Dewulf, G. (2012). Climate Change and Infrastructure Performance: Should We Worry About? *Procedia - Social and Behavioral Sciences*, 48, 1775–1784. <http://doi.org/10.1016/J.SBSPRO.2012.06.1152>
- Ostrom, E. (2015). *Governing the commons : the evolution of institutions for collective action*. Cambridge University.
- Ouzeau, G., Soubeyroux, J.-M., Schneider, M., Vautard, R., & Planton, S. (2016). Heat waves analysis over France in present and future climate: Application of a new method on the EURO-CORDEX ensemble. *Climate Services*, 4, 1–12. <http://doi.org/10.1016/J.CLISER.2016.09.002>
- Palin, E. J., Thornton, H. E., Mathison, C. T., McCarthy, R. E., Clark, R. T., & Dora, J. (2013).

- Future projections of temperature-related climate change impacts on the railway network of Great Britain. *Climatic Change*, 120(1–2), 71–93. <http://doi.org/10.1007/s10584-013-0810-8>
- Pams-Capoccioni, C., Coeur, D., Chenier, D., Chazelle, B., Saint-Marc, C., & Lang, M. (2013). Impacts des inondations historiques sur un réseau de transport: exemple des installations et des circulations ferroviaires en France. In *Événements extrêmes d'inondation : de l'étude de l'aléa à la gestion du risque pour les ouvrages hydrauliques*.
- Pams Capoccioni, C., Nivon, D., Amblard, J., De Cesare, G., & Ghilardi, T. (2015). Analyse de risques pour les circulations ferroviaires d'un débordement de drainage sur ligne à grande vitesse (LGV). *La Houille Blanche*, (4), 39–45. <http://doi.org/10.1051/lhb/20150044>
- Pant, R., Hall, J. W. ., & Blainey, S. P. (2016). Vulnerability assessment framework for interdependent critical infrastructures: Case-study for Great Britain's rail network. *European Journal of Transport and Infrastructure Research*, 16(1), 174–194. <http://doi.org/http://dx.doi.org/>
- Paugam, A., Pachauri, R. K., & Tubiana, L. (2015). *Regards sur la Terre 2015 : Une nouvelle coopération internationale pour le développement durable*. Presses de Sciences po.
- Pelling, M., High, C., Dearing, J., & Smith, D. (2008). Shadow spaces for social learning: A relational understanding of adaptive capacity to climate change within organisations. *Environment and Planning A*, 40(4), 867–884. <http://doi.org/10.1068/a39148>
- Pelling, M., O'Brien, K., & Matyas, D. (2015). Adaptation and transformation. *Climatic Change*, 133(1), 113–127. <http://doi.org/10.1007/s10584-014-1303-0>
- Perennes, P. (2014). Les économistes et le secteur ferroviaire : deux siècles d'influence réciproque. *L'Économie Politique*, n° 62(2), 101–112.
- Pestre, D. (2006). *Introduction aux science studies*. La Découverte.
- Petersen, A. C., Cath, A., Hage, M., Kunseler, E., & van der Sluijs, J. P. (2011). Post-normal science in practice at the Netherlands environmental assessment agency. *Science Technology and Human Values*, 36(3), 362–388.

<http://doi.org/10.1177/0162243910385797>

Picon, A. (2001). Imaginaires de l'efficacité, pensée technique et rationalisation., 5, 18–50.

Pilli-Sihvola, K., Nurmi, V., Perrels, A., Harjanne, A., Bösch, P., & Ciari, F. (2016). Innovations in weather services as a crucial building block for climate change adaptation in road transport. *European Journal of Transport and Infrastructure Research*, 16(1), 150–173.

Porter, J., & Dessai, S. (2016). Is co-producing science for adaptation decision-making a risk worth taking?, (263), 1–29.

Porter, J., & Dessai, S. (2017). *Mini-me : Climate scientists ' (mis) perceptions of users and their needs. Working Paper No . 12 SRI PAPERS (Vol. Paper No .)*.

Porter, T. M. (1996). *Trust in numbers: The pursuit of objectivity in science and public life*. Princeton University Press.

Preston, B. L., Mustelin, J., & Maloney, M. C. (2015). Climate adaptation heuristics and the science/policy divide. *Mitigation and Adaptation Strategies for Global Change*, 20(3), 1–31. <http://doi.org/10.1007/s11027-013-9503-x>

Preston, B. L., Westaway, R. M., & Yuen, E. J. (2011). Climate adaptation planning in practice: An evaluation of adaptation plans from three developed nations. *Mitigation and Adaptation Strategies for Global Change*, 16(4), 407–438. <http://doi.org/10.1007/s11027-010-9270-x>

Quesada, B., Vautard, R., Yiou, P., Hirschi, M., & Seneviratne, S. I. (2012). Asymmetric European summer heat predictability from wet and dry southern winters and springs. *Nature Climate Change*, 2(10), 736–741. <http://doi.org/10.1038/nclimate1536>

Quilcaille, Y., Giguët, S., Jézéquel, A., Rajaud, A., Ferron, C., Amat, A., ... Ranché, M. (2015). *(In)certitudes et adaptation au climat futur : le regard des « acteurs de demain*. Paris.

Quinet, E., Baumstark, L., Bonnet, J., Croq, A., Ducos, G., Meunier, D., ... Auverlot, D. (2013). L'évaluation socioéconomique des investissements publics.

Ranger, N. (2011). Adaptation as a Decision Making Under Deep Uncertainty. In I. Linkov & T. S. Bridges (Eds.), *Climate* (pp. 89–122). Springer Netherlands.

- Rasmussen, L. B. (2005). The narrative aspect of scenario building - How story telling may give people a memory of the future. *AI and Society*, 19(3), 229–249. <http://doi.org/10.1007/s00146-005-0337-2>
- Rayner, S. (2012). Uncomfortable knowledge: The social construction of ignorance in science and environmental policy discourses. *Economy and Society*, 41(1), 107–125. <http://doi.org/10.1080/03085147.2011.637335>
- Regniault, F. (2017). *La SNCF Pour les Nuls*. (First, Ed.) (First). Paris: Pour Les Nuls.
- RFF. (2009). *Evaluation des incidences du réchauffement climatique sur l'infrastructure ferroviaire existante entre Montpellier et Perpignan*.
- RFF. (2013). *Le temps de la modernisation : grand plan de modernisation du réseau*.
- Rial, J. A., Pielke, R. A., Beniston, M., Claussen, M., Canadell, J., Cox, P., ... Salas, J. D. (2004). Nonlinearities, feedbacks and critical thresholds within the earth's climate system. *Climatic Change*. <http://doi.org/10.1023/B:CLIM.0000037493.89489.3f>
- Ribeill, G. (2011). Des territoires et de leurs transports : infrastructures et choix techniques à l'épreuve de la longue durée. In *Transports, territoires et société* (Picard, pp. 261–266).
- Richard, E. (2016). *L'adaptation aux changements climatiques Les réponses de l'action publique territoriale*. Rennes: PUR.
- Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning., 4(2), 155–169.
- Rivier, R., & Putallaz, Y. (2005). *Audit sur l'état du réseau ferré national français*.
- Roggero, M. (2013). Shifting Troubles: Decision-Making versus Implementation in Participatory Watershed Governance. *Environmental Policy and Governance*, 23(1), 63–74. <http://doi.org/10.1002/eet.1603>
- Roggero, M., Bisaro, A., & Villamayor-Tomas, S. (2017). Institutions in the climate adaptation literature: a systematic literature review through the lens of the Institutional Analysis and Development framework. *Journal of Institutional Economics*, 1–26. <http://doi.org/10.1017/S1744137417000376>

- Roggero, M., & Thiel, A. (2017). Adapting as usual: integrative and segregative institutions shaping adaptation to climate change in local public administrations. *Journal of Institutional Economics*, 1–22. <http://doi.org/10.1017/S1744137417000418>
- Rotter, M., Hoffmann, E., Pechan, A., & Stecker, R. (2016). Competing priorities: how actors and institutions influence adaptation of the German railway system. *Climatic Change*, 137(3–4), 609–623. <http://doi.org/10.1007/s10584-016-1702-5>
- RSSB. (2016). Tomorrow's Railway and Climate Change Adaptation : Final Report, 150.
- Rudberg, P. M., Wallgren, O., & Swartling, Å. G. (2012). Beyond generic adaptive capacity: Exploring the adaptation space of the water supply and wastewater sector of the Stockholm region, Sweden. *Climatic Change*, 114(3–4), 707–721. <http://doi.org/10.1007/s10584-012-0453-1>
- Rumpala, Y. (2010). Gouverner en pensant systématiquement aux conséquences ? Les implications institutionnelles de l'objectif de « développement durable ». *Vertigo – La Revue En Sciences de l'environnement*, 10(1). <http://doi.org/10.4000/vertigo.9468>
- Russill, C. (2015). Climate change tipping points: origins, precursors, and debates. *Wiley Interdisciplinary Reviews: Climate Change*, 6(4), 427–434. <http://doi.org/10.1002/wcc.344>
- Ryghaug, M., & Solli, J. (2012). The appropriation of the climate change problem among road managers: Fighting in the trenches of the real world. *Climatic Change*, 114(3–4), 427–440. <http://doi.org/10.1007/s10584-012-0449-x>
- Saint-Marc, C. (2013). Approches cartographiques pour une meilleure connaissance des dynamiques spatio-temporelles des risques naturels : application aux risques d'inondation impactant le réseau ferroviaire.
- Saltelli, A., Giampietro, M., Avan, E., Ambientals, T., & Autonoma, U. (2015). The fallacy of evidence based policy Science for policy . Predicaments and doubts. *Futures*, (January), 1–30.
- Sanderson, M. G., Hanlon, H. M., Palin, E. J., Quinn, A., & Clark, R. T. (2016). Analogues for the railway network of Great Britain. *Meteorological Applications*, 23(4), 731–741.

<http://doi.org/10.1002/met.1597>

Sarewitz, D., & Pielke, R. (2007). The neglected heart of science policy: reconciling supply of and demand for science, *10*(1), 6–16.

Savonis, M. J., Potter, J. R., & Snow, C. B. (2014). Continuing Challenges in Transportation Adaptation. *Current Sustainable/Renewable Energy Reports*, 27–34. <http://doi.org/10.1007/s40518-014-0004-7>

Schär, C., Vidale, P. L., Lüthi, D., Frei, C., Häberli, C., Liniger, M. A., & Appenzeller, C. (2004). The role of increasing temperature variability in European summer heatwaves. *Nature*, *427*(6972), 332–336. <http://doi.org/10.1038/nature02300>

Schulz, A., Zia, A., & Koliba, C. (2017). Adapting bridge infrastructure to climate change: institutionalizing resilience in intergovernmental transportation planning processes in the Northeastern USA. *Mitigation and Adaptation Strategies for Global Change*, *22*(1), 175–198. <http://doi.org/10.1007/s11027-015-9672-x>

Sénat. (2016). Audition de M. Guillaume Pepy, Président-directeur général de SNCF Mobilités, et de M. Jacques Rapoport, Président-directeur général de SNCF Réseau.

Serres, M. (2012). *Petite poucette*. le Pommier.

Shukla, J., Hagedorn, R., Miller, M., Palmer, T. N., Hoskins, B., Kinter, J., ... Slingo. (2009). Strategies: revolution in climate prediction is both necessary and possible: a declaration at the world modelling summit for climate prediction., *90*(2), 175–178.

Simonet, G. (2009). Le concept d'adaptation: polysémie interdisciplinaire et implication pour les changements climatiques, *17*(4), 392–401. <http://doi.org/10.1051 / nss / 2009061>

Simonet, G. (2010). The concept of adaptation: Interdisciplinary scope and involvement in climate change. *Sapiens*, *3*(1), 1–14.

Simonet, G. (2011, June 9). *Enjeux et dynamiques de la mise en œuvre de stratégies d'adaptation aux changements climatiques en milieu urbain : les cas de Montréal et Paris*. Paris 10.

Simonet, G. (2015). Une brève histoire de l'adaptation: l'évolution conceptuelle au fil des rapports du {GIEC} (1990-2014), *Sup-3*, 52–64.

- Simonet, G. (2016). De l'ajustement à la transformation : vers un essor de l'adaptation ? *Http://Developpementdurable.Revues.Org*, (Vol. 7, n°2).
- Simonet, G., & Leseur, A. (2015). *Projet ABSTRACT COLURBA - Rapport Final*.
- Sippel, S., Zscheischler, J., & Reichstein, M. (2016). Ecosystem impacts of climate extremes crucially depend on the timing. *Proceedings of the National Academy of Sciences*, 113(21), 5768–5770. <http://doi.org/10.1073/pnas.1605667113>
- Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16(3), 282–292. <http://doi.org/10.1016/j.gloenvcha.2006.03.008>
- Smith, S. (2011). *Environmental Economics: A Very Short Introduction*. <http://doi.org/10.1093/actrade/9780199583584.001.0001>
- SNCF. (2013). *Projet stratégique : Excellence 2020*.
- SNCF. (2015). *Profil 2015*.
- SNCF. (2016a). Communiqué de presse : “SNCF mène le plus grand chantier d'Europe.”
- SNCF. (2016b). *Document de référence : Coordination de la gestion des situations de crise du système ferroviaire. Evolution*.
- SNCF. (2016c). *Profil 2016*.
- SNCF. (2017a). *Incident du 29 Juillet au 1er Août 2017 - Poste d'aguillage de vanves*.
- SNCF. (2017b). *Rapport Innovation & Recherche 2016*.
- SNCF. (2017c). *Rapport RSE Groupe SNCF 2016*.
- SNCF Réseau. (2014). *LNMP : Eau et transparence hydraulique*.
- SNCF Réseau. (2018a). *2018 : Des chantiers exceptionnels sur toute la région occitanie*.
- SNCF Réseau. (2018b). *Un réseau pour demain : rapport d'activité responsable 2017*.
- Soraya Boudia. (2014). Gouverner par les instruments économiques. La trajectoire de l'analyse coût-bénéfice dans l'action publique. In Dominique Pestre (Ed.), *Le gouvernement des technosciences* (La Découverte, pp. 231–259). PARIS: La Découverte.
- Soubeyran, O., & Lolive, J. (2007). *L'émergence des cosmopolitiques*. La Découverte.

- Soubeyroux, J.-M., Schneider, M., & Ouzeau, G. (2015). Recensement des vagues de chaleur en France à différentes échelles spatiales et évolution en contexte de changement climatique. In *XXVIIIe Colloque de l'Association Internationale de Climatologie*, (p. 6). Liège.
- Spinetta, J.-C. (2018). *L'avenir du Transport ferroviaire*.
- Staber, U., & Sydow, J. (2002). Organizational adaptive capacity: A structuration perspective. *Journal of Management Inquiry*. <http://doi.org/10.1177/1056492602238848>
- Stamos, I., Mitsakis, E., Salanova, J. M., & Aifadopoulou, G. (2015). Impact assessment of extreme weather events on transport networks: A data-driven approach. *Transportation Research Part D: Transport and Environment*, 34, 168–178. <http://doi.org/10.1016/j.trd.2014.11.002>
- Star, S. L. (1999). The Ethnography of infrastructure. *The American Behavioral Scientist*, 43(3), 377.
- Stecker, R., Pechan, A., Steinhäuser, M., Rotter, M., Sholl, G., & Eisenack, K. (2011). Why are utilities reluctant to adapt to climate change.
- Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., ... Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences of the United States of America*, 115(33), 8252–8259. <http://doi.org/10.1073/pnas.1810141115>
- Steiner, P. (2011). *La sociologie économique*. La Découverte.
- Stengers, I. (2003). *Cosmopolitiques. I*. La Découverte.
- Stern, N. H. (2006). *Stern Review: The economics of climate change*.
- Stott, P. A., Stone, D. A., & Allen, M. R. (2004). Human contribution to the European heatwave of 2003. *Nature*, 432(7017), 610–614. <http://doi.org/10.1038/nature03089>
- Strauss, A., & Corbin, J. (1997). *Grounded theory in practice*. Sage Publications.
- Studenty, C. (1995). *L'invention de la vitesse : France : XVIIIe-XXe siècle*. Gallimard.
- Surminski, S. (2013). Private-sector adaptation to climate risk. *Nature Climate Change*, 3(11),

- 943–945. <http://doi.org/10.1038/nclimate2040>
- Swart, R. J., Biesbroek, R., & Lourenço, T. C. (2014). Science of adaptation to climate change and science for adaptation. *Frontiers in Environmental Science*, 2(July), 1–8. <http://doi.org/10.3389/fenvs.2014.00029>
- Swart, R. J., & Singh, T. (2013). *MEDIATION and the adaptation challenge: Identifying appropriate methods and tools to support climate change adaptation decision making*.
- Tacnet, J.-M., Carlados, S., Curt, C., Legat, Y., Rulleau, B., & Wery, C. (2016). Combiner les modèles d'aide à la décision pour la gestion patrimoniale des infrastructures. *Sciences Eaux et Territoires*, (20), 90–97.
- Taleb, N. N. (2008). *The Black Swan: The Impact of the Highly Improbable*. Random House Trade Paperbacks. <http://doi.org/10.1007/s11138-008-0051-7>
- Tavasszy, L., Bollinger, L. A., & Dijkema, G. P. J. (2016). Editorial: Special Issue on Climate Adaptation of Infrastructure Networks. *EJTIR Issue*, 16(1), 95–97.
- Thao, S., Ribes, A., & Cattiaux, J. (2016). Jeudi du climat : Attribution des évènements extrêmes (unpublished work).
- The new climate economy. (2014). Better Growth Better Climate.
- Tissot, A.-C., Amiotte-suchet, P., Brulebois, E., Castel, T., Ponnou-delaffon, V., Richard, Y., ... Bertrand, F. (2016). *Projet HYCCARE Bourgogne, Rapport Final*.
- Tollis, C., Créton-Cazanave, L., & Aublet, B. (2014). *L'effet Latour : ses modes d'existence dans les travaux doctoraux*. Éditions Glyphe.
- Tompkins, E. L., & Eakin, H. (2012). Managing private and public adaptation to climate change. *Global Environmental Change*, 3(11), 3–11. <http://doi.org/10.1016/j.gloenvcha.2011.09.010>
- ToPDAd. (2014). *Overview of system responsiveness to climate change impacts in energy, transport and tourist sectors*.
- Touili, N., & Vanderlinden, J. (2017). Flexibilité adaptative et gestion du risque : étude de cas des inondations dans l'estuaire de la Gironde (France), 17, 0–25.

- TRB. (2015). System Resilience and Climate Change. *Transportation Research Record: Journal of the Transportation Research Board*, 2532.
- TRB. (2016). System Resilience and Climate Change. *Transportation Research Record: Journal of the Transportation Research Board*, 2599.
- TRB. (2017). System Resilience and Climate Change. *Transportation Research Record: Journal of the Transportation Research Board*, 2604. <http://doi.org/10.3141/2604-00>
- Troin, J.-F. (2010). Désirs de gares TGV: Du projet des édiles locaux au 'désaménagement' du territoire. *Belgeo - Revue Belge de Géographie*, (1–2), 23–34.
- Trutnevyte, E., Guivarch, C., Lempert, R. J., & Strachan, N. (2016). Reinvigorating the scenario technique to expand uncertainty consideration. *Climatic Change*, 135(3–4), 373–379. <http://doi.org/10.1007/s10584-015-1585-x>
- Turnbull, K. (2016). *Transportation Resilience: Adaptation to Climate Change*. National Academies Press. <http://doi.org/10.17226/24648>
- Tushman, M. L., & Katz, R. (2015). External Communication and Project Performance : An Investigation into the Role of EXTERNAL COMMUNICATION AND PROJECT PERFORMANCE : AN INVESTIGATION INTO THE ROLE OF GATEKEEPERS *. *Management Science*, 26(11), 1071–1085.
- UIC. (2011). ARISCC-Adaptation of Railway Infrastructure to Climate Change. Final report. Nolte, R Berlin, I Z T.
- UIC. (2017). *Rail Adapt - Adapting the railway for the future*.
- UK government. (2011). *Climate Resilient Infrastructure : Preparing for a Changing Climate*.
- UK government. (2014). *Transport Resilience Review - A review of the resilience of the transport network to extreme weather events*.
- UKCIP. (2012). The UKCIP Adaptation Wizard v 4.0.
- UNEP. (2016). *The Adaptation Gap Report 2016*. Nairobi,.
- Valéry, P. (1992). *Introduction à la méthode de Léonard de Vinci, 1894*. Gallimard.
- Vallejo, L., & Mullan, M. (2016). The role of government in making infrastructure investment

climate resilient – Draft survey of current practices.

- Vallejo, L., & Mullan, M. (2017). *Climate-resilient infrastructure - Getting policy right* (No. 121). Paris. <http://doi.org/10.1787/02f74d61-en>
- Van Bree, L., & Van der Sluijs, J. P. (2014). Background on uncertainty assessment supporting climate adaptation decision-making. In Capela Lourenço T. et al. (Ed.), *Adapting to an Uncertain Climate: Lessons from Practice* (pp. 17–40). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-04876-5_2
- Van der Sluijs, J. P. (1997). *Anchoring Amid Uncertainty: On the Management of Uncertainties in Risk Assessment of Anthropogenic Climate Change*. Universiteit Utrecht.
- Van der Sluijs, J. P. (2010). Uncertainty and complexity: the need for new ways of interfacing climate science and climate policy. In D. Driessen, P. Leroy, & W. Van Vierssen (Eds.), *From Climate Change to Social Change: Perspectives on Science—Policy Interaction* (pp. 31–49). Utrecht: International Books.
- Van der Sluijs, J. P. (2012). Uncertainty and Dissent in Climate Risk Assessment: A Post-Normal Perspective. *Nature and Culture*, 7(2), 174–195. <http://doi.org/10.3167/nc.2012.070204>
- Vanderlinden, J. (2015). Prévoir l'imprévu. In *Ceriscope Environnement et relations internationales*. PARIS.
- Vatin, F. (2008). L'esprit d'ingénieur : pensée calculatoire et éthique économique. *Revue Française de Socio-Économie*, 1(1), 131. <http://doi.org/10.3917/rfse.001.0131>
- Vautard, R., Planton, S., Soubeyroux, J.-M., Bolliet, T., Brockmann, P., Caud, N., ... Yiou, P. (2016). *Projet EXTREMOSCOPE*.
- Vautard, R., van Oldenborgh, G. J., Thao, S., Dubuisson, B., Lenderink, G., Ribes, A., ... Planton, S. (2015). Extreme fall 2014 precipitations in the Cévennes mountain range. *Bull. Amer. Meteor. Soc.*, 96(12), S56--S60. <http://doi.org/doi:10.1175/BAMS-D-15-00088.1>
- Venturini, T. (2010). Diving in magma: how to explore controversies with actor-network theory. *Public Understanding of Science*, 19(3), 258–273. <http://doi.org/10.1177/0963662509102694>
- Venturini, T., Baya Laffite, N., Cointet, J.-P., Gray, I., Zabban, V., & De Pryck, K. (2014). Three

- maps and three misunderstandings: A digital mapping of climate diplomacy. *Big Data & Society*, 1(2), 205395171454380. <http://doi.org/10.1177/2053951714543804>
- Venturini, T., Ricci, D., Mauri, M., Kimbell, L., & Meunier, A. (2015). Designing Controversies and Their Publics. *Design Issues*, 31(3), 74–87. http://doi.org/10.1162/DESI_a_00340
- Verderosa, A. (2004). *Trains de vies . Enquête sur la SNCF d'aujourd'hui* (Paris, Ed.). PARIS.
- Vico, G. (2001). *La science nouvelle*. Gallimard.
- Vidaud, M., Bernard, O., Crouigneau, S., Putallaz, Y., Lévêque, J., & Jacquier, R. (2012). Financing railway infrastructure: How to invest and what maintenance policy? In *WIT Transactions on the Built Environment* (Vol. 127, pp. 663–671). <http://doi.org/10.2495/CR120561>
- Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. *Sustainability*, 5(3), 955–979.
- Wardekker, J. A., de Jong, A., Knoop, J. M., & van der Sluijs, J. P. (2010). Operationalising a resilience approach to adapting an urban delta to uncertain climate changes. *Technological Forecasting and Social Change*, 77(6), 987–998. <http://doi.org/10.1016/j.techfore.2009.11.005>
- Wardekker, J. A., Klopogge, P., Petersen, A. C., Janssen, P. H. M., & van der Sluijs, J. P. (2013). Guide for Uncertainty Communication.
- Watkiss, P., & Hunt, A. (2013). *Method Overview: Decision Support Methods for Adaptation* (MEDIATION Project).
- WBCSD. (2014). *Building a Resilient Power Sector*.
- Weaver, C. P., Lempert, R. J., Brown, C., Hall, J. A., Revell, D., & Sarewitz, D. (2013). Improving the Contribution of Climate Model Information to Decision Making., 4(1), 39–60.
- Welcome Complexity. (2017). *Manifesto Welcome Complexity : Agir et Penser en Complexité eBook: Welcome Complexit*. Fourth Revolution Publishing.
- Werners, S. E., Pfenninger, S., van Slobbe, E., Haasnoot, M., Kwakkel, J. H., & Swart, R. J. (2013). Thresholds, tipping and turning points for sustainability under climate change. *Current*

Opinion in Environmental Sustainability, 5(3–4), 334–340.
<http://doi.org/10.1016/j.cosust.2013.06.005>

Williams, R., & Edge, D. (1996). The social shaping of technology. *Research Policy*, 25, 864–899.

Winner, L. (1986). Do Artefacts Have Politics? *The Whale and the Reactor. A Search for Limits in an Age of High Technology*, 19–39. <http://doi.org/10.2307/20024652>

Wise, R. M., Fazey, I., Stafford Smith, M., Park, S. E., Eakin, H. C., Archer Van Garderen, E. R. M., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, 28, 325–336.

World Economic Forum. (2018). *The global risks report 2018, 13th edition*. <http://doi.org/978-1-944835-15-6>

World Meteorological Organization. (2018). *WMO Statement on the State of the Global Climate in 2017*.

Yin, R. K. (2003). *Case Study Research . Design and Methods*. SAGE Publications. <http://doi.org/10.1097/FCH.0b013e31822dda9e>

Yiou, P., Cattiaux, J., Ribes, A., Vautard, R., & Vrac, M. (2018). Recent Trends in the Recurrence of North Atlantic Atmospheric Circulation Patterns. *Complexity*, 2018, 1–8. <http://doi.org/10.1155/2018/3140915>

Yiou, P., & Jouzel, J. (2015). *Le temps s'est-il détraqué ? : comprendre les catastrophes climatiques*. (Buchet-Chastel, Ed.). Paris.

Zask, J. *Introduction à John Dewey* (2015). Paris: La Découverte.

Zelinka, M. D., Randall, D. A., Webb, M. J., & Klein, S. A. (2017). Clearing clouds of uncertainty. *Nature Climate Change*, 7(10), 674–678. <http://doi.org/10.1038/nclimate3402>

Zembri, P., & Libourel, E. (2017). Towards oversized high-speed rail systems? Some lessons from France and Spain. In *Transportation Research Procedia* (Vol. 25, pp. 368–385). <http://doi.org/10.1016/j.trpro.2017.05.414>

Aknowledgements - remerciements

Il y a un peu plus de quatre ans, alors que je préparais ce projet, j'ai eu l'occasion d'assister à un séminaire de l'Institut EDS en environnement, développement et société à Québec. Au détour d'un mot d'accueil, le Prof. E. Bourget a dépeint le travail de recherche comme essentiellement relationnel. Il faisait le portrait d'un chercheur qui sort de son laboratoire, va rencontrer d'autres scientifiques et des non scientifiques, ne s'arrête pas aux limites des disciplines, est capable d'enrichir sa vision du monde de multiples perspectives, de se mettre sans cesse en situation d'apprendre, de renouveler son effort de compréhension, de créer et de laisser émerger des connections. Cette figure d'un chercheur « passeur de frontières » (Jollivet, 1992), faiseur de ponts (Serres, 2012), médiateur entre des « mondes de pensée » (Dépoues & Masera, 2013) est celle à laquelle je n'ai eu de cesse de me référer pour ce travail. Je n'ai pas tant cherché à avoir une vue d'ensemble, un panorama « méta » du sujet qu'à cheminer d'un texte à une discussion, d'un point à l'autre, à arpenter une partie, toujours infime, du paysage qui s'offrait à moi. On comprendra donc que, même si une thèse est en apparence un effort relativement solitaire, je consacre 3 pages - forcément à l'arrivée - pour remercier une grande diversité de personnes rencontrées en chemin.

Je remercie en tout premier lieu Jean-Paul et Tommaso de m'avoir permis et aidé à mener le projet ainsi, d'avoir compris pourquoi je m'étais lancé dans cette aventure et conseillé, challengé, en cohérence avec cette intention. Jamais vous ne m'avez imposé vos vues mais toujours vous avez su poser les bonnes questions, celles qui font réfléchir en profondeur et aident à formuler clairement les choses. On dit que la communication avec ses directeurs de thèse est un point d'achoppement courant d'un doctorat, vous me l'avez épargné.

- Tommaso, dont je suis honoré d'avoir été le premier doctorant - plus de 6 ans après avoir suivi le fameux module de cartographie des controverses si symbolique des scubes (pour qui tu incarnes en partie ces années hors du commun). Merci pour ta disponibilité, ta patience, la clarté et la profondeur derrière l'apparente simplicité de tes conseils méthodologiques et merci pour ton exigence m'invitant sans cesse à abandonner le jargon, à être capable de préciser d'assumer et de partager une analyse.
- Jean-Paul, rencontré dans une gare parisienne (déjà) alors qu'Aglaé, Sabine, Yann et moi préparions la participation d'un groupe interdisciplinaire d'étudiants au colloque du GIS climat « (In)certitudes et adaptation au climat futur » (Dépoues, Giguët, Jézéquel, & Quilcaille, 2015; Quilcaille et al., 2015). Avec cette thèse vous avez aussi accepté une forme d'expérimentation méthodologique et un terrain différent. Ces choix ont parfois pu donner l'impression de trop bien cacher leur dimension critique, rassurez-vous, nos discussions m'y ont aussi sensibilisé.

Merci à Anders Blok et Arnaud Diemer d'avoir été les rapporteurs critiques et constructifs de ce travail – ainsi qu'à Angel Aparicio, Franck Lecoq, Aude Bodiguel et Benoît Leguet pour votre participation au jury. A tous les six merci pour vos questions et commentaires qui ont largement enrichi la discussion.

J'en profite aussi pour remercier ceux qui étaient dans le même train de thèse que moi, avec qui nous partageons une certaine vision de la recherche :

- Sarah et nos cafés réguliers, nos échanges sur la recherche en entreprise ;
- Pascale et tous les jeunes chercheurs du groupe des « Indisciplinés » ;
- Et tout spécialement Aglaé qui a poussé encore plus loin le pari de l'interdisciplinarité en mariant avec succès sciences du climat et STS¹⁵¹. En parlant de canicules, d'extrêmes climatiques, de négociations climat nous avons appris à penser ensemble et à collaborer concrètement (Dépoues, Vanderlinden, Venturini, et al., 2018; Jézéquel et al., 2017).

Je remercie ensuite vivement ceux qui ont partagé un intérêt pour ce projet alors qu'il n'était qu'au stade de l'idée, en ont accompagné le montage et l'ont (au moins pendant un temps) suivi, notamment Alexia Leseur (CDC Climat) et Christian Dubost (SNCF)¹⁵². Une pensée spéciale pour Bruno Latour : c'est lors de l'un de vos cours qu'a été semée la première graine des questionnements qui ont sous-tendu à ce travail, c'est vous qui m'avez aiguillé quand je recherchais un directeur de thèse et vos textes ont nourri la réflexion tout au long du processus.

Il en faut des choses pour passer de l'idée au projet, puis du projet à ses résultats ; je remercie donc tous ceux qui pendant plus de trois ans ont accordé du temps, ont contribué à la réflexion et à la discussion, ont mis à disposition des moyens pour que la recherche puisse se faire :

- Chez SNCF : Christian Dubost, Antoine Rothery (mon guide dans le milieu ferroviaire et souvent un des premiers avec qui discuter des résultats), Bernard Torrin, Jean-François Ruiz, Sophie Jalabert puis Jean-Baptiste Frier et Claire Rousselet (et Samia Sebbar car monter un comité de pilotage avec des gens occupés n'est logiquement pas simple).
- A l'ADEME : Bruno Lafitte, ingénieur référent du projet, Valérie Pineau et Maguy Favrelière de la cellule thèses et Aude Bodiguel du service climat.
- Chez I4CE : Benoît pour ton soutien, ta confiance et ton ouverture, ta présence aux moments clés, Malika, Jessica et Simon.

Une thèse comme celle-ci serait tout simplement vide si des dizaines de personnes - cadres de SNCF, associatifs, chercheurs, etc. - ne m'avaient pas accordé de leur temps pour me renseigner tout au long de l'enquête, partager des documents, me faire visiter leurs sites de travail. En toute cohérence avec l'esprit d'une méthode comme l'ANT, ce sont ces acteurs qui font tout ce qu'il se passe d'intéressant dans ce manuscrit, infiniment merci.

Trois ans de recherche c'est aussi un quotidien de bureau, un environnement intellectuel et des relations humaines, merci donc énormément à toute l'équipe d'I4CE : mention spatiale à Romain, co-bureau contre

¹⁵¹ Cf. <http://www.theses.fr/s167826> - consulté pour la dernière fois en août 2018

¹⁵² Je n'oublie pas ceux qui s'étaient intéressés à une de ses multiples variantes qui n'ont finalement pas pris corps (à Lyonnaise des eaux, au CSI, etc.)

canicules et travaux ; à Cécile binôme du grand pôle VIC et Marion qui m'avez permis de suivre aussi d'autres sujets pour m'aérer l'esprit ; à Mariana et Igor pour vos conseils avisés, votre expérience sereine, votre bonne humeur ainsi que vos relectures en anglais ; à tous ceux de l'équipe actuelle et passée de la rue de la Victoire puis de l'Avenue Marceau pour les déjeuners, les brainstormings, les soirées jeu, etc.

La recherche est un monde parfois très compétitif mais souvent ouvert : les lectures, les colloques, les écoles d'été (la *journey Climate Kic*, la *Summer school* « Autour du 2°C ») depuis 2015 et même avant ont planté ou arrosé beaucoup de graines. A tous ces autres chercheurs, enseignants, aux personnes rencontrées lors d'évènements, aux auteurs et docteurs dont j'ai lu (parfois relu et re-relu) les textes, aux reviewers : merci.

Il n'y avait pas que la thèse dans la vie mais dans le cerveau d'un doctorant tout est lié (ou mélangé) et il y a eu ces dernières années d'autres activités et réflexions qui ont nourri et complété cette recherche :

- D'abord, merci Cédric, tu étais là à Québec et puis aussi là pour ce thé avec Jean-Louis Le Moigne. Nous avons dessiné beaucoup de schémas sur des tableaux, découvert de multiples auteurs, mangé beaucoup de gushis. J'espère très vivement que nos discussions « chercheur & consultant » et notre amitié se prolongeront encore longtemps en philosophie, là où la complexité est la bienvenue et ailleurs.
- Je disais « faiseur de ponts », « médiateur entre des mondes de pensée » - merci Florine, Mike et tous ceux qui ont pris part à l'aventure Idap.
- Parfois les idées viennent d'un peu plus loin du sujet, de liens indirects ou de connections inattendues : merci donc aussi à tous les partenaires avec qui j'ai pu travailler : à I4CE, avec CliMates, avec Welcome Complexity (2017), via les cours, etc.
- Et puis il y a tous les moments de respiration, quand l'esprit se détend, se libère, se repose - merci à ceux qui les ont accompagnés. Merci notamment aux lampions pour ces années de théâtre.

Enfin il y a ceux qui sont toujours là, peu importe la situation et le moment, pour des choses futiles ou sérieuses, toujours importantes : merci à vous qui êtes des amis proches (Bastien, les scubes...), et bien sûr à mes parents, grands-parents et à ma famille qui me demandent depuis 3 ans « tu travailles sur quoi en ce moment » et se sont habitués à une réponse un peu monotone. *Vielen Danke* Cécile, pour le soutien, les relectures, et pour tout, notamment de m'avoir aidé à comprendre ce qui compte et qu'au bout d'une forme de « méditation épistémique » il y a la nécessité d'incarner au quotidien ce que l'on a intellectualisé.

Appendices

| | |
|---|------|
| I. COMPLEMENTARY MATERIAL | A, P |
| <i>Attended events and presentations</i> | 1 |
| <i>Presentations of the project (posters)</i> | |
| <i>Des connaissances scientifiques sur les changements climatiques à l'analyse économique pour la prise de décision en vue de l'adaptation des infrastructures (2015).</i> | 2 |
| <i>Pour un système ferroviaire adapté aux changements climatiques : des connaissances scientifiques à l'analyse économique dans la prise de décision. (2016)</i> | 3 |
| <i>Guiding documents for interviews with Ethical preamble</i> | 5 |
| <i>Workshop</i> | |
| <i>Participants' workbook</i> | 9 |
| <i>Presentation support</i> | 19 |
| <i>Press clipping:</i> Examples of major topics related to SNCF covered in the French Medias between 2015 and 2018. | 23 |
| II. PORTFOLIO | |
| <i>Modernisation du système ferroviaire français et changement climatique : Oser penser des transformations profondes pour des réseaux robustes et adaptés.</i> I4CE. Point Climat (2016). | 29 |
| <i>Uptaking a robust approach and DMDU tools to adapt infrastructures to climate change? The example of the French railway network.</i> Dépoues, V. Poster, DMDU annual workshop, Washington DC. (2016). | 37 |
| <i>Adaptation des réseaux aux changements climatiques : comment poser la question ?</i> I4CE. Support de discussion, Colloque International de la Météo et du Climat (2017). | 38 |
| <i>Article 1:</i> Organizational uptake of scientific information about climate change by infrastructure managers: the case of adaptation of the French railway company. Dépoues, V. <i>Climatic Change</i> , 143(3-4), 473-486. | 46 |
| <i>Corporate adaptation plans or the pressure of finance.</i> Cochran, I. et al. (2017). In B. Laville, A. Euzen, & S. Thiébaud (Eds.), <i>Adapting to Climate Change: a question for our societies</i> (CNRS Editions). Paris. | 60 |
| <i>Ce que peut nous apprendre le cas de la gestion de la végétation sur l'adaptation au changement climatique pour SNCF.</i> Dépoues (2018). Publication à venir, <i>Revue Générale des Chemins de Fer</i> . | 68 |

PRESENTATIONS AND ATTENDED EVENTS

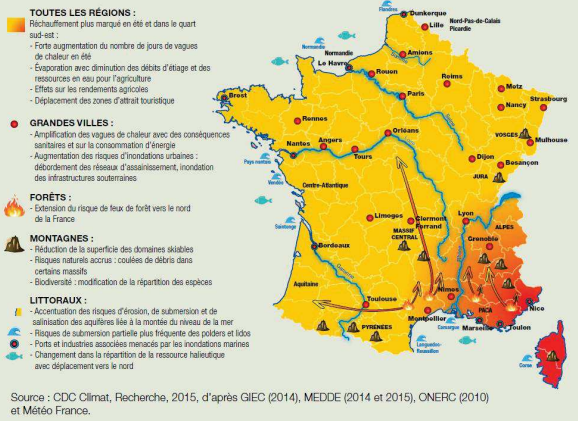
- (2018, July). *L'exemple du réseau ferroviaire français : Prendre des décisions pour des infrastructures adaptées aux changements climatiques*. Internal seminar of the Interministerial French team for international climate negotiations, session on adaptation to climate change. Paris.
- (2018, June). *How to make infrastructure investment more climate-resilient? The case of adaptation of the French railway company SNCF*. Internal seminar of the European Investment Bank. Luxembourg.
- (2018, February). *Le changement climatique chez les autres opérateurs européens : éléments de revue de littérature*. 3rd meeting of the SNCF Synapse experts' group on climate change adaptation. Paris.
- (2017, September). *Etude de cas sur le secteur ferroviaire dans le Languedoc Roussillon*. DGITM/PNACC seminar (With Rothey, A.). Paris.
- (2017, June). *Quelle mobilisation des outils économiques d'aide à la décision pour des infrastructures ferroviaires adaptées aux changements climatiques ? Une variété d'usages*. Summer school « Autour du 2°C », session on *Climate and society, from rhetoric to action*.
- (2017, June). *Adaptation of the French railway system: climate change as a strategic driver of decision making? An in-depth case-study*. 3rd European Conference on Climate Change Adaptation (ECCA 2017), session 9.2 Energy and Transport Infrastructure under Climate Change: Adaptation, Mitigation and Resilience. Glasgow. <http://ecca2017.eu/conference/wp-content/uploads/2017/04/ECCA-Parallel-Sessions-V4-1.pdf>
- (2017, March). *Pannel session: "Quelles stratégies déjà adoptées - Réseaux et infrastructures"*. Symposium "Adaptation des infrastructures et des réseaux au changement climatique". 14th International Weather and Climate Forum. Paris. <https://forumeteoclimat.com/>
- (2016, November). *Poster: Adaptation of French transports infrastructure to climate change: taking ownership of a robust mindset and DMU tools? The example of railway infrastructures*. DMDU Society 4th Annual Workshop, session "Decision-making under Deep Uncertainty Techniques in Practice: Stories". Washington DC. <http://www.deepuncertainty.org/annual-meetings/>



Des connaissances scientifiques sur les changements climatiques à l'analyse économique pour la prise de décision en vue de l'adaptation des infrastructures

Projet de thèse de Vivian Dépoues dirigé par Jean-Paul Vanderlinden (UVSQ-CEARC) & Tommaso Venturini (SciencesPo, Médialab) et suivi par Alexia Leseur (I4CE) et Bruno Lafitte (ADEME)

■ Carte schématique des impacts potentiels du changement climatique en France métropolitaine à l'horizon 2050 et au-delà



Ce projet se propose d'analyser la manière dont les connaissances scientifiques sur le changement climatique sont appropriées par des décideurs économiques tels que les gestionnaires d'infrastructures et la façon dont l'analyse économique pourrait être plus efficacement mobilisée pour les traduire en éléments opérationnels de prise de décision d'adaptation.

Contexte et besoins

Des changements climatiques déjà en cours avec des impacts encore incertains à l'échelle régionale

L'adaptation est un défi majeur pour les infrastructures

- Passer d'un modèle de décision qui pouvait se fonder sur les expériences passées à un modèle capable de prendre en compte le caractère incertain et nouveau des conditions climatiques futures
 - Hypothèse que l'analyse économique peut être un intermédiaire utile entre l'analyse des impacts physiques du changement climatique et la prise de décision
 - Nombreux outils économiques d'aide à la décision développés mais mal appropriés
- ➔ **Poser les questions du choix et de l'appropriation de ces outils et de leur rôle pour la prise en compte des questions d'adaptation**

Objectifs scientifiques : mobiliser une grille de lecture sociologique pour prendre en compte la réalité des processus complexes de l'adaptation

- Interroger la place et le rôle du scientifique et de la connaissance sur le climat dans la prise de décision
- Interroger l'interaction entre outils mobilisés et attitude adoptée face au changement climatique
- Poser la question de l'information nécessaire, de la valeur de l'information, des critères de décision (efficacité, robustesse, précaution...)

Objectifs opérationnels :

- Renforcer la sensibilisation et la capacité d'action collectives pour une économie et des territoires plus résilients et mieux adaptés au climat futur
- Proposer une analyse des outils existants tenant compte du contexte opérationnel français
- Contribuer à l'émergence d'une offre d'outils et de services d'aide à la décision directement mobilisables pour appuyer les gestionnaires publics ou privés dans l'adaptation de leurs infrastructures bâties

⇔ Trois questions pour structurer la recherche

Comment se pose la question de la prise en compte des connaissances sur les impacts possibles du changement climatique aux décideurs économiques ?

Quel type d'analyse économique peut être mobilisée pour informer et équiper les gestionnaires d'infrastructure et les aider à mieux intégrer les impacts possibles du changement climatique dans leurs choix ?

Comment ces outils sont-ils effectivement appropriés et pourraient être adaptés pour mieux s'inscrire dans le processus de décision et améliorer la gouvernance de l'adaptation ?

Démarche et outils

Etude de sciences et des techniques : la « science en train de se faire », interactions scientifique/social,

- Théorie de l'acteur réseau : déployer et étudier des réseaux sociotechniques hétérogènes
- Cartographie de « controverses » : coexistence de visions du monde multiples, ouverture des boîtes noires de l'activité collective en univers incertain pour rendre visible les relations, les hybridations, les choix, etc.

Analyse économique : comprendre et mettre en perspective les processus observés à la lumière des travaux existants en matière d'aide à la décision et d'économie des infrastructures.



Terrain identifié : infrastructures ferroviaires (gares et réseau) en Languedoc Roussillon, en partenariat avec la SNCF et SNCF Réseau,

Etude de cas approfondie

Partir du terrain : enquête sur le processus de gestion d'une infrastructure implantée sur un territoire

➔ Les infrastructures de **transport** :

- Des enjeux certains : longue durée de vie, structurantes, investissements importants ;
- Moins étudiées en France qu'ailleurs ;
- Une culture « techniciste » et déterministe de la décision remise en cause ?

Pour un système ferroviaire adapté aux changements climatiques : des connaissances scientifiques à l'analyse économique dans la prise de décision .

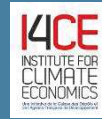


Photo: Network rail (UK, 2014)

Ce projet a pour objectif d'analyser la manière dont le gestionnaire et l'exploitant d'une infrastructure telle qu'un réseau de transport ferroviaire peut s'appropriier les connaissances scientifiques existantes sur le changement climatique. Il explore notamment comment l'analyse économique pourrait être plus efficacement mobilisée pour traduire cette connaissance en éléments opérationnels de prise de décision et d'adaptation.

Motivations : étudier les évolutions envisageables pour prendre en compte le caractère incertain des conditions climatiques futures à l'échelle régionale :

- Des changements climatiques déjà en cours :
 - des changements progressifs (ex. hausse du niveau de la mer) ;
 - une évolution des événements extrêmes (inondations, canicules : ex.2003 , etc.) ;
- L'utilisation d'historiques statistiques pour la prise de décision remise en cause ;
- Un défi majeur pour les territoires et les infrastructures qui les desservent. Des décisions structurantes prises maintenant sur lesquelles il sera difficile de revenir.

Objectifs : identifier, comprendre et modéliser les situations et décisions dans lesquelles il serait pertinent de poser la question du changement climatique :

- Quelle information scientifique disponible, quelle information scientifique utile, quel rapport au monde scientifique ?
- Quels arguments pour tenir compte de ce paramètre dans les décisions ? Quel rôle pour l'analyse économique ?
- Quels outils mobiliser pour s'approprier ce sujet ? Comment décider malgré les incertitudes ? Comment articuler cette problématique avec d'autres objectifs de gestion (financiers, de sécurité, etc.) ?
- Quelles évolutions des usages et des pratiques ? Quelles formes d'adaptation ? Des options techniques mais également managériales et organisationnelles.

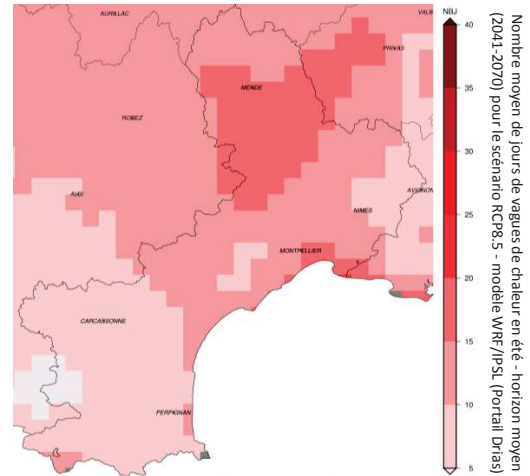
Etude détaillée d'une situation concrète, une portion du système ferroviaire, entre Nîmes et Perpignan :

- Implantée sur le territoire régional : territorialiser les questions d'adaptation ;
- Exposée aux conditions climatiques (canicules, montée du niveau de la mer, risques inondations, vents) aujourd'hui et de manière exacerbée demain, avec le changement climatique ;
- Des projets en cours à différents stades d'avancement : renouvellement, gares nouvelles, CNM, LNMP etc.



→ Une Enquête de terrain ? Phase 1 : octobre 2016

- Des entretiens ; des observations *in situ* ; une étude de la documentation :
 - Avec l'ensemble des acteurs intervenant dans la gestion du système ferroviaire : métiers SNCF & SCNF Réseaux de la planification/conception à la maintenance en passant par la construction et l'exploitation ; partenaires économiques ; partenaires institutionnels ; usagers, etc.
 - Importance méthodologique de l'observation directe pour mieux comprendre et pouvoir analyser de façon homogène l'ensemble des étapes.
 - Intérêt pour tous types d'informations, expériences, connaissances, exemples, opinions, documents relatifs à :
 - La compréhension des enjeux de chaque métier, le rapport des différentes activités de gestion et d'exploitation à la météo et au climat, l'identification (ou pas) du changement climatique comme enjeu, l'information disponible/nécessaire, les modalités des prises de décision.



→ Perspectives

- Sélection et expérimentation d'outils d'aide à la décision adaptés : ex. éléments d'objectivation des coûts du changement climatique, test de robustesse au changement climatique des scénarios socio-économiques, aide à la décision en situation d'incertitude profonde, outils prospectifs : trajectoires d'adaptation, etc.
- Interrogation du potentiel d'appropriation de tels outils dans les processus de décisions,

→ Les situations d'intérêt

Opérations courantes : quelle sensibilité aux conditions climatiques ? De la résilience actuelle au climat futur.

Ex. Tournées de chaleur, opérations de maintenance, gestion de la végétation, travaux sur les voies, etc.

Les pratiques actuelles sont-elles remises en question par le changement climatique ? Des adaptations locales sont-elles déjà entreprises ? Est-il possible, pertinent (notamment économiquement) d'anticiper des évolutions ?



Investissements et grands projets : le climat comme variable structurante des choix ?

Ex. Choix de localisation, de dimensionnement, de conception, options techniques privilégiées, caractéristiques des matériels, etc.

Les options envisagées sont-elles robustes à d'éventuelles évolutions du climat ? A partir de quel scénario de changement climatique sont-elles remises en cause ? L'analyse socio-économique des projets peut-elle tenir compte du risque climatique ? Comment arbitrer entre plusieurs alternatives en tenant compte du facteur climat ?



Pensée prospective et stratégique : quelle vision du transport ferroviaire avec un climat différent ?

Ex. Travaux de recherche et réflexions prospectives, contribution aux débats territoriaux, etc.

Quel niveau de confort climatique le ferroviaire pourra-t-il offrir tout au long du voyage (en gare, au cours du trajet) même en plein été ? Le système sera-t-il assez résilient pour apparaître comme fiable et sûr, contribuant à la résilience du territoire ? Quelles seront les fenêtres d'opportunité à saisir ?



Projet de thèse mené par Vivian Dépoues, dirigé par Jean-Paul Vanderlinden (UVSQ-CEARC) & Tommaso Venturini (SciencesPo. Médialab) soutenu par l'ADEME, I4CE, SNCF & SCNF Réseau, suivi par Christian Dubost (SNCF), Bernard Torrini (SNCF-Réseau); Alexia Leseur (I4CE) et Bruno Lafitte (ADEME).

Pour plus d'informations, ne pas hésiter à me contacter :



Vivian DEPOUES

- 06 48 83 43 33
- vivian.depoues@i4ce.org
- fr.linkedin.com/in/vdepoues
- @vivian_dps

GUIDING DOCUMENT – EXPLORATORY INTERVIEWS

Ethical preamble – as exposed to interviewees

« EXPLIQUER LE CONTEXTE DE L'INTERVIEW

Au vu des changements climatiques déjà en cours mais dont les impacts à l'échelle régionale sont encore incertains, l'adaptation devient un défi majeur pour les infrastructures. Il s'agit de parvenir à passer d'un modèle de décision qui pouvait se fonder sur les expériences passées à un modèle capable de prendre en compte le caractère incertain et nouveau des conditions climatiques futures. Ce projet fait l'hypothèse que l'analyse économique peut être un intermédiaire utile entre l'analyse des impacts physiques du changement climatique et la prise de décision. De nombreux outils économiques d'aide à la décision ont été développés mais ne sont forcément appropriés. Notre objectif est de poser les questions du choix et de l'appropriation de ces outils et de leur rôle pour la prise en compte des questions d'adaptation.

Cette thèse se propose ainsi d'analyser la manière dont les connaissances scientifiques sur le changement climatique sont appropriées par des décideurs économiques tels que les gestionnaires d'infrastructures et la façon dont l'analyse économique pourrait être plus efficacement mobilisée pour les traduire en éléments opérationnels de prise de décision d'adaptation.

En partenariat avec SNCF/SNCF Réseau (DDD), ADEME et I4CE

Approche : enquête de terrain – entretien

Cette interview intervient en phase amont du projet/exploratoire, à un moment où la formulation précise des questions de recherche est encore à affiner. Compréhension du contexte, des jeux d'acteurs, des etc.

INCONVENIENTS ET AVANTAGES

- Le fait de vous interviewer environ une heure présente le seul inconvénient de la démarche de cette interview.
- Les avantages, par contre, de cette interview sont collectifs et ne peuvent que vous impacter positivement d'une façon indirecte.

COLLECTE ET TRAITEMENT DE DONNEES

Afin de pouvoir traiter l'ensemble des informations que cette entrevue va nous fournir, cette interview sera enregistrée si vous le permettez.

Chaque fichier-interview serait anonyme, un numéro aléatoire lui sera attribué.

Pour chaque interview, on procède par une transcription, une sauvegarde sous forme de fichier anonyme.

Seuls les interviewers peuvent intervenir dans la procédure d'enregistrement et de transcription des interviews qui les concernent. Cette intervention ne sera jamais révélée publique. Quelques informations de votre interview peuvent être utilisées en public sans que ceci vous soit associé en tant que personne.

VOTRE PARTICIPATION

Votre participation est volontaire et vous pouvez arrêter cette interview quand ceci vous semble nécessaire ».

GUIDING DOCUMENT – INTERVIEWS FOR THE CASE-STUDY IN THE MONTPELLIER REGION

Ethical preamble – as exposed to interviewees

« Bonjour, et merci beaucoup d’avoir accepté cet entretien, l’idée est qu’il prenne la forme d’une discussion qui, à partir de certaines questions que je souhaiterais vous poser nous amène vers les sujets qui vous sembleront les plus pertinents. Je vous propose de commencer par vous représenter très brièvement le contexte et les conditions de l’entretien - comme l’exige la méthode scientifique d’enquête.

EXPLIQUER LE CONTEXTE DU PROJET : ce projet a pour objectif d’analyser la manière dont le gestionnaire et l’exploitant d’une infrastructure telle qu’un réseau de transport ferroviaire est en capacité de s’adapter aux contraintes environnementales et aux dynamiques de changement. Il explore notamment comment l’analyse économique pourrait être plus efficacement mobilisée pour traduire cette connaissance en éléments opérationnels de prise de décision.

Projet suivi par C.Dubost, B.Torin à la SNCF ; JF.Ruiz dans la région.

EXPLIQUER LE CONTEXTE DE L’ENTRETIEN : cette interview intervient dans la 2^{ème} phase du projet, et a pour objectif de territorialiser la réflexion, de l’inscrire dans ce qui est la réalité des pratiques de gestion sur le terrain. Elle a pour but de m’aider à mieux comprendre les enjeux de chaque métier, le rapport des différentes activités de gestion et d’exploitation à la météo et au climat, l’identification (ou pas) du changement climatique comme enjeu, l’information disponible/nécessaire, les modalités des prises de décision.

→ Type d’informations importantes et pourquoi : toute info (expérience, connaissance, exemple, opinion, doc...) relative : (i) aux processus de décision, (ii) à la manière dont l’activité est/peut être influencée par des paramètres climatiques, (iii) aux tendances d’évolution et enjeux (incertains/complexes) auxquels SNCF est confrontée.

INCONVENIENTS ET AVANTAGES

- Le fait de vous interviewer environ une heure présente le seul inconvénient de la démarche de cette interview.
- Les avantages de cette interview sont collectifs et ne peuvent que vous impacter positivement d’une façon indirecte.

PERSPECTIVES

Exploration et expérimentation de dispositifs permettant de soulever et de discuter la question de l’adaptation au changement climatique : ex. éléments d’objectivation des coûts du changement climatique, test de robustesse au changement climatique des scénarios socio-économiques, aide à la décision en situation d’incertitude profonde, outils prospectifs : trajectoires d’adaptation, etc. Interrogation du potentiel d’appropriation de tels outils dans les processus de décisions.

Selon votre intérêt vous pourrez être associé à ces prolongements.

COLLECTE ET TRAITEMENT DE DONNEES

Afin de pouvoir traiter l’ensemble des informations que cette entrevue va nous fournir, cette interview sera enregistrée si vous le permettez. Chaque fichier-interview serait anonyme. Pour chaque interview, on pourra procéder à une transcription, une sauvegarde sous forme de fichier anonyme.

Un nombre très limité de personnes (interviewer + éventuellement assistance à la retranscription) peuvent intervenir dans la procédure d’enregistrement et de transcription des interviews. Cette intervention ne sera jamais révélée publique. Quelques informations de votre interview peuvent être utilisées en public sans que ceci vous soit associé en tant que personne.

VOTRE PARTICIPATION : est volontaire et vous pouvez arrêter cette interview quand ceci vous semble nécessaire.

DUREE : 1h dans l’idéal (de combien de temps disposez-vous ?) »

Personnal guidelines for the interview

Topics to cover

- ✓ Formation et métier
- ✓ Type de décisions/choix auxquels est amené à contribuer – sous quelle forme ?
- ✓ Processus de décisions (calcul, outils, scénarios, organes, études, partenaires...)
- ✓ Analyse économique
- ✓ Risques, enjeux, opportunités ; variables clés des choix
- ✓ Relation
 - Au changement, à l'anticipation, à la planification,
 - À l'incertain
 - À la météo et au climat
- ✓ Changement climatique, adaptation, résilience
- ✓ Information scientifique

General outline

1. Présentations, description de l'activité et des pratiques

- Pouvez-vous vous présenter (fonction-métier, formation, expérience...) ?
- Pourriez-vous m'en dire un peu plus sur votre service : situation dans l'entreprise priorités/obj, etc. ?
- Pourriez-vous me parler plus en détail de vos pratiques habituelles qui vous paraissent en lien avec ces sujets ? [de climat ; de changement climatique ; de risque climatique ; de résilience ; de changement global ; de relation aux conditions environnementales ...]
 - Types de décisions/projets, où sont les risques, les enjeux principaux, etc.

Processus de prise de décisions

- Pouvez-vous m'en dire plus sur la manière dont sont prises les décisions ? [Éventuellement préciser dans quel contexte, quel type de décision en fonction des réponses sur le climat] *processus formalisés, pratiques, information utilisé, indicateurs, unité de décision (tronçon, secteur, élément...)* - *organe de décision* - [inciter à prendre un cas concret]
 - *SNCF: beaucoup de processus qui semblent formalisés (standards, référentiels, etc.): quelle utilisation réelle ?*

Analyse économique : processus existants

- Quelle place est accordée aux arguments économiques/à l'analyse économique ? Réalisée comment, sous quelle forme ?
- Qui réalise ces analyses (interne/externe, service dédié/BE...) ?
- Quelles sont les variables clés de la décision ?
- Utilisation de scénarios de références ?
- Habitude à l'incertain ?

2. Relation à la météo, au climat et au changement climatique

- En quoi les conditions climatiques sont un enjeu pour vous ? En quoi vous concernent-elles dans votre activité ? [Des exemples de cas/événements ? Des chiffres ?]
- Le changement climatique [i.e. l'évolution des conditions par rapport à la situation connue] est-il identifié comme un phénomène nouveau et important dans votre activité ?
 - Détection éventuellement de tendances de changement (par quels dispositifs ?)
 - [follow up selon réponse : illustrer enjeu, voir comment se rapproche d'autres grandes tendances: ex. détérioration des matériels, coûts des retards, évolution demande...]
- Que pouvez-vous m'en dire ? De quelles informations disposez-vous ?
- Quels types d'informations complémentaires pourraient vous être utiles ?
- L'adaptation au changement climatique est-il un enjeu que vous avez identifié/dont vous avez entendu parler ? La réduction de la vulnérabilité aux aléas climatiques ? La résilience ?
- Avez-vous connaissance de travaux passés ou existants sur l'adaptation au changement climatique ? (auriez-vous des ressources, des documents, des liens à me communiquer ?)
- Quelles sont les sources de ces informations ? (*Avez-vous l'habitude d'utiliser des ressources à caractère scientifique (publications, rapports...): dans quelle situation et lesquelles ?*)

3. Et si ? Perspectives, relation au changement

- Caractère nouveau, spécifique de ce sujet ?

Clôture

-Pouvez-vous nous conseiller des personnes à contacter pour notre étude ? Coordonnées ?

-Nous avons couvert les différents thèmes que j'avais pré-identifié, vraiment très utile pour mieux comprendre. Voyez un autre sujet/point que nous n'aurions pas abordé et qui vous semblerait intéressant ?

Dans tous les cas vous pouvez me recontacter ou m'envoyer des infos supplémentaires. Dans les prochains mois.

Souhaitez-vous être tenu au courant des avancées de cette étude/être impliqué plus si pertinent à un stade ultérieur (ex. focus group) ?

ATELIER ADAPTATION AU CHANGEMENT CLIMATIQUE

Cahier du participant

Montpellier
20 octobre 2017



Et si les conditions climatiques estivales devenaient de plus en plus difficiles ? Quelles implications pour le système ferroviaire ?

Le projet de thèse

Cet atelier s'inscrit dans le cadre du projet de thèse intitulé « *Des connaissances scientifiques sur les changements climatiques à l'analyse économique pour la prise de décision en vue de l'adaptation des infrastructures* » mené par Vivian DEPOUES sur la période 2015-2018.

Ce projet a pour objectif d'analyser la manière dont le gestionnaire et l'exploitant d'une infrastructure telle qu'un réseau de transport ferroviaire peuvent s'approprier les connaissances scientifiques existantes sur le changement climatique.

Il explore notamment quelles sont les évolutions envisageables pour prendre en compte le caractère incertain des conditions climatiques futures à l'échelle régionale :

- Quelle information scientifique disponible, quelle information utile, quel rapport au monde scientifique ?
- Quels arguments pour tenir compte de ce paramètre dans les décisions ? Quel rôle pour l'analyse économique ?
- Quels outils mobiliser pour s'approprier ce sujet ? Comment décider malgré les incertitudes ? Comment articuler cette problématique avec d'autres objectifs de gestion ?
- Quelles évolutions des usages et des pratiques ? Quelles formes d'adaptation ? Des options techniques mais également managériales et organisationnelles.

Cet atelier

Cet atelier prolonge l'étude détaillée d'une portion du système ferroviaire initiée en 2016 entre Nîmes et Perpignan. Il fait suite à une série d'entretiens menée dans la région en fin d'année dernière et est organisé avec le Pôle EDD de la DT Occitanie, la direction du développement durable de SNCF et la direction de l'environnement et du développement durable de SNCF Réseau.

Il se propose d'ouvrir un espace où mettre en lumière et en discussion certaines caractéristiques et implications fondamentales du changement climatique, notamment :

- La certitude de changements en cours avant tout caractérisés par une plus forte variabilité ; la possibilité de situations météorologiques nouvelles ; des conjonctions inédites d'évènements.
- Les conséquences à en tirer pour le modèle ferroviaire dans son ensemble au regard de ses finalités et au-delà des aspects techniques (conséquences sur le modèle économique et le service offert aux usagers, etc.).

L'atelier se déroulera en trois temps :

1. Un premier temps consacré aux pratiques actuelles qui se propose au travers de l'exemple des canicules de revenir sur l'analyse issue des entretiens menés dans la région.
2. Un deuxième temps dédié aux connaissances dont on dispose sur les changements climatiques et les étés à venir, autour de quelques éléments présentés par une chercheuse en climatologie (Aglaré Jézéquel, IPSL/LSCE) et d'un récit de ce que pourrait être un été difficile dans le futur.
3. Un troisième temps consacré aux adaptations possibles au regard des possibles évolutions climatiques et à leurs implications sur le système ferroviaire.

Programme de la matinée : 9h - 13h

| | |
|-------------|--|
| 9h-9h20 | Introduction présentation de l'atelier, préambule méthodologique & éthique, tour de table |
| 9h20-10h10 | <p>Temps 1 : un été compliqué aujourd'hui</p> <ul style="list-style-type: none"> - Présentation (Vivian Dépoues, 15') – Discussion des pratiques actuelles : une adaptation au fil de l'eau <ul style="list-style-type: none"> ○ Retour sur les entretiens ○ L'exemple des vagues de chaleur - Discussion 1 <ul style="list-style-type: none"> ○ Réactions directes à la présentation ○ Mise en perspective |
| 10h10-10h55 | <p>Temps 2 : proposition d'une lecture de la connaissance sur le changement climatique</p> <ul style="list-style-type: none"> - Présentation (Aglé Jézéquel, 15') – changement climatique, variabilité et extrêmes météorologiques - Discussion 2 <ul style="list-style-type: none"> ○ Réactions directe à la présentation et discussion sur les informations nécessaires à l'adaptation |
| 10h55-11h10 | Pause |
| 11h10-12h50 | <p>Temps 3 : Exploration des implications pour l'adaptation au changement climatique</p> <ul style="list-style-type: none"> - Présentation (Aglé Jézéquel & Vivian Dépoues, 10') - Un été difficile demain ? - Discussion 3 <ul style="list-style-type: none"> ○ Et alors : quelles implications ? Quelles adaptations ? ○ Quels types d'actions pourraient être prises par anticipation ? |
| 12h50 – 13h | Conclusion et remerciements |
| 13h | Déjeuner |

Quelques éléments de méthode :

Les ateliers de ce type sont un des formats qui peuvent être mobilisés dans le cadre de recherches en sciences sociales, en complément d'observations de terrain, d'études bibliographiques ou encore d'entretiens, pour produire des données qui nourriront l'analyse. L'interaction en groupe permet d'échanger et de mettre en discussion les visions individuelles.

Un tel atelier se veut être [un espace de discussion libre et sûr](#). Nous vous demandons d'y mobiliser votre expérience professionnelle et vos connaissances des sujets et vous invitons à débattre sans que le contenu des échanges ne soit engageant pour vous ou votre entité. C'est un moment de réflexion qui autorise la prise de recul par rapport aux postures du quotidien.

Vous avez entre vos mains un [cahier du participant](#). Il s'agit d'un outil méthodologique qui permet d'optimiser le temps que nous passons ensemble :

- En formalisant des moments d'arrêt, avec pause écrite, nous ancrons mieux nos délibérations dans ce que nous apportons chacun, dans nos interrogations.
- En nous permettant de collecter une partie des données, sous la forme de vos écrits.

Ces données - complétées par des lectures et éventuellement des entretiens complémentaires - seront ensuite analysées en respectant les canons méthodologiques des disciplines mobilisées dans le projet.

Préambule éthique

[Qui nous sommes](#)

Ce projet de recherche s'inscrit dans le cadre du programme de thèse de l'ADEME. Il est cofinancé à parts égales par l'ADEME ; I4CE – *Institute for Climate Economics* ; SNCF (3D) et SNCF Réseau (DEDD).

Le doctorant est inscrit à l'Université de Versailles-Saint-Quentin-en-Yvelines, rattaché au laboratoire CEARC. La thèse est codirigée par Jean-Paul Vanderlinden (OVSQ/CEARC) et par Tommaso Venturini (INRIA/SciencesPo Médialab).

Le chercheur référent est Vivian DEPOUES (vivian.depoues@i4ce.org ; 06 48 83 43 33). C'est à lui que doivent être adressées toutes les questions relatives à cette recherche et à son cadre.

[Votre participation](#)

Cet atelier vise à la fois à approfondir la recherche en cours sur le sujet et à contribuer à la dynamique d'adaptation de l'entreprise. Votre participation est importante car elle nous permet de progresser dans la compréhension de ces sujets à la fois du point de vue de la recherche et des démarches de l'entreprise.

Elle se fait sur une base volontaire. Vous pouvez à tout moment interrompre votre participation. Personne ne sera informé de votre non-participation ou de votre retrait en cours d'atelier.

[Sécurisation, traitement et utilisation des données](#)

Sauf si un participant ou plus s'y oppose(nt) nos échanges seront enregistrés. Les enregistrements seront numérotés au moyen d'un code aléatoire qui ne permettra leur identification que par les membres de l'équipe de recherche. Tout le matériel sera rendu anonyme, en particulier les courts extraits de nos délibérations qui pourraient être utilisés à titre d'illustration dans la publication de nos résultats.

Vu la nature collective de l'exercice nous ne serons pas en mesure de vous donner accès aux enregistrements ou aux transcriptions afin d'y apporter des modifications ou corrections.

Participant :

Cahier à compléter (p.5 à 8 à remettre à l'équipe de recherche à l'issue de l'atelier).

Avant de démarrer

Pouvez-vous indiquer les raisons qui vous ont fait accepter de participer à cet atelier ?

Temps 1 : un été compliqué aujourd'hui

Présentation : « Une adaptation au fil de l'eau ? »

La description qui vous est proposée des pratiques actuelles et de la façon de répondre aux aléas climatiques vous paraît-elle bien refléter la réalité ? Y a-t-il des éléments avec lesquels vous n'êtes pas d'accord ? Y a-t-il des éléments que vous souhaiteriez ajouter ?

L'exemple des canicules aujourd'hui

Discussion en séance

Dans ce type de situations quel est, de votre point de vue, le principal enjeu ? Quelles sont les priorités ?

Quel est pour vous le degré d'importance de ces problématiques par rapport à d'autres qui affectent le système ferroviaire, lesquelles ?

Ce mode de réponse vous semble-t-il volontairement poursuivi et adapté ? Quelles limites aux pratiques actuelles ?

Autres remarques, commentaires ou questions dont vous voudriez nous faire part sur ce premier temps, en complément ?

Temps 2 : proposition d'une lecture de la connaissance sur le changement climatique

- **Présentation** : « Changement climatique, variabilité et extrêmes météorologiques »

Cette présentation diffère-t-elle de ce que vous avez pu entendre auparavant sur ce sujet ? En quoi ?

Vous paraît-elle plus ou moins informative ? Pourquoi ?

Quels éléments vous paraissent les plus notables ?

De quel type d'information complémentaire auriez-vous besoin ?

Autres remarques, commentaires ou questions dont vous voudriez nous faire part sur ce deuxième temps, en complément ?

Temps 3 : Exploration des implications pour l'adaptation au changement climatique

- **Présentation** : « Un été difficile demain ? »

Cette manière de présenter le climat futur sous forme de récits de situations possibles vous paraît-elle utile ? En quoi ? Serait-elle à prolonger ?

Discussion en séance

Quelles seraient les premières implications de telles évolutions pour le système ferroviaire et son organisation selon vous ? Quels éléments de vulnérabilité identifiez-vous ?

Dans une telle situation pourrait-on continuer à faire pareil qu'aujourd'hui ou faudrait-il faire évoluer les priorités et les pratiques ?

Compléments que vous souhaiteriez ajouter à ce qui a été discuté ?

Travail autour de différentes stratégies d'adaptation

Discussion en séance

Quels types d'actions pourraient être prises par anticipation ? Lesquelles ne seraient au contraire pas acceptables ?

- Des investissements ad-hoc pour des infrastructures et équipements plus résistants ; pour le maintien ou le développement de plus d'itinéraires de substitution ; pour des aménagements dédiés (ex. ombrières, fontaines)
- Des actions en faveur d'une capacité accrue à gérer les crises et à revenir rapidement à la normale
- Un renforcement de l'agilité de l'entreprise et de sa capacité à réagir hors-crisis
- Des évolutions de l'offre et des services tenant compte de la nouvelle donne climatique

Quels éléments déclencheurs pourraient faire évoluer la réponse ci-dessus ?

Autres remarques, commentaires ou questions dont vous voudriez nous faire part sur ce dernier temps, en complément ?

Merci pour votre participation





(0) Introduction

- Présentation de l'atelier
 - Inscription dans le projet de thèse
 - Objectifs
 - Structure de la matinée en 3 temps
- Préambule méthodologique et éthique
 - Le matériel collecté
 - Le cahier du participant
- Tour de table

Présentation de l'atelier

- **Objectifs :**
 - Mettre en lumière et en discussion certaines caractéristiques et implications fondamentales du changement climatique pour le système ferroviaire
 - Expérimenter une approche exploratoire du sujet
- **Mise en parallèle deux récits qui peuvent se répondre :**
 - La manière de s'adapter telle qu'elle s'observe aujourd'hui ;
 - Ce que pourrait vouloir dire de prendre différemment le problème pour aller plus loin au regard de l'information scientifique disponible.
- **Une structure en 3 temps**
- **Ce que vous pouvez apporter :** votre connaissance du secteur et de l'entreprise, vos expériences diverses et vos expertises.

Enregistrement et cahier du participant

- **Le cadre d'un projet de recherche** → un espace de discussion libre et sûr
- **Trace des échanges**
- **Le cahier du participant : un outil méthodologique qui permet d'optimiser le temps que nous passons ensemble :**
 - Formaliser des pauses écrites pour nous ancrer nos délibérations
 - Collecter également vos points de vue individuels

(1) Discussion des pratiques actuelles : une adaptation au fil de l'eau

→ Retour sur les entretiens
→ L'exemple des vagues de chaleur connues

Objectifs :

- Mettre des mots sur les pratiques actuelles
- Identifier leurs limites vis-à-vis des finalités poursuivies

Le climat régional bien connu

- Bien connu des agents
- Spécificités et saisonnalité
- Qui affecte le système ferroviaire

→ Un réseau globalement adapté
→ Mais qui peut présenter des vulnérabilités locales

Se préparer au connu & gérer l'incident quand il se produit

« Des choses qu'on a du mal à anticiper dans l'organisation, on est obligé de tenir compte de certains aléas mais on ne peut pas s'interdire de programmer [...] à cause de cela ».

L'exemple de la canicule

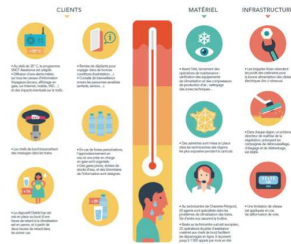


Ex. des gares nouvelles adaptées



Des actions pour se préparer aux chaleurs estivales

- **Matériel**
 - Ex. maintenance préventive des climatisations, renforcement des équipes des technicentres
- **Infrastructure**
 - Ex. brûlage dirigé
- **Usagers**
 - Ex. Sensibilisation, avaraillement en bouteilles d'eau



Quand un épisode caniculaire survient

Des mesures additionnelles prises en application du Plan caniculaire

- Renforcement des tournées de chaleur
- Vérification-augmentation des stocks de bouteilles d'eau
- Mise en alerte d'agents
- Messages de prévention

Et des actions correctives mises en place quand la situation l'impose :

- réductions de vitesse ;
- Gestion des incidents (ex. pannes de climatisation, incendies).

Le bilan négatif est attribué à des « causes externes »



Représentatif d'une adaptation au fil de l'eau ? (1/2)

- **Importance du constat et de l'expérience**
 - « Les gens travaillent à l'expérience » ; « l'œil du mainteneur est la base »
- **Peu d'anticipation des problèmes inconnus : une logique réactive & réparatrice**
 - « On fonctionne sous forme d'ajustement, au fur et à mesure », en « réaction seulement »
- **Des évolutions lourdes, qui passent avant tout par la technique (ex. évolution des matériels roulants suite à la canicule de 2003) et sur un mode industriel**
- **Difficulté à expérimenter des modes de faire originaux, réponses dans la continuité**
 - « on est très prudents à SNCF, [...] avant qu'on se lance dans un nouveau système [...] il faut qu'il ait fait l'objet d'essais, d'études »

« Il faudra quelques cas malheureux d'investissements avant de mettre en place de choses »

« si deux ou trois incidents de suite se passent mal par exemple »

« C'est le cumul des anomalies, des vérifications, des corrections éventuelles dont peut se charger la maintenance qui au bout du compte commence à donner une idée de l'âge à laquelle il va falloir penser à renouveler tout ou une partie du système. »

« Aujourd'hui la conception du matériel d'infrastructure répond à des cahiers des charges qui répondent à des contraintes ferroviaires liées à un vécu »

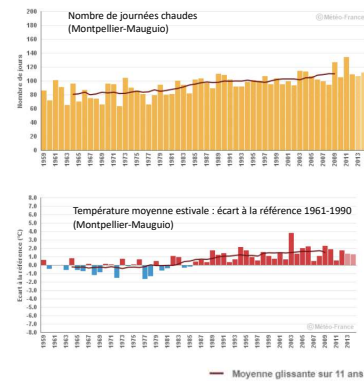
« ce sont des choses qu'on a du mal à anticiper dans l'organisation, on est obligé de tenir compte de certains aléas mais on ne peut pas s'interdire de programmer des travaux à cause de cela ».

« Pour réaliser des études on doit partir des risques avérés »

« Il y a des référentiels pour certains risques, il y a aussi l'expérience des agents »

Représentatif d'une adaptation au fil de l'eau ? (2/2)

- **Le changement climatique**
 - Conscience du phénomène en général
 - Focus sur les évolutions moyennes et progressives « Cela va peut-être s'accélérer »
 - Un risque extérieur, maîtrisable ;
 - Parmi des dynamiques multiples de renforcement des risques et de moindre acceptabilité du risque.
- **Difficile d'intégrer plus ou autrement ce phénomène**
 - Pas la légitimité, ce rôle incombe au national voire à l'Etat ;
 - Pas la compétence et l'expertise nécessaires ;
 - Doit se faire en amont, en conception ;
 - De trop nombreuses contraintes pèsent sur les projets et les équipes pour intégrer des dimensions en plus.



Réactions, discussion



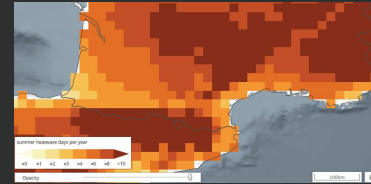
- ➔ Cette description des pratiques actuelles vous paraît-elle refléter la réalité ?
- ➔ Dans ce type de situations, quelles sont les priorités ?
- ➔ Ce mode de réponse vous semble-t-il volontairement poursuivi et adapté ?
- ➔ Quelles pourraient être les limites ?

(2) Ce que l'on sait aussi du changement climatique

Variabilité et extrêmes météorologiques

Objectifs :

- Mettre des mots sur ce que l'on sait du changement climatique : ce l'on en retient, ce que peuvent dire les scientifiques en insistant sur certains aspects : variabilité, indéterminisme, extrêmes.



Présentation par



Aglae JEZEQUEL
DSM/LSCE/CLIMAT-CYCLES/ESTIMR
Climat et Cycles - Modélisation de leurs variabilités et de leurs interactions

Laboratoire des Sciences du Climat et de l'Environnement

- Pas que les tendances moyennes
- Climat : dynamique, variabilité interp
- De nouvelles situations météo
- Spécificités locales et régionales
- Etalement des périodes
- Répétition probable
- La définition même de ce que sera un élément extrême va évoluer
- Conjonction/simultanéité d'événements inédits.

Un été difficile demain ?

Exercice prospectif

Histoire d'un futur été compliqué

- Printemps sec
- Vague de chaleur précoce
- Chaleurs prolongées de juillet à septembre,
- Conjonction d'événements

(3) Comment le changement climatique pose des questions sur les pratiques et l'organisation ferroviaires

Objectifs :

- Explorer comment ce changement climatique vient interroger les pratiques et l'organisation ;
- Discuter des formes d'adaptation envisageables, acceptables, préférables et de comment les comparer.



Réactions, discussion



1. Quelles implications pour l'entreprise vis-à-vis de ses objectifs ?

- Sur l'infrastructure et le matériel
- Pour les agents et l'organisation du travail
- Pour les voyageurs et le service rendu : régularité, confort, etc.



2. Pourrait-on continuer à faire pareil ou faudrait-il faire évoluer les priorités et les pratiques ?

- Jusqu'à quel point ? Quel type d'indicateurs ?
- Dans quelle finalité ? Quelles motivations ?
- Quels types d'actions pourraient être prises par anticipation ? Que faudrait-il pour les rendre crédibles & acceptables ?



"Il faisait tellement chaud ! j'avais besoin de m'échapper, un sentiment d'étouffement et de perte de conscience, envie de vomir" Marie M.



"Avoir de l'eau à bord aurait sans doute aidé un peu. J'ai été un peu choqué du manque de réaction car il y avait plusieurs personnes âgées dans la voiture" Simon D.

"Pas le choix, je me suis donc résignée ! Heureusement, j'avais un bon bouquin..." Clara S.



"Tout le monde était assez assommé... mais pas d'énerverment, plutôt du fatalisme partagé. Il y a une dame qui a fait une crise de panique" Jean L.



Témoignage d'un agent/d'un contrôleur ?

Quels types d'actions pourraient être prises par anticipation ?

■ Vous paraîtraient acceptables, envisageables, préférables :

- Des investissements ad-hoc :
 - pour des infrastructures et équipements plus résistants,
 - pour le maintien ou le développement de plus d'itinéraires de substitution,
 - Pour des aménagements dédiés (ex. ombrières, fontaines)
- Des actions en faveur d'une capacité accrue à gérer les crises et à revenir rapidement à la normale :
 - Nouvelles technologies (ex. smart).
 - Evolutions des doctrines et de l'organisation
- Un renforcement de l'agilité de l'entreprise et de sa capacité à réagir hors-crisis
 - Evolution des technologies utilisés, des modes d'organisation (ex. des travaux), des pratiques de maintenance ; expérimentations ; REX dédiés.
- Des évolutions de l'offre et des services tenant compte de la nouvelle donne climatique

#Confort #fiabilité #innovation #agilité #résilience #robustesse #sécurité

Merci pour votre participation



Atelier d'architectes - et Alors ? <http://www.etalors.eu>

Cette manière de présenter le changement climatique vous paraît-elle utile ? A approfondir ?

Des retours, commentaires, questions sur l'atelier ou le projet ?



Les inondations dans le Sud pourraient coûter jusqu'à 650 millions d'euros

Le Monde.fr | 09.10.2015 à 15h34

ledauphine.com

ACTUALITÉS DÉPARTEMENTS FRANCE/MONDE FAITS DIVERS SPORTS MONTAGNE
ANN | ALPES DE HAUTE-PROVENCE | HAUTES-ALPES | ARDECHE | DRÔME | SUD ISÈRE | NORD ISÈRE | SAVOIE | HAUTE-SAVOIE | VAUCLUSE | COMMUNES |
> ledauphine.com

Feu de forêt : trafic SNCF perturbé

LA QUESTION DU JOUR

Mardi 24 août 2016

Votre journal en version PDF
Télécharger l'édition du jour
+ 28 jours d'archives

LADÉPÊCHE.fr

Mise 23 février, 18:24 Saint-Augustin

Actualité - Grand Sud - Haute-Garonne - Toulouse

La SNCF distribue de l'eau en gare et surveille l'état des rails

Publié le 06/07/2015 à 09:48. Mis à jour le 06/07/2015 à 07:37

Transports - Canicule



LA GARANTIE VOYAGE

Chère cliente, cher client,

Vous avez prévu de voyager avec SNCF le 29/08/2017 sur le train 6869 au départ de TOULOUSE MATABIAU et à destination de MONTPELLIER ST-RO.

Nous vous informons qu'en raison des conditions climatiques exceptionnelles, la circulation de votre train 6869 est susceptible d'être perturbée. En effet, les épisodes de canicule peuvent avoir un impact sur le matériel et les installations (liés à la dilatation des voies d'un point de vue technique, plus de détails sur sncf.com). Par mesure de précaution, des limitations de vitesse des trains sont mises en place avec pour conséquences des allongements de temps de parcours.

Par ailleurs, pour votre bien-être, nous vous recommandons de vous munir d'une bouteille d'eau.

Pour consulter l'état des circulations en temps réel, rendez-vous sur horaires.sncf.com ou l'application mobile SNCF.

En voyageant avec TGV et INTERCITES, pour tout parcours en France, vous bénéficiez de LA GARANTIE VOYAGE dont les conditions d'application spécifiques sont notamment consultables sur sncf.com.

SNCF vous remercie de votre compréhension.

Ce jeudi 28 juillet, un incendie s'est déclaré entre Nîmes et Millhaud vers midi. Il a détruit 3 hectares de proussailles en bordure de la voie ferrée. La SNCF a prévenu l'interruption du trafic le temps que les fumées disparaissent.

Une trentaine de sapeurs-pompiers sont intervenus aux alentours de midi et, vers 13 heures, sur la route reliant nîmes à Millhaud, l'incendie était en phase d'extinction. Même si le trafic des trains n'était pas gêné, en dehors des fumées qui se dégageaient de l'incendie, la SNCF a préféré interrompre le temps que le feu soit totalement maîtrisé. Du côté de l'autoroute A9, seuls deux véhicules perturbés sur les trois dans le sens de circulation nord-sud.

A 14 h 30, le trafic SNCF avait pu reprendre et la troisième voie de 1,69 avait été reconstruite.

Intempéries : le trafic SNCF perturbé après des coulées de boue dans le Languedoc-Roussillon

Plusieurs TGV étaient bloqués dans le Languedoc-Roussillon dimanche soir à cause de coulées de boue dues au mauvais temps. Le trafic a repris progressivement dans la nuit de dimanche à lundi.

PAR LA RÉDACTION NUMÉRIQUE DE RTL, AVEC AFP PUBLIÉ LE 23/08/2015 À 20:10

Canicule : la SNCF est-elle mal préparée aux coups de chaud sur les rails ?

Par L. Ols

Publié le 02-07-2015 à 18:25

Ile-de-France : contre la canicule, 70 000 éventails distribués par la SNCF



La SNCF a distribué gratuitement 70 000 éventails pour lutter contre la chaleur lors de la canicule. Les éventails sont distribués gratuitement dans les gares de la SNCF. (RTL)

ACCUEIL SECOURS
2015
ÉVALUÉS

SNCF : 1.000 passagers débarqués après une panne de climatisation dans un TGV Paris-Marseille

CHALEUR Plus de 1.000 passagers ont fait escale à Auxerre après une panne de climatisation dans leur Paris-Marseille...

Maison, Auxerre | Publié le 05/07/17 à 21:57 - Mis à jour le 05/07/17 à 22:10

DIRECT. Canicule : importants retards dans plusieurs gares parisiennes

La forte chaleur perturbe le trafic en région parisienne. Certains trains accusent des retards de près de deux heures.





La SNCF gère les incertitudes

Dominique Bomstein

Prévoir des mesures concrètes d'adaptation au changement climatique sans données locales précises est un exercice délicat auquel la SNCF s'essaie en s'appuyant sur son expérience de gestion de crise.

La publication du Plan national d'adaptation au changement climatique en 2011 est l'élément déclencheur des réflexions de la SNCF sur le sujet. Une première analyse a ainsi listé les impacts attendus sur les infrastructures, les gares et le matériel roulant, mais pas seulement. Elle a également pris en compte les conditions de travail des personnels (240 000 salariés) et plus globalement les conséquences sur les modes de vie et la mobilité des Français. Mais le groupe ne part pas de rien. « Nous avons déjà mené des travaux sur l'influence de la météo sur la circulation des trains, par exemple en croisant les données de régularité avec les données météo de vent, de températures minimale et maximale et de précipitations. Du fait de l'impact important de la chaleur et du froid sur nos matériels, nous connaissons le degré de sensibilité des différentes installations. Là, il s'agit d'aller plus loin avec la difficulté des incertitudes

des scénarios », explique Christian Dubost, directeur du développement durable du groupe. Ce dernier entame donc une deuxième phase de réflexions plus opérationnelles qui va se poursuivre pendant douze à dix-huit mois. « On pourrait aller jusqu'à revoir les référentiels techniques des matériels », ajoute Christian Dubost.

Mais là aussi, la SNCF dispose d'une longue expérience. « La vulnérabilité des composants métalliques à la chaleur est déjà très surveillée, tant sur les caténaires que sur les voies. Et sur les infrastructures, nous appliquons déjà des coefficients de sécurité plus élevés, comme pour le dimensionnement des piles de ponts des ouvrages d'art pour tenir compte des risques de fortes eaux », précise Bernard Torrin, directeur développement durable de SNCF réseau.

La difficulté n'est pas technique car beaucoup de solutions existent déjà. « Par exemple, les infrastructures de la future ligne à grande vitesse au Maroc sont adaptées aux fortes températures », explique Bernard Torrin. Elle est de faire les bons choix d'investissement. « Le ferroviaire est un secteur de temps long. Les

matériels roulants que nous commandons, la voie que nous posons aujourd'hui seront encore là en 2050. Les décisions d'aujourd'hui nous emmènent donc loin, d'où l'importance d'intégrer les évolutions climatiques », pointe Christian Dubost. Reste qu'aujourd'hui, il faut apprendre à mieux gérer les risques d'événements extrêmes jusqu'à anticiper l'accueil des passagers en gares. « Nous avons noué un partenariat avec Météo-France pour suivre toutes les alertes et prendre les meilleures décisions. Avec un principe de précaution : mieux vaut un train supprimé qu'un train naufragé », ajoute-t-il. La SNCF travaille particulièrement sur le risque d'inondation. En 2014, elle a élaboré un plan de protection contre les inondations sur la zone Paris-Ile-de-France. Elle planche maintenant sur un plan de continuité d'activité (PCA) national qui devrait être terminé en 2017. Cet outil doit décliner l'ensemble des dispositions à prévoir pour répondre à une situation de crise, organiser la continuité des activités en mode dégradé et leur redémarrage dès le retour à la normale. Un élément majeur de la stratégie d'adaptation du groupe. |

Illustration(s) :

SNCF

Les inondations et les glissements de terrain suspendent le trafic et mettent à mal les infrastructures.

SNCF SE PROJETTE DANS LE MONDE ENVIRONNEMENTAL DE DEMAIN

Adaptabilité. Depuis octobre 2015, Vivian Dépoues conduit une thèse sur l'appropriation par SNCF des données scientifiques sur le changement climatique, en appuyant son analyse sur la ligne Nîmes - Perpignan. Point d'étape avec le chercheur et Jean-François Ruiz, directeur du pôle Environnement et Développement durable à la direction territoriale Languedoc-Roussillon.

LES INFOS : Quelle a été la genèse de votre thèse ?

Vivian Dépoues : Avec I4Ce, un centre de recherche et d'aide à la décision sur les questions liées au changement climatique, nous avons proposé à la direction du Développement durable de SNCF un sujet de thèse sur ce thème. Avec son accord, j'ai débuté mon étude intitulée « Pour un système ferroviaire adapté aux changements climatiques : des connaissances scientifiques à l'analyse économique dans la prise de décision ». Cofinancée par l'Ademe*,

I4Ce, SNCF et SNCF Réseau, elle est inscrite à l'université Paris-Saclay.

Jean-François Ruiz : SNCF met en œuvre des projets à très long terme, qui sont donc impactés par le fait que le climat sera vraiment différent dans quarante ans. Il importe d'appréhender ce changement, et d'en déduire les solutions à adopter dès à présent.

LES INFOS : Quel est le périmètre de votre étude ?

V. D. : Je voulais comprendre comment un acteur économique, dont le métier

est complexe au quotidien, perçoit l'information scientifique sur l'évolution du climat et ses effets sur le territoire. Et de quelle manière il peut l'intégrer dans sa stratégie de développement et ses processus de décision.

J.-F. R. : Nous nous concentrons sur la ligne Nîmes - Perpignan. Elle est de fait concernée, étant sujette aux inondations, à la sécheresse, aux risques d'incendie, au vent... avec un contexte de plus en plus hostile. Nous devons nous poser des questions telles que : doit-on la laisser au milieu des étangs ?

Faudra-t-il modifier la fréquence de remplacement de ses rails ? Prévoir une autre maintenance ? Comment traiter la végétation ? Autant d'interrogations valables pour SNCF Réseau, Intercités ou Gares & Connexions.

LES INFOS : Où en êtes-vous ?

V. D. : J'ai rencontré des représentants de M & T, I & P, Gares & Connexions et du Matériel, afin de connaître les enjeux, les priorités, le mode de gestion du groupe et la façon dont il intègre les questions climatiques. J'ai rendez-vous, d'ici à décembre, avec une trentaine d'acteurs de la liaison Nîmes - Perpignan, afin d'identifier une approche d'aide à la décision et de l'expérimenter, via la comparaison d'options d'adaptation. La dernière étape consistera à valider leur pertinence et ce, jusqu'en octobre 2018.

J.-F. R. : Ces entretiens, puis leur analyse, déboucheront sur un diagnostic et des conclusions relatives au système ferroviaire, qui nous aideront à prendre des décisions argumentées.

Propos recueillis par S. B.

* Agence de l'environnement et de la maîtrise de l'énergie.

ADAPTATION AU CHANGEMENT CLIMATIQUE



— Politique

Suite à la sortie de différents documents nationaux et internationaux tels que :

- les rapports du GIEC ;
- la Communication du 16 avril 2013 de la Commission européenne sur la stratégie européenne d'adaptation au changement climatique ;
- le premier plan national d'adaptation au changement climatique 2011-2016 (PNACC) lancé par la loi Grenelle 1 ;
- le rapport Jouzel sur l'évolution du climat français à l'horizon 2050 ;

SNCF a pleinement pris conscience que les évolutions climatiques vont nécessiter une adaptation du système ferroviaire d'ici à 2050 et 2100. Compte tenu de la longue durée de vie des équipements et infrastructures ferroviaires, ces évolutions

doivent être anticipées. Celles-ci sont de plusieurs ordres :

- l'augmentation du niveau général des températures, en particulier dans la moitié sud du pays ;
- la diminution probable des précipitations ;
- l'évolution du trait de côte ;
- la fréquence accrue des événements extrêmes (canicules, fortes précipitations et inondations, tempêtes...).

Pour adapter le système ferroviaire, SNCF développe une méthode aux approches complémentaires :

- une vision de la résilience du système ferroviaire dans son ensemble en croisant une vision de détail centrée sur les questions de confort ou d'accessibilité des clients et une vision liée à l'exploitation ferroviaire ;
- une différenciation entre les enjeux d'adaptation dans la conception des nouvelles infrastructures ou les travaux de régénération par rapport aux enjeux d'exploitation et de gestion des circulations
- une contribution aux groupes de travail ad hoc des instances de normalisation nationales (AFNOR) et européennes (CEN/CENELEC) ;
- la réflexion locale en lien avec d'autres parties prenantes (clients, État, collectivités locales, autres gestionnaires d'infrastructure).

En 2016, la thèse de 3 ans lancée en 2015 en partenariat avec l'Université de Saint Quentin en Yvelines, I4CE (Institute for Climate Economics), l'Ademe, SNCF et SNCF Réseau sur l'appropriation des connaissances scientifiques pour la prise de décision en matière d'adaptation au changement climatique a suivi son cours et va inclure une étude de cas en Languedoc-Roussillon. Elle a donné lieu à la publication d'un premier papier de réflexion générale intitulé « Modernisation du système ferroviaire français et changement climatique » :

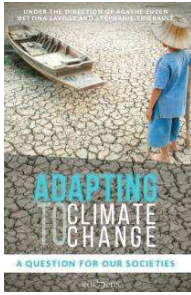
<http://www.i4ce.org/wp-core/wp-content/uploads/2016/11/PC-Modernisation-du-syst%C3%A8me-ferroviaire-et-changement-climatique-1.pdf>

Par ailleurs, deux études ont été lancées en 2016 avec un consultant spécialisé dans les questions Climat/énergie :

- la première étude porte sur des indicateurs changement climatique au niveau national définis en fonction de l'analyse sur plusieurs années de la météo-sensibilité de l'exploitation ferroviaire. En effet, la réflexion climatique et celle sur la météo-sensibilité sont étroitement liées.;
- la seconde étude porte sur le périmètre Transilien et vise à identifier les conséquences du changement climatique pour l'exploitation ferroviaire et les clients et à proposer des recommandations d'adaptation

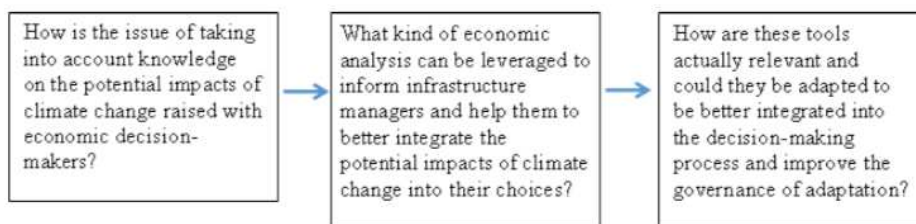
Les résultats de ces deux études sont attendus en 2017.

Rapport RSE Groupe SNCF 2016, pp61-62



“[...] Heat softens the sciences

[...] Other sciences enlisted by SNCF include economic analysis and organizational sociology. SNCF and SNCF Réseau (Network) are co-financing, with ADEME (the French environment and energy management agency) and I4CE (the Paris-based Institute for Climate Economics) a thesis entitled “From scientific knowledge on climate change to economic analysis for decision-making for infrastructure adaptation”¹. This project aims to analyse how scientific knowledge about climate change is adapted by economic decision-makers such as infrastructure managers and how economic analysis could be more effectively leveraged to translate this into operational elements for adaptation-related decision making.



Vivian Dépoues, research fellow at I4CE and ADEME PhD student at CEARC (Cultures, Environments, Arctic, Representations, Climate in collaboration with the University of Versailles Saint-Quentin-en-Yvelines and the Paris-Saclay University), took the Languedoc rail artery as her field of investigation. Together with its feeder lines, this artery combines most of the major issues related to climate change: heatwaves, proximity to the sea (some parts of the line are only one or two metres above level) and frequent (and unfortunately often fatal) floods.

Climate change: the time for action is now

The thesis presented in the previous section fits well with central question concerning adaptation today: decision-making. How can a company, which is necessarily focused on the short term (for SNCF, ensuring the safety and comfort of four million passengers every day), reflect and act to take climate change into consideration?

This is the heart of the matter: effective adaptation of the planet/ of the French territory requires spending time and especially money to plan for the future. In a world in crisis, this is not the least of our difficulties. SNCF is, as with many other things, a witness, a fairly faithful reflection of our country. [...] »

Dubost, C. (2017). SNCF: face to face with climate change. In B. Laville, A. Euzen, & S. Thiébault (Eds.), *Adapting to Climate Change: a question for our societies* (CNRS Editions).

Modernisation du système ferroviaire français et changement climatique

Oser penser des transformations profondes pour des réseaux robustes et adaptés

Paris, novembre 2016

Rédigé par Vivian Dépoues

RÉSUMÉ

Ce Point Climat cherche à inscrire les questionnements sur l'évolution du système ferroviaire français dans la dynamique de transition vers une économie neutre en carbone, résiliente et adaptée aux changements climatiques. Compte-tenu de la durée de vie de plusieurs dizaines d'années des infrastructures et du rôle structurant des formes de mobilités sur les territoires, les choix qui vont être faits doivent être cohérents avec les objectifs définis par l'Accord de Paris sur le Climat, le Paquet Energie Climat européen et la Loi de transition énergétique. Bien conduite, la modernisation des réseaux peut être une incroyable fenêtre d'opportunité pour ancrer des trajectoires de développement économique compatibles et cohérentes avec ces objectifs. Réciproquement, tenir compte en amont des enjeux climatiques permet d'éviter les effets de verrouillage¹ et d'anticiper les impacts potentiels des changements climatiques sur des systèmes qui y sont souvent vulnérables.

Si la transition énergétique dessine une vision de plus en plus claire de ce qui est souhaitable, des incertitudes profondes existent sur des paramètres jusque-là considérés comme stables tels que les conditions climatiques. Cette situation oblige à réinterroger nos manières de planifier et de décider en explorant une plus grande diversité de possibles plutôt qu'en essayant de se projeter dans un futur probable. Cette ouverture invite à être imaginatifs, à envisager des ruptures, à intégrer des évolutions de valeurs et de modes de vie. Les outils de planification et d'aide à la décision doivent s'adapter pour rendre compte de ces attentes dans un processus transparent, dynamique et robuste.

Inscrire la modernisation du système ferroviaire dans la transition vers une économie neutre en carbone et adaptée aux changements climatiques

Le système ferroviaire est un des systèmes critiques² dans la structuration des chaînes de valeur européennes et nationales. Il participe à l'aménagement du territoire et à l'organisation des mobilités et donc de l'activité économique. En France, l'état des installations ferroviaires est jugé préoccupant et les besoins d'investissements sont très importants³. La concurrence d'autres modes de transport, la libéralisation du secteur, ses rigidités et son niveau d'endettement⁴ posent par ailleurs des questions quant à son avenir. Les réformes récentes et notamment la réforme ferroviaire de 2014 n'ont pas su totalement y répondre. Des opérations lourdes de modernisation sont pourtant en cours. En 2015 et 2016, SNCF, aux côtés des Régions, a investi près de 5 milliards d'euros par an dans la modernisation du patrimoine ferroviaire. Cet effort devrait se poursuivre mais demeure insuffisant pour rattraper le sous-investissement chronique de ces dernières décennies.

Les interventions de renouvellement et de modernisation du réseau doivent être hiérarchisées, en tenant compte des contraintes budgétaires mais également d'une vision stratégique du futur de la mobilité. Comme le souligne un récent rapport du Sénat⁵, il est nécessaire de dépasser les controverses isolées sur tel ou tel grand projet⁶ et de mettre en cohérence les choix et les investissements à faire. La transition vers une économie décarbonée, résiliente et adaptée au changement climatique peut et doit être un axe stratégique de ces choix.

¹ « Lock-in », blocage dans des choix qui pourraient s'avérer coûteux et peu judicieux dans une économie post-carbone.

² Qualifié par la Commission Européenne de « *critical infrastructure* » dans un rapport sur l'adaptation des infrastructures au changement climatique (2014)

³ Voir notamment l'audition des dirigeants de SNCF et SNCF par le Parlement en mars 2016. Des ralentissements doivent par exemple être imposés sur 4000 km de voies ferrées pour garantir la sécurité des circulations en attente de travaux.

⁴ La dette de la SNCF s'élève en 2016 à 52 milliards d'euros, dont 44 concernent le réseau

⁵ Commission des finances sur le financement des infrastructures de transport du Sénat. (2016). « Infrastructures de transport : sélectionner rigoureusement, financer durablement ». www.senat.fr/notice-rapport/2015/r15-858-notice.html

⁶ Voir pour les projets en cours et récents : www.developpement-durable.gouv.fr/Selection-de-grands-dossiers-et.htm

.....

A chaque grand moment de développement des infrastructures d'un pays correspond une certaine conjonction de technologies - énergétiques, de transport, de communication⁷ et de financement - mais également un modèle organisationnel et une vision du développement du territoire. La structure des réseaux de transport d'une économie bas carbone et adaptée aux changements climatiques ne pourra qu'être très différente du modèle dominant au siècle dernier mais reposera en Europe en grande partie sur les systèmes dont nous héritons qui doivent se transformer. Les experts s'accordent pour dire que des infrastructures compatibles avec les objectifs climatiques ne seront pas beaucoup plus chères à condition de bien s'y prendre, suffisamment en amont : au moment de la planification, de la conception et du renouvellement des systèmes.

La transition énergétique contribue à clarifier l'horizon en fixant un cap. Il s'agit maintenant de s'assurer que les choix qui sont faits et les arbitrages qui sont rendus sont en cohérence avec ce cap. La modernisation et le renouvellement des infrastructures de mobilité mêlent des enjeux de politique industrielle, de protection de l'environnement, de développement territorial et de maintien de certains services considérés comme acquis⁸. Ce sont des processus complexes, influencés par de multiples facteurs et marqués par des incertitudes profondes. Rien ne permet d'affirmer que les tendances que nous lisons sont totalement robustes. Il ne faut pas négliger le caractère extrêmement rapide, possiblement brutal, irréversible et toujours fondamentalement incertains des changements climatiques et de leurs implications, ni sous-estimer l'ampleur des transformations à venir. Parfois de simples ajustements suffiront mais pas toujours.

Un peu de prospective climatique et ferroviaire

Dans un contexte de transitions, marqué par les incertitudes, il est toujours intéressant d'explorer une diversité de futurs possibles. C'est l'objet de la prospective qui procède en identifiant, parmi la multiplicité des facteurs

d'évolution du monde, quelques variables qui pourraient être particulièrement motrices des changements à venir. En jouant de ces variables sur un spectre suffisamment large, il est possible de dessiner des scénarios contrastés de l'avenir qui éclairent sous un angle nouveau le présent. L'objectif n'est pas tant d'imaginer de quoi demain sera fait de manière certaine (et après ?/what's next ?) mais bien ce qu'entraînerait un futur possible ou probable (et si ?/what if ?)⁹. Le secteur du transport et des mobilités est coutumier de ce type de démarches et sait bien explorer les scénarios technologiques et/ou d'évolution de la demande. Ces exercices permettent de nourrir les réflexions et les débats sur le développement de nouvelles infrastructures, l'aménagement des territoires, l'évolution des modes de vie, etc. (ex. Transports 2050¹⁰ en France, travaux du McKinsey Global Institute¹¹, études préalables à la réalisation de grands projets type LGV). L'intégration du changement climatique dans ces réflexions est par contre nouvelle et potentiellement disruptive, elle se décompose en deux questions :

- **Celle de la place du secteur du transport dans la dynamique de transition vers une économie neutre en carbone.** Cette dimension recouvre à la fois des enjeux d'efficacité énergétique : quelle(s) source(s), quel(s) vecteur(s) d'énergie, quel mix technologique¹², etc. ; et de sobriété : quelle évolution des modes de transports, des usages et des formes même de nos mobilités¹³.
- **Celle des conséquences sur le secteur des transports des impacts climatiques que nous n'avons et que nous n'aurons pas su éviter et le rôle des acteurs de la mobilité dans l'adaptation de nos sociétés et de nos économies à ces changements.**

Si la première question fait l'objet de nombreux travaux et réflexions et a déjà été au centre de démarches prospectives (voir par exemple les travaux de l'ADEME¹⁴ ou certaines démarches internes d'entreprises), la seconde offre un terrain encore peu arpenté. Même sans réaliser formellement l'exercice de prospective qui demanderait d'approfondir plusieurs scénarios de changement climatique (par exemple un scénario +2°C, un scénario plus

⁷ Comme le formule Jeremy Rifkin en théorisant sa Troisième Révolution Industrielle

⁸ Comme a pu l'illustrer l'actualité de ces derniers mois autour de sujets comme le sauvetage d'Alstom, la fermeture de lignes de trains de nuit, la mise en place de « cars Macron » ou les conflits autour de grands projets comme Notre Dame des Landes ou le Barrage de Sivens.

⁹ Nidhi Kalra. *What if? The key to making good decisions.* (2016). TEDx Manhattan Beach www.youtube.com/watch?v=17w-ngKDZag

¹⁰ Démarche initiée et conduite par le Conseil Général des Ponts et Chaussées en 2006 www.ladocumentationfrancaise.fr/var/storage/rapports-publics/064000342.pdf

¹¹ McKinsey Global Institute. (2012). www.mckinsey.com/~media/mckinsey/dotcom/client_service/automotive%20and%20assembly/pdfs/mobility_of_the_future_brochure.ashx

¹² L'électricité et l'hydrogène sont par exemple deux vecteurs dont le développement est très souvent mis en avant en substitution des combustibles fossiles même si le mix technologique idéal est encore loin d'être évident.

¹³ En regardant par exemple les projections de croissance du trafic aérien on se rend bien compte que l'optimisation technologique ne sera pas suffisante pour réduire les émissions et atteindre les objectifs fixés par l'Accord de Paris. Il faudra donc s'interroger : devra-t-on, pourra-t-on se déplacer moins, plus lentement, autrement ? La mobilité deviendra-t-elle (encore) plus exclusive ?

¹⁴ ADEME. Mobilité et transport : vision prospective. (2014) www.ademe.fr/expertises/produire-autrement/mobilite-transport-vision-prospective

probable de +3 ou +4°C et un scénario pessimiste de +5 ou +6°C), il est possible de tracer quelques lignes d'analyse à même d'alimenter les discussions sur l'avenir d'un secteur comme le transport ferroviaire. Certains acteurs de la filière ont déjà conduit ce type d'études dans le cadre de leurs réflexions prospectives. C'est par exemple le cas du transporteur DHL¹⁵ dont certaines des hypothèses et des conclusions nous ont servi de source d'inspiration ici.

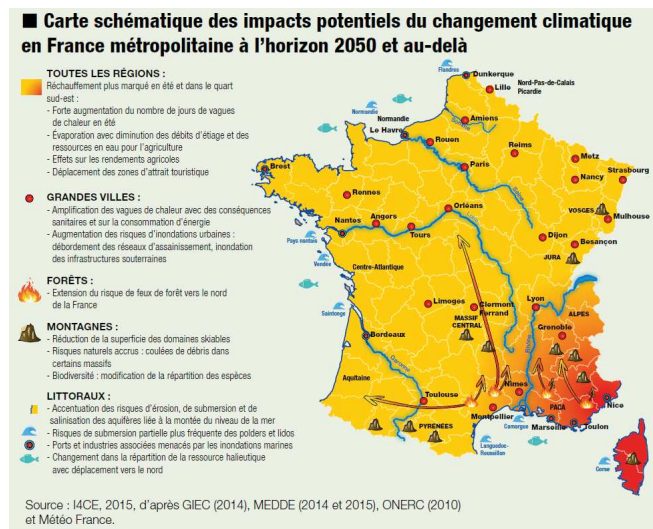
ET SI NOUS VIVONS DANS UN MONDE A +3, +4 OU +6°C ?

Les projections et travaux de recherche existants permettent d'imaginer dans les grandes lignes à quoi

pourrait ressembler un monde fortement impacté par le changement climatique.

A l'échelle de la France, la série des Rapports Jouzel et les données disponibles sur le [portail Drias](#) (ou le portail [Climat HD](#) pour une visualisation rapide et grand public) proposent des scénarios régionalisés de référence décrivant le climat au 21^{ème} siècle (figure).

Pour un éclairage sectoriel, [l'atlas Impact2C](#) décrit quels seraient les impacts sur différents pans de l'économie d'un réchauffement moyen de 2°C (sans présager du moment auquel ce seuil sera atteint)¹⁶.



Les principales incertitudes qui demeurent sur les changements climatiques concernent la trajectoire de réduction des émissions de gaz à effet de serre que nous allons suivre. D'un scénario à l'autre, ces trajectoires peuvent significativement varier dans la 2^{ème} moitié du siècle mais sont relativement proches pour les décennies à venir. Choisir de travailler avec un scénario d'émission en particulier – miser sur l'atteinte des objectifs de Paris ou au contraire privilégier un scénario dans lequel l'empreinte carbone de nos économies resterait très forte - n'est pas une question scientifique mais bien un choix stratégique dépendant de la vision que l'on porte sur l'évolution du monde : quel futur veut-on explorer, quelle tendance perçoit-on ? De tels choix sont communs pour tout décideur habitué à avancer dans un environnement incertain. Une fois un scénario choisi, les scientifiques sont en mesure de

fournir des projections assez précises et fiables de ce à quoi pourrait ressembler le climat de demain¹⁷.

Parmi les grandes tendances à l'horizon 2050 - d'autant plus marquées on étudie des scénarios d'émissions pessimistes - on peut retenir deux types d'impacts :

- Des changements progressifs et notamment : une hausse des températures moyennes de 0,6 à 1,3°C, une hausse significative du niveau de la mer et un décalage des saisons.
- Une évolution de la variabilité des événements climatiques extrêmes : augmentation du nombre de jours de vagues de chaleur en été (plus de canicules et de sécheresses), diminution des extrêmes froids et épisodes de pluies intenses plus fréquents¹⁸.

¹⁵ DHL. Delivering Tomorrow. Logistics 2050 A Scenario Study. (2012) www.dhl.com/content/dam/Local/Images/e0/aboutus/SpecialInterest/Logistic%2050/szenario_study_logistics_2050.pdf

¹⁶ Voir, <http://drias-climat.fr/>; www.meteofrance.fr/climat-passe-et-futur/climathd et <http://atlas.impact2c.eu/>. Il existe également des projections à l'échelle européennes. Une analyse globale des effets du changement climatique et des impacts socio-économiques est également disponible dans le volume 2 du 5^{ème} rapport d'évaluation du GIEC, paru en 2014.

¹⁷ Pour des informations plus détaillées ou plus spécifiques, un travail dédié entre gestionnaires d'infrastructures et producteurs de données climatiques et nécessaires et débute par une formulation claire des situations critiques à étudier.

¹⁸ Voir, Yiou, P. Jouzel, J. (2016). Le temps s'est-il détraqué ? : comprendre les catastrophes climatiques. Buchet-Chastel.

Une pluralité de risques est associée à ces impacts, par exemple l'accroissement et l'extension des feux de forêts, une augmentation des risques d'inondations urbaines ou encore, la réduction de la superficie des domaines skiables.

L'horizon 2050 souvent utilisé pour établir les projections est particulièrement critique dans le secteur des transports. Il correspond en effet à la durée de vie des infrastructures et des équipements qui sont conçus et construits aujourd'hui. Par exemple, une voie de chemin de fer a vocation à rester en place plusieurs dizaines d'années, un matériel roulant dont la conception commencerait aujourd'hui serait mis en service après 2020 et circulerait encore en 2050.

Les analyses de vulnérabilité existantes des systèmes ferroviaires – notamment à l'étranger¹⁹ – tendent à démontrer que ces derniers sont relativement robustes (i.e. capables de continuer à opérer même si les conditions évoluent) et seront a priori peu impactés directement par les évolutions de températures ou de précipitations moyennes. Ils sont par contre beaucoup plus vulnérables aux événements extrêmes comme les inondations, les vagues de chaleurs ou les tempêtes.

Jusqu'ici le système a pu être conçu et entretenu en s'appuyant sur les statistiques météo passées établissant un climat considéré comme stable : des températures moyennes, des périodes de retour d'événements extrêmes, et donc des probabilités d'occurrence et un risque bien circonscrit contre lequel se prémunir. Mais ces statistiques sont remises en cause par les changements climatiques. Les conditions limites de fonctionnement pourraient être atteintes beaucoup plus souvent, multipliant les situations de crise et renforçant le stress sur l'organisation du système²⁰.

UNE SOCIÉTÉ QUI S'ADAPTERAIT

Certaines voix s'élèvent dès aujourd'hui pour agir au maximum par anticipation et se préparer aux changements à venir. De nombreux travaux démontrent en effet qu'une action précoce permettrait d'éviter de douloureuses crises et serait économiquement bien moins coûteuse²¹. Que ces voix soient entendues ou non, il est certain que l'on assistera à des adaptations, à minima réactives au fur et à mesure que les changements seront constatés et ressentis. Même sans pouvoir prévoir comment chaque acteur socio-économique va réagir individuellement, il est facile d'imaginer que les déterminants stratégiques de la mobilité seront affectés. Les flux de déplacements devraient évoluer

avec la variation des productions primaires, de la demande touristique, du coût de l'énergie ; les contraintes pesant sur les conditions d'exploitation des matériels ou encore l'univers réglementaire devraient être modifiés.

Parmi toutes les possibilités d'évolution, les hypothèses retenues dans le scénario « *Global Resilience – local adaptation* » de DHL illustrent très bien le type de questions intéressantes à se poser. Les auteurs de cette étude envisagent notamment la multiplication des événements extrêmes mettant en tension les chaînes logistiques internationales et source de coûts importants. En réaction, ils postulent une régionalisation des circuits de production et de consommation. Le maintien de la sécurité d'approvisionnement entre les boucles régionales deviendrait alors une priorité. La fiabilité prendrait plus de place dans le service de transport que seraient capables d'offrir différents opérateurs et deviendrait un avantage concurrentiel fort. Garantir cette fiabilité demanderait le développement de systèmes plus redondants, proposant des options de secours et des solutions de repli telles que des entrepôts pour mettre les marchandises transportées à l'abri en cas d'interruption du trafic. Ces installations seraient bien évidemment coûteuses mais jugées nécessaires par la société car sans elles, chaque rupture des circulations aurait un impact économique inacceptable. Une des dynamiques notables de ce scénario est le basculement dans un univers économique très différent, moins marqué par la recherche d'optimisation des ressources et de maximisation de l'efficacité que par celle de robustesse et de sécurité. Les réorganisations territoriales et sectorielles seraient également très importantes, favorisant les acteurs les plus agiles et capables d'opérer à des échelles différentes.

Une autre tendance à explorer est celle de l'évolution de la demande de mobilité à cause des évolutions du climat. Les flux touristiques pourraient par exemple être parmi les premiers affectés en hiver - avec une diminution des activités de sports d'hiver en moyenne montagne, la neige se raréfiant – et en été, avec un gain d'attractivité de littoraux plus septentrionaux que ceux qui sont actuellement les plus fréquentés.

FIABILITE ET CONFORT CLIMATIQUE : NOUVEAUX ELEMENTS DE DIFFERENTIATION ?

Cet exercice ouvre plusieurs axes de réflexion. Historiquement, chaque mode de transport s'est développé

¹⁹ Voir par exemple UIC. (2011). ARISCC-Adaptation of Railway Infrastructure to Climate Change. Final report. Nolte, R Berlin, I Z

²⁰ Voir : « La SNCF gère les incertitudes ». Environnement Magazine. 23/02/2016

²¹ I4CE. (2015). ClimacCOPe #5 : l'adaptation au changement climatique www.i4ce.org/download/climascope-5-ladaptation-aux-changements-climatiques-2/

en mettant l'accent sur certaines caractéristiques. L'automobile a misé sur le confort du véhicule individuel et l'autonomie qu'il procure, l'avion offre la possibilité d'aller vite et loin, jusqu'ici le train a insisté sur la sécurité et la vitesse et est très attendu sur sa ponctualité.

Dans un futur où l'environnement physique traversé sera radicalement différent, les priorités et les spécificités de chaque mode pourraient être réinterrogées.



Anciennes affiches publicitaires : arguments marketing mis en avant par différents modes de transport, source Gallica

Fiabilité. Si aujourd'hui ce qui compte est d'aller vite, loin et d'être à l'heure, peut-être que demain les voyageurs et les transporteurs de marchandises seront surtout prêts à payer pour être sûrs d'arriver sans encombre dans un temps raisonnable même si l'heure exacte d'arrivée n'est pas précise à la minute. Fiabilité et sécurité deviendraient ainsi des arguments de différenciation encore plus importants que la vitesse et la ponctualité. Alors que les modes de transport sur un territoire sont à la fois en concurrence et complémentaires, être celui sur lequel on peut toujours compter peut devenir un atout majeur.

Confort. Les conditions de voyage ont toujours constitué un élément de différenciation entre solutions de transport. La plupart des opérateurs cherchent à offrir le meilleur confort à des usagers dont le niveau d'exigence ne cesse de croître. Les paramètres climatiques sont aujourd'hui un des déterminants critiques du confort aux différentes étapes des trajets. Un transport collectif ou des lieux d'attente non protégés de la chaleur peuvent par exemple être rédhibitoires et inciter les usagers à choisir un déplacement en véhicule individuel climatisé, peu importe la dépense énergétique ou la congestion des routes. Ce facteur est encore plus important en situation perturbée, si ces dernières sont appelées à se multiplier, alors il devient indispensable de s'assurer qu'elles ne seront pas trop inconfortables à vivre pour les usagers et les personnels. Il en va du fonctionnement même des systèmes car un usager ou un agent se sentant mal peut aggraver la crise²².

Développer la fiabilité et le confort comme nouveaux points forts du transport ferroviaire pourrait représenter une nouvelle source de valeur commerciale pour les clients et sociale pour les territoires. La prospective expose ce type de pistes, mettre l'accent sur tel ou tel atout relève ensuite de choix stratégiques et politiques.

SOMMES-NOUS SUR LA BONNE VOIE ?

Bien entendu, le changement climatique n'est pas le seul facteur déterminant des choix qui doivent être faits. Il peut par contre être un prisme au travers duquel examiner certaines des options favorisées aujourd'hui :

- Même en présence d'options de transport concurrentes (ex. aérien, autoroutes et autocars), conserver un bon réseau ferroviaire permettrait de disposer de plus d'itinéraires alternatifs et donc de renforcer la résilience des économies, d'autant que la transition énergétique pourrait mettre à mal certaines des alternatives (par exemple si le trafic aérien devait être réduit).
- Le changement climatique est un argument de plus justifiant le fort niveau de priorité à accorder à l'entretien et au renouvellement des infrastructures existantes afin de réduire leur vulnérabilité au climat et d'être certains de pouvoir compter sur elles. Choisir de maintenir les ressources et l'attention allouées aujourd'hui à la sécurité et à l'entretien courant des réseaux peut être un pari d'autant plus payant demain si le risque augmente.
- Plusieurs grandes gares sont en cours de renouvellement. Favoriser les complexes mieux intégrés au tissu urbain,

²² A l'image de passagers de RER qui immobilisés dans un train non climatisé décident de forcer l'ouverture des portes et de descendre sur les voies se rafraîchir, perturbant encore plus la circulation sur le réseau. Voir par exemple

« Canicule : incidents en série sur le réseau Transilien », Le Parisien, 1/07/2015. www.leparisien.fr/info-paris-ile-de-france-oise/trafic-ralenti-sur-l-ensemble-du-reseau-transilien-01-07-2015-4910539.php

adaptés aux spécificités des conditions climatiques locales (ex. gares bioclimatiques) contribuerait à assurer ce niveau de confort tout au long du voyage. La tendance actuelle est de penser des aménagements intérieurs facilement modifiables pour s'adapter plus facilement à l'évolution des attentes clients²³. Cette flexibilité est indirectement un atout car elle permettra aussi de s'adapter aux évolutions du climat à moindre coût.

- Le développement récent d'offres de mobilité intégrées, couvrant les trajets « porte à porte » contribue au renforcement de la coordination entre les différents acteurs du transport²⁴. L'expérience d'une telle coordination ne peut qu'être positive pour offrir des solutions complètes aux usagers dans des situations de stress climatique.
- L'orientation des nouveaux projets et investissements dans l'innovation pourraient être interrogée au regard de ces perspectives climatiques. Pour certains la vitesse demeure un idéal de progrès comme l'illustre l'emballement médiatique autour du projet Hyperloop. Cette « fascination pour la vitesse »²⁵ est pourtant à nouveau discutée, comme elle a pu l'être lorsque certains maires ont fait le choix de la piétonisation et de transports publics lents en réaménagent leurs centres villes.

Des pistes et des outils pour équiper la décision

La prise en compte des enjeux climatiques est encore peu intégrée aux prises de décision sur le développement du ferroviaire. Trois raisons peuvent être avancées pour cela :

- i. La première est le besoin d'une vision intégrative capable d'assurer une cohérence entre les agendas politiques climatique, territorial et de transport ;
- ii. La deuxième est le manque d'interactions entre spécialistes du climat et acteurs des débats sur les infrastructures qui ne permet pas la mise en discussion de nombreux paramètres intégrés tels quels dans les discussions – par exemple la démographie, l'évolution de l'implantation des activités sur un territoire, de l'urbanisation, des préférences des usagers ou des risques – alors qu'ils peuvent être très sensibles aux

changements climatiques et fortement influencés par les actions prises pour y faire face. Plusieurs formats sont envisageables pour renforcer ces interactions, au travers de coopérations techniques, de programmes de recherche communs ou encore de partenariats industriels ;

- iii. La troisième est la faible capacité des outils de décision actuels à intégrer ces dimensions. Les outils de planification par exemple restent encore largement déterministes et s'appuient sur des statistiques issues des périodes passées et des tendances, intégrant difficilement les ruptures potentielles. Les outils d'analyse économique comme l'analyse coût-bénéfice, l'analyse-coût efficacité ou les analyses multicritères rencontrent également plusieurs limites, bien décrites dans la littérature. Face à un phénomène comme le changement climatique : elles ont notamment beaucoup de mal à gérer l'incertitude et l'incapacité à attribuer des probabilités claires à l'évolution de paramètres auxquels elles sont très sensibles.

La manière de structurer les discussions, les acteurs invités autour de la table et les outils d'aide à la décision mobilisés font partie intégrante du processus de construction d'une stratégie. Comme nous l'apprennent la sociologie et les sciences de gestion²⁶, les outils ne sont pas neutres : ils incarnent et ils participent à la réalisation d'une certaine vision du monde. Les évolutions successives du secteur ferroviaire ont d'ailleurs historiquement été un des terrains privilégiés de l'élaboration et de l'expérimentation d'instruments de calcul comme la valeur actualisée nette²⁷. La perte récente d'influence du calcul économique est aussi le signe, comme constaté par Y.Crozet ou O.Godard²⁸, que les outils classiques ne sont plus en mesure de rendre compte des situations actuelles et de ce à quoi il s'agit d'accorder de l'importance. En partageant ce constat, il est possible et de mobiliser des outils alternatifs et/ou complémentaires capables de le dépasser. Trois dimensions sont importantes à intégrer : la transparence, la robustesse et enfin la flexibilité et l'agilité.

²³ « Les architectes redessinent les gares pour transformer les quartiers ». AFP. 16/10/2016. www.afp.com/fr/infos/258/les-architectes-redessinent-les-gares-pour-transformer-les-quartiers

²⁴ Voir par exemple la stratégie « porte à porte » de SNCF Mobilités (www.sncf.com/ressources/groupe_sncf_excellence_2020_cp_octobre_2013.pdf). D'autres expériences allant dans le même sens peuvent être citées, par exemple à l'été 2016, la RATP a travaillé avec des acteurs du covoiturage pour assurer de façon totalement intégrée une alternative à ses clients pendant une phase de travaux prolongés qui a interrompu la circulation du RER A pendant plusieurs semaines. Voir : « La RATP propose du covoiturage pour les usagers du RER A ». Le Figaro. 7/072015.

²⁵ Voir par exemple certains commentaires à l'égard du projet américain : « Hyperloop, ou une certaine fascination pour la vitesse ». Eric Vidalenc, blog

Alternatives Economiques. 26/05/2016. <http://alternatives-economiques.fr/blogs/vidalenc/2016/05/26/hyperloop-ou-une-certaine-fascination-pour-la-vitesse-22/>

²⁶ Voir par exemple les travaux de Callon, M. & Muniesa, F. Doganova, L., Chiappello, E. & Gilbert, P.

²⁷ Sur ces sujets voir notamment les travaux historiques de Mazoyer, H. ou de Finez, J.

²⁸ Crozet, Y. (2004). Calcul économique et démocratie : des certitudes technocratiques au tâtonnement politique. Cahiers D'économie Politique, 2(47), 155–172. & Godard, O. (2004). Autour des conflits à dimension environnementale Évaluation économique et coordination dans un monde complexe. Les Cahiers D'économie Politique, 47

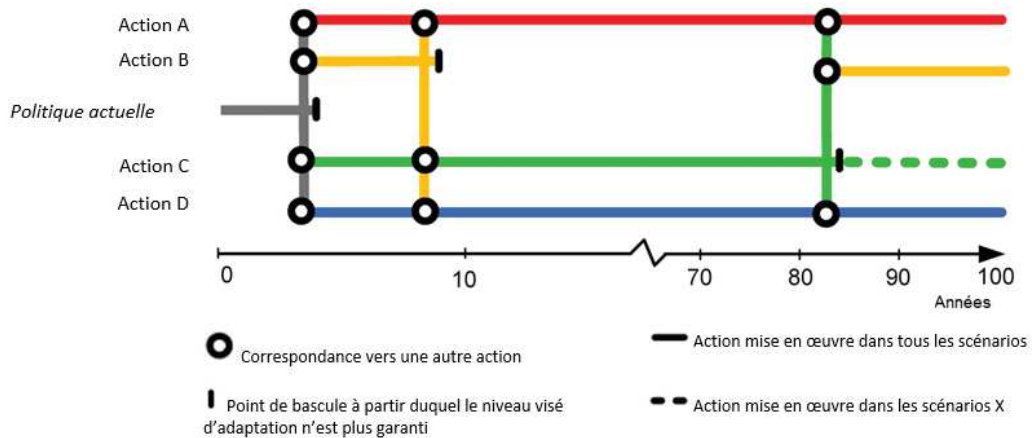
Transparence : il s'agit de s'éloigner des modèles de décision opaques, souvent qualifiés de « boîtes noires » qui rendent impossible toute discussion sur les hypothèses de base utilisées. Au contraire, l'ensemble des variables de la décision doivent être rendues visibles pour être interrogées et discutées.

Robustesse : à défaut de savoir exactement de quoi demain sera fait, il est préférable de tester la robustesse des différentes options face à une multitudes d'évolutions possibles. Dans certains cas, il vaudra mieux opter pour une solution qui ne maximise pas les bénéfices dans le cas le plus probable mais s'avère être une bonne solution dans une grande variété de possibles. De nombreux choix de conception et de développement d'infrastructures (ex. systèmes de drainage, ouvrages d'art, localisation de lignes) et de matériels (ex. type de climatiseurs) qui sont faits aujourd'hui, souvent de la même manière qu'hier, pourraient être confrontés à des scénarios de changement climatique afin d'en évaluer la robustesse²⁹. Se demander comment réagirait le système dans certaines situations inhabituelles doit faire partie de la grille d'analyse des choix d'aménagement et d'organisation des transports.

Agilité et flexibilité : on ne peut plus penser un système de manière figée et statique, trop d'évolutions devront pouvoir être intégrées au fur et à mesure. Il peut donc être

souhaitable de privilégier des options suffisamment flexibles, parfois réversibles et de réduire les horizons de temps de la décision. Il s'agit de ne plus privilégier une option sans se poser la question de l'échéance à laquelle elle nous amène et de la marge d'évolution qu'elle nous laisse. Il s'agit au contraire d'échelonner les décisions dans le temps, d'identifier les moments – au cours du cycle de vie des infrastructures – où des ajustements seront possibles.

Différentes méthodologies existent³⁰ pour intégrer ces caractéristiques, plus ou moins élaborés et complexes à mettre en œuvre – par exemple l'analyse par options réelles, les approches de *Robust Decision Making* ou différents outils de planifications dynamiques (ex. *Dynamic adaptation pathways*³¹). Souvent développés dans des contextes différents, plus habitués à gérer des incertitudes profondes (par exemple dans le domaine de l'eau), ces outils et surtout les principes qui les sous-tendent peuvent petit à petit être appropriés et adaptés au contexte ferroviaire français. Cependant ils ne se substituent pas à la prise de décision. Proposant une diversité d'options et de manières possibles de les articuler sous formes de trajectoires ils ne dégagent pas une bonne solution dans l'absolu mais déploient l'éventail des choix possibles, à faire collectivement.



Exemple de représentation des trajectoires d'adaptation utilisée dans l'outil *Dynamic Adaptation Pathways* (Haasnoot et al. 2013).

²⁹ Lempert, R.J. Infrastructure Design Must Change with Climate. The Rand Blog – 12/08/2016. www.rand.org/blog/2016/08/infrastructure-design-must-change-with-climate.html

³⁰ Voir par exemple les approches expérimentées au sein de l'Association pour la prise de décision en contexte d'incertitude profonde (<http://deepuncertainty.org/>). Plusieurs panoramas des outils également existants dans la littérature : ex. Dittrich, R., Wreford, A., & Moran, D. (2016). A survey of decision-making approaches for climate change adaptation: Are

robust methods the way forward? Ecological Economics. ou Hallegatte, S., Shah, A., Brown, C., Lempert, R., & Gill, S. (2012). Investment Decision Making Under Deep Uncertainty: Application to Climate Change. Policy Research Working Paper, (6193)

³¹ Haasnoot, M., Kwakkel H, J., Walker, W., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world, 23(2), 485–498.

CONCLUSION

Emblématique de la révolution industrielle, le rail peut sembler à certains dépassé – incarnant un âge des infrastructures lourdes, énergivores et particulièrement rigides dans une époque d'agilité³². Pourtant, c'est aussi un réseau déjà en place qui a ses atouts et a déjà su profondément se transformer par le passé en faisant notamment évoluer ses technologies et son organisation - jusqu'à changer de vecteur énergétique en passant du charbon au diésel et à l'électricité. Pressé de clarifier une vision des mobilités et du réseau ferroviaire du futur, le décideur public a aujourd'hui à sa disposition une multitude de visions exprimées³³, des informations et des outils dont il peut se saisir pour explorer les possibles et éclairer ses choix malgré les incertitudes qui les entourent. Cependant, c'est in fine une vision stratégique assumée et des moyens de la mettre en œuvre et de la rendre acceptable qui sont attendus. Cette vision ne peut pas uniquement être un plan de développement du transport et doit s'inscrire en cohérence avec les grandes dynamiques d'évolution des économies et des territoires, notamment climatiques. Elle doit même activement contribuer à ancrer la transition vers une économie bas carbone et adaptée au changement climatique dans les trajectoires de développement des territoires. Elle doit envisager sans détours des transformations d'ampleur de l'économie, de la société et de l'environnement enchevêtrés pour privilégier des choix robustes et un mode de gestion dynamique.

REMERCIEMENTS

L'auteur souhaite remercier Benoit Leguet, Cécile Bordier & Alexia Leseur (I4CE), Christian Dubost & Antoine Rothey (SNCF) pour leurs retours et commentaires.

Ce Point Climat s'appuie sur des réflexions développées dans le cadre d'une [thèse cofinancée par l'ADEME, SNCF et I4CE \(2015-2018\)](#)³⁴ sur l'aide à la décision et l'adaptation des infrastructures au changement climatique, mais n'engage pas ces institutions.

Pour en savoir plus ...

- Agence Européenne de l'Environnement. (2014). "Adaptation of transport to climate change in Europe: challenges and options across transport modes and stakeholders." www.eea.europa.eu/publications/adaptation-of-transport-to-climate
- Duron, P. (2013). Mobilité 21 « Pour un schéma national de mobilité durable ». Rapport au ministre chargé des transports, de la mer et de la pêche.
- Forum Vies Mobiles <http://fr.forumviesmobiles.org>
- New Climate Economy. (2016). The Sustainable Infrastructure Imperative. <http://newclimateeconomy.report/2016>
- Portail du service Drias. Les Futurs du Climat. <http://drias-climat.fr>
- Projet Européen TopDad. (2014) Adaptation and resilience in the transport sector. www.topdad.eu/upl/files/120163
- Richard, E. (2016). L'adaptation aux changements climatiques : les réponses de l'action publique territoriale. Presses universitaires de Rennes.
- Travaux du WRI sur les transports www.wri.org/tags/transportation
- Vallejo, L., & Mullan, M. (2016). The role of government in making infrastructure investment climate resilient – Draft survey of current practices. OECD [www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WPCID\(2016\)2&docLanguage=En](http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WPCID(2016)2&docLanguage=En)
- Watkiss, P., & Hunt, A. (2013). Method Overview: Decision Support Methods for Adaptation, Briefing Note 1. Summary of Methods and Case Study Examples from the {MEDIATION} Project.

³² Par ex., Cahen, P. « Ne posons plus de rail ». La Tribune - 20/10/2015, www.latribune.fr/opinions/blogs/signaux-faibles/ne-posons-plus-de-rail-513730.html ou Gorrieri, S. « Et si la SNCF disparaissait ? ». IFRAP – 19/05/2016, www.ifrap.org/agriculture-et-energie/et-si-la-sncf-disparaissait

³³ Avec des contributions d'une grande diversité d'acteurs comme les collectivités ou les associations d'utilisateurs : ex. ARF ([http://regions-](http://regions-france.org/publications/communiqués/zoom-volet-transport-mobilite-de-plateforme-etat-regions)

[france.org/publications/communiqués/zoom-volet-transport-mobilite-de-plateforme-etat-regions](http://regions-france.org/publications/communiqués/zoom-volet-transport-mobilite-de-plateforme-etat-regions)), FNAUT (Manifeste des usagers pour le renouveau de la mobilité ferroviaire. Septembre 2016 www.fnaut.fr/images/docs/actes/2016rail2020/manifefnaut.pdf).

³⁴ Détails sur www.i4ce.org/ro_project/prendre-decisions-infrastructures-adaptees-aux-changements-climatiques/

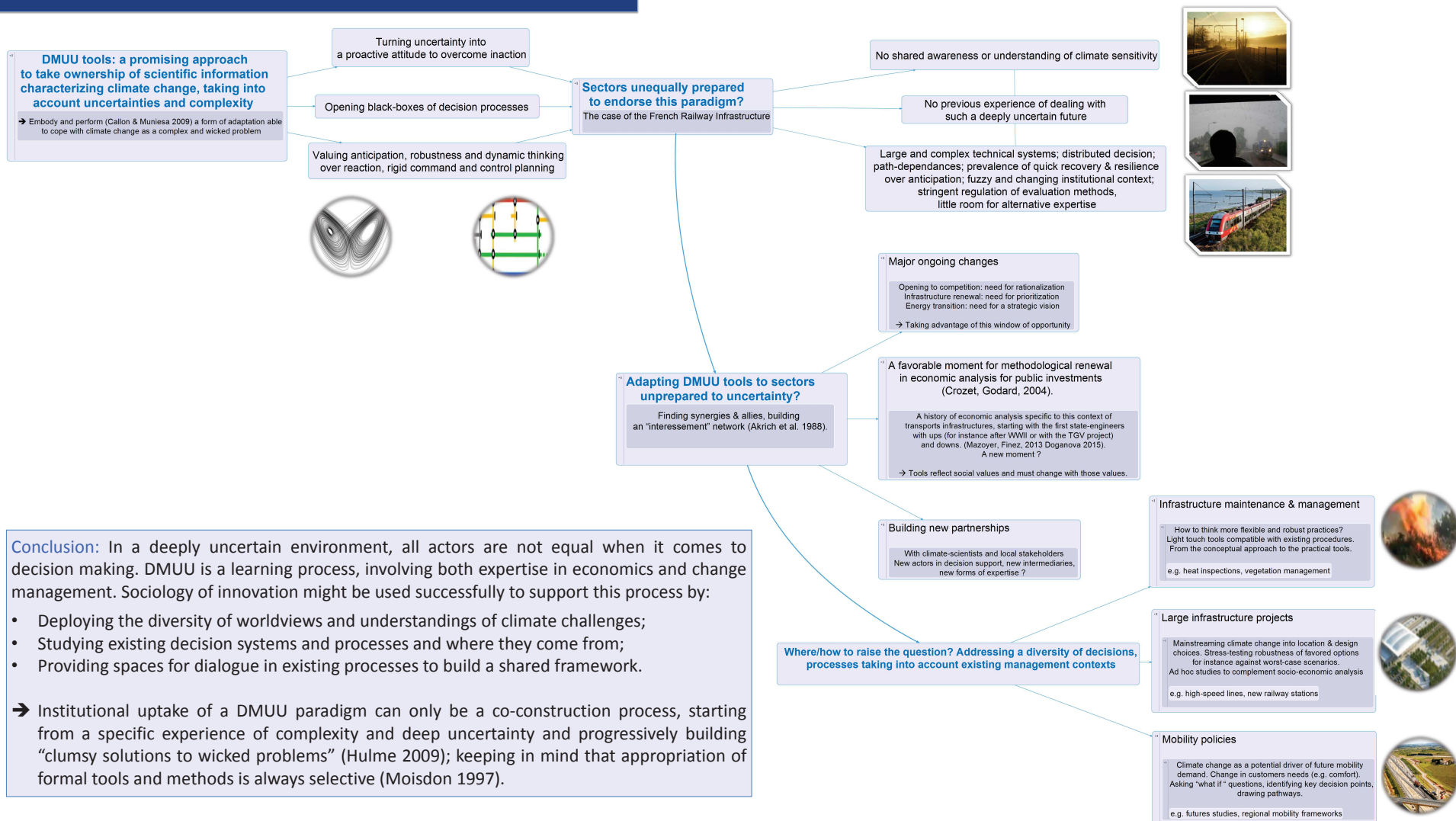


Uptaking a robust approach and DMUU tools to adapt infrastructures to climate change? The example of the French railway network

Vivian Dépoues - as part of a doctoral project supervised by par Jean-Paul Vanderlinden (UVSQ-CEARC) & Tommaso Venturini (Kings College, SciencesPo.), in partnership with ADEME, I4CE and SNCF.

Exploring how an infrastructure manager can take ownership of scientific information characterizing climate change, taking into account uncertainties and complexity:

DMUU tools as a promising approach to reach this objective? **How to make them fitted to sectors unprepared to uncertainty?**



Adaptation des réseaux aux changements climatiques : comment poser la question ?

Infrastructures et adaptation des territoires

Les gestionnaires d'infrastructures et de réseaux sont parmi les premiers acteurs économiques à devoir s'interroger sur les conséquences des changements climatiques en cours¹ sur leur activité. Le cycle de vie des décisions qui caractérisent leurs installations correspond en effet au pas de temps caractéristique de ces changements : les infrastructures construites ou modernisées dans les prochains 5 à 10 ans vont structurer les économies et les territoires jusque dans la seconde partie du 21^{ème} siècle. Les choix technologiques et d'organisation qui vont être faits à court terme vont fortement conditionner les modèles énergétiques, d'aménagement, les flux de mobilité et de communication de la période à venir. Ils caractériseront aussi leur capacité d'adaptation et de résilience à des conditions climatiques différentes de celles expérimentées par le passé.

Des exigences accrues de redevabilité

La perception sociale de ces changements a elle aussi évolué dans la période récente et se caractérise aujourd'hui par une attention accrue de la société-civile et une exigence plus forte de transparence et de redevabilité. Les pouvoirs publics, les associations, les usagers mais également les partenaires économiques et financiers – banques, actionnaires, clients, etc. - d'une organisation peuvent être amenés à lui demander des comptes sur la manière dont celle-ci gère les risques, associés au changement climatique. Ces exigences sont renforcées par la nature systémique de ces risques dont la prise en charge est une nécessité pour la stabilité de l'économie au-delà de chaque acteur individuel. Par exemple, une collectivité locale peut interroger ses délégataires de services publics et exiger qu'ils tiennent compte des conséquences de leur activité sur la vulnérabilité et la résilience du territoire lui-même.

Risque de transition

Face aux risques du changement climatique à l'échelle globale, un objectif collectif de transformation des modèles de développement vers des économies neutres en carbone à l'horizon 2100 a été adopté lors de la COP21 à Paris en 2015. Au travers de cet Accord de Paris, l'ensemble des Etats et des acteurs socio-économique est aujourd'hui engagée dans un processus de transition énergétique². En France cet objectif est décliné au sein de la Loi de Transition Energétique pour la Croissance Verte, de politiques locales et de stratégies sectorielles.

La transition énergétique concerne toutes les activités et a des conséquences à chaque étape des chaînes de valeur. Elle est potentiellement synonyme de transformations majeures de certains secteurs comme l'énergie, le transport, l'agriculture ou encore le bâtiment. La notion de « risque de transition » est utilisée pour caractériser les impacts économiques des politiques de transition énergétique sur les activités. Ces changements peuvent en effet constituer des risques comme des opportunités par rapport auxquels chaque acteur économique doit se positionner. Des demandes de redevabilité quant à la prise en compte de ce risque commencent à se faire entendre (cf. par exemple l'article 173 de la loi de Transition Energétique pour la Croissance Verte).

¹ Le changement climatique : évolutions du fait des activités humaines des conditions climatiques par rapport aux siècles précédents pendant lesquels elles ont pu être considérées comme stables. Il s'agit de changements déjà en cours dont on connaît les grandes tendances et dont l'ampleur dépendra de la capacité collective à réussir la transition énergétique. Ces changements sont documentés dans les rapports du GIEC à l'échelle internationale et dans les rapports sur le Climat de la France au 21^{ème} siècle à l'échelle nationale

² Article 2 de l'Accord de Paris, extrait : « Pour contenir l'élévation de la température moyenne de la planète nettement en dessous de 2C° par rapport aux niveaux préindustriels en promouvant un développement à faible émission de GES ».

→ Transition énergétique et changement climatique sont des dynamiques étroitement liées à penser ensemble. Il s'agit de participer à la première tout en intégrant la deuxième. Cette note se concentre sur les impacts physiques du changement climatique sans jamais perdre de vue la transition énergétique.

Pourquoi anticiper ?

Une partie des évolutions à venir se fera par ajustements successifs et en réaction à des changements constatés. Cependant suffisamment d'éléments de compréhension sont disponibles pour adopter et démontrer une posture plus proactive et anticiper :

- Pour ne pas s'enfermer dans des impasses (lock-in) ou investir dans des équipements dont la durée de vie ou d'utilisation serait écourtée du fait du changement climatique ;
- Pour modérer les coûts de la transition qui, selon toutes les évaluations économiques seront d'autant plus élevés que nous attendrons à agir³ ;
- Pour conserver une liberté de choix stratégique et prendre part à la construction des trajectoires de changement, s'accorder sur des répartitions acceptables des coûts et des bénéfices plutôt que de les subir ;
- Pour saisir les opportunités et trouver des synergies avec les autres dynamiques d'évolutions globales ou locales, environnementales, économiques et sociales telles que les processus d'urbanisation, la transition démographique ou la révolution digitale.

Le changement climatique comme variable stratégique

Chaque activité entretient des relations spécifiques avec son environnement. Chaque organisation a sa propre histoire – technologique, économique, politique - ; évolue dans un environnement économique spécifique ; dispose de sa gouvernance propre et doit jouer avec des priorités et des leviers d'action particuliers. Ce qui peut être nouveau pour les uns, ne l'est pas forcément pour tous.

Il n'y a donc pas de façon unique de soulever la question de son positionnement et de son rapport vis-à-vis au changement climatique. Les enjeux varient énormément d'un secteur à l'autre. Cependant, les infrastructures de réseau partagent un grand nombre d'interrogations quant à leurs rapports aux impacts du changement climatique et donc à leur robustesse, vulnérabilité, résilience et capacité d'adaptation. Le changement climatique semble notamment en mesure de questionner :

Leur rapport aux conditions météorologiques et climatiques. L'importance des conditions climatiques varie avec les caractéristiques de l'activité considérée. Dans certains cas (ex. réseaux de transport) la question des conditions climatiques n'est abordée que lors de la conception et de la construction des infrastructures et oubliée ensuite, ne se manifestant à nouveau que lors d'épisodes climatiques extrêmes. Dans ces cas-là un domaine de variabilité au sein duquel le service peut être rendu est défini et bien maîtrisé. Certains secteurs y sont plus sensibles et gèrent leur météo-sensibilité de manière plus réactive, à l'échelle de saisons (ex. tourisme, transport d'électricité) voire au quotidien (ex. production énergétique). Les liens au climat peuvent être directs – par exemple au travers d'infrastructures exposés aux phénomènes météo – ou indirects, au travers de certaines caractéristiques de l'environnement (ex. végétation, qualité des sols) ou des chaînes de valeur (Garnaud & Ferret, 2009). Ce sont souvent des variables en particulier et le franchissement de certains seuils spécifiques (ex. un seuil de température,

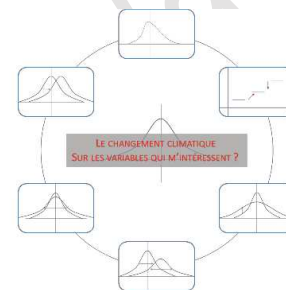
³ Cf. par exemple New Climate Economy. 2016, IPCC 2014, OCDE 2016, UNEP 2016.

un cumul de précipitations) qui sont importants à suivre pour une activité. Dans tous les cas le changement climatique peut venir réinterroger des référentiels et des pratiques considérés comme stables et acquis. Des conditions inédites peuvent se présenter, les distributions basées sur des observations passées peuvent être rendues obsolètes et ainsi affaiblir les choix de conception ou les pratiques d'organisation existantes. Ce qui était connu et maîtrisé ne l'est plus forcément.

Types d'interactions entre des installations industrielles et les conditions climatiques selon Garnaud & Ferret, 2009 :

- Disponibilité des ressources tout le long des chaînes logistiques (ex. eau, énergie, matière première) ;
- Normes de conception et de dimensionnement des composants techniques et bâtis ;
- Influence des conditions climatiques sur les procédés industriels ;
- Impact du climat sur la demande ;
- Dommages causés par des incidents ou événements climatiques extrêmes sur les infrastructures.

Au-delà des connaissances générales existant sur les changements climatiques, le phénomène acquiert ainsi une signification particulière pour chaque acteur économique : plus de variabilité pour les uns, évolutions des moyennes et décalage du domaine d'opération pour les autres ; phénomènes très localisés ou dynamiques globales selon l'organisation de l'activité ; évolutions linéaires, passages de seuils ou changements de régime, etc.



Leur rapport au temps, au changement et à l'incertitude. Le changement climatique est un phénomène en cours qui devrait s'accroître dans le futur et ce d'autant plus que la réduction des émissions de GES prendra du temps. De premiers effets commencent à se faire sentir, d'autres ne deviendront perceptibles que progressivement ou au contraire se manifesteront brusquement. Cette évolution demande de réinterroger les capacités d'adaptation – en réaction ou par anticipation – de son activité sur différents pas de temps : quels sont les horizons de planification, quelles échéances d'investissement, quelles durées des cycles de renouvellement, quelle capacité à réagir, quelles sont les marges de flexibilité existantes, comment ces différentes durées caractéristiques s'articulent avec les changements climatiques ? Les expériences passées mais également l'habitude à gérer des incertitudes – éventuellement radicales⁴ – sur l'avenir sont un déterminant clé de la capacité d'une organisation à appréhender ces transformations. En fonction de l'histoire récente (ex. ruptures technologiques ou économiques vécues⁵) et des modes d'organisation, tous les gestionnaires d'infrastructure ne s'inscrivent pas dans les mêmes trajectoires.

« L'anticipation des effets du changement climatique vient rappeler à l'homme moderne ses interdépendances oubliées » Elsa Richard

⁴ On parle d'incertitude quand on est dans l'incapacité d'attribuer une probabilité à un certain état du monde ou cours d'actions. La notion d'incertitude radicale, ou profonde est utilisée lorsque les parties prenantes à une décision ne savent pas ou n'arrivent pas à s'accorder sur un modèle de la situation ferait le lien entre les variables importantes et permettrait de raisonner à partir de certaines distributions de probabilités éventuellement subjectives (cf. par exemple <http://www.deepuncertainty.org/about-us/>). Il y a à la fois des variables dont on ne connaît pas les distributions mais également des variables non identifiées (des « inconnues inconnues »).

⁵ On peut par exemple penser aux entreprises énergétiques qui ont dû faire face aux conséquences des crises pétrolières dans les années 70 et s'adapter à des transformations durables de leur environnement économique devenu plus volatil et incertain.

Ces deux dimensions – rapport aux conditions climatiques et rapport au changement & à l’incertain - sont ainsi à considérer en relation avec :

- Les processus de gestion et d’organisation des réseaux - exploitation, maintenance, entretien - au quotidien en mettant en place des dispositifs de suivi, d’apprentissage et d’accompagnement des changements, etc.
- Les décisions tactiques de conception technique (ex. dimensionnement d’éléments ou choix d’options technologiques) en s’assurant de la prise en compte des évolutions aux étapes pertinentes.
- Les choix stratégiques et la vision du futur de son activité en osant considérer la question de la pérennité d’un certain modèle économique et en explorant comment les différentes dynamiques d’évolution structurelles à l’œuvre (changement climatique, transition énergétique, transition démographique, etc.) peuvent se conjuguer. Réaliser cet exercice nécessite de se positionner quant aux évolutions dont on veut tenir compte – celles que l’on considère comme plus probables, plus désirables et celles que l’on accepte de ne pas considérer (par exemple en termes de trajectoire d’émissions de CO₂).

Ce travail incite à penser à la fois⁶ :

- **Les continuités** : A quelles conditions (techniques, économiques, environnementales, sociales, etc.) peut-on continuer selon le modèle actuel ? Quel est le bon rythme pour accompagner les évolutions ?
- **Des ruptures** : Dans quels cas le modèle d’organisation lui-même (ou une partie du modèle) voire la nature de l’activité sont remis en cause par le changement climatique ? A quel moment devient-il nécessaire d’envisager une diversification ou une reconversion ?

Il n’y a pas de point de départ unique à partir duquel soulever ces questions. Souvent cela dépend de la raison initiale qui motive une telle analyse. Il peut s’agir par exemple d’une démarche exploratoire d’une direction de la stratégie, d’un audit des risques, d’un projet de R&D, voire de questionnements techniques remontant des activités opérationnelles – ou bien encore, de pressions exercées par les parties-prenantes externes de l’entreprise. Dans tous les cas, il est indispensable de suffisamment réfléchir à la manière de formuler les questions en tenant compte des spécificités de chaque activité et des trajectoires existantes. Le tableau ci-dessous présente quelques exemples schématiques de questions qui peuvent être posées par différents types de gestionnaires d’infrastructures :

⁶ Par exemple dans le cas d’une station de ski : la première question est celle des investissements à faire dans de nouveaux équipements d’enneigement artificiel pour assurer une continuité de l’activité hiver après hiver ; la seconde renvoie aux cas où il devient préférable de s’éloigner des activités de sport d’hiver pour proposer de nouvelles offres de valeur aux visiteurs.

Tableau 1 : exemple d'approches de questionnaires d'infrastructures pour questionner l'impact du changement climatique sur leur activité



Transport d'électricité :
identification de situations critiques inédites

Les conditions climatiques sont une variable centrale pour l'équilibre d'un réseau électrique : les températures influencent historiquement la demande (chauffage/climatisation) et, avec le déploiement des renouvelables, les précipitation, l'ensoleillement et le vent influencent l'offre. Par ailleurs le réseau de transport est exposé aux extrêmes climatiques. La continuité de l'approvisionnement en électricité étant vitale pour l'économie, les transporteurs s'efforcent d'anticiper toutes les situations possibles pour s'assurer que le réseau sera en mesure de répondre aux besoins en toutes circonstances.

Question posée par le changement climatique : le changement climatique peut-il être à l'origine de situations critiques pour le réseau jusqu'ici jamais expérimentées et si oui de quel type de situations inédites pourrait-il s'agir ?

En fonction de la réponse à cette question, des investissements sur le réseau peuvent être programmés pour assurer sa robustesse à une gamme élargie de possibilités climatiques.



Transports terrestres :
identification des vulnérabilités critiques

Les réseaux de transport terrestre (ex. routier, ferroviaire) sont conçus pour être utilisés dans certaines conditions climatiques et être capables de supporter certains épisodes exceptionnels (ex. inondations décennales ou centenales). Ces paramètres sont intégrés, souvent de manière réglementaire, dans les étapes de conception – dimensionnement, choix de matériaux, etc. – et beaucoup moins perceptibles en opérations.

Questions posées par le changement climatique : l'infrastructure existante est-elle toujours adaptée à son environnement, quels éléments des réseaux pourraient être vulnérables à certains scénarios de changement climatique ? Peut-on identifier des seuils de limite de vulnérabilité ? Peut-on localiser des portions critiques (« hotspots ») ?

Les mesures d'adaptation, souvent techniques, se concentrent sur ces zones. Dans certains cas des évolutions des référentiels techniques de conception peuvent être envisagées. cf. projets [GERICI](#), [RIMAROC](#), [ROADAPT](#), guide [CEN-CENELEC 32](#).



Transport fluvial :
risque-t-on de sortir du domaine de variabilité maîtrisé ?

L'eau fait partie intégrante du système et sa disponibilité est directement liée aux conditions climatiques. La disponibilité de cette ressource est donc suivie de près par les professionnels de ce secteur qui connaissent très bien le domaine de variabilité – débits minimum et maximum - au sein duquel le système est opérationnel.

Question posée par le changement climatique : ce domaine de variabilité historique risque-t-il d'évoluer significativement à cause du changement climatique et quelle pourraient en être les implications sur les modes de gestion de la ressource ?

Parmi les pistes d'adaptation envisageables, des mesures techniques et des mesures organisationnelles (ex. évolution vers des flottes de petites bateaux pour permettre la navigation avec des étiages moindres, création d'installations de stockage pour atténuer les pertes dues aux interruptions de navigation). cf. projet [KLIWAS](#)



Stations de sports d'hiver : à quelles conditions continuer à opérer ?

L'activité des stations de ski dépend fortement du niveau d'enneigement naturel des domaines et de la possibilité de produire de la neige artificielle. L'expérience acquise saison après saison permet à leurs exploitants de bien connaître les conditions d'enneigement minimum pour opérer.

Question posée par le changement climatique : quelles sont les conditions à réunir pour garantir une ouverture des pistes identifiées comme critiques presque tous les hivers dans les prochaines décennies ?

Réalisation des investissements permettant de réunir ces conditions qui pourront être économiquement rentables – dans le cas où, ils ne le seraient plus, diversification des activités vers de nouvelles sources de valeur (ex. tourisme vert). Cf. projet [ADAMONT](#)

*Souvent des épisodes exceptionnels ou marquants sont à l'origine des questionnements des questionnaires d'infrastructures sur ces sujets. La canicule de 2003, des tempêtes historiques ou des inondations ayant eu des conséquences importantes, une succession de saisons perçues comme difficiles (ex. enneigement, sécheresses) éveillent l'attention des décideurs.

Avant même l'interrogation des changements climatiques à venir, la première question souvent posée est alors celle de l'objectivation des tendances qui sont ressenties : les phénomènes récents ou la succession d'évènements étaient-ils vraiment inédits, ont-ils réellement été plus intenses, plus fréquents ou bien est-ce notre sensibilité à de tels épisodes qui évolue ?

*Ces dynamiques sont à penser en lien avec les autres facteurs clés d'évolution de chacun de ces secteurs, par exemple l'évolution de la structure des marchés à l'échelle européenne (ouverture à la concurrence, interconnexions des réseaux, etc.) ; les évolutions technologiques ; les évolutions des usages ou encore les transformations de l'environnement dans lequel sont implantées ces infrastructures (ex. urbanisation).

*Une dimension non abordée dans ces exemples (sauf indirectement dans celui de l'électricité) est celle des impacts des changements climatiques sur la demande : en effet, l'évolution des conditions climatiques pourra amener une évolution des besoins et des préférences de consommation des services rendus par ces infrastructures. Les flux de mobilité, la demande touristique, les consommations énergétiques ou encore la répartition des activités industrielles pourraient ainsi être amenées à évoluer. Il s'agit cependant de phénomènes complexes difficile à anticiper sans analyses approfondies. Cf. Projets [ToPDaD](#) ; [Impact2C](#), travaux de la Commission Européenne.

Des questions bien posées dont découlent des démarches d'adaptation

A partir de questions ainsi formulées peut découler une démarche spécifique de prise en compte des effets du changement climatique sur le développement, la rénovation et la gestion des réseaux d'infrastructures. La question posée (i) permet de clarifier et d'explicitier son rapport à la connaissance scientifique et son besoin d'information et (ii) cadre le type de réponse apportée.

(i) **Rapport à la connaissance scientifique et besoin d'information.** Le manque de projections très précises ou adaptées à des besoins spécifiques et l'existence d'incertitudes apparaissent souvent comme des barrières à l'adaptation. Or l'acquisition d'information complémentaire n'est pas toujours possible ou bien peut s'avérer très coûteuse. Une fois la question réellement importante pour une activité formulée, il devient possible d'utiliser beaucoup plus efficacement l'information déjà disponible et d'interagir plus facilement avec la communauté scientifique et les pouvoirs publics pour préciser ce qui a besoin d'être précisé. Il n'est ainsi souvent pas nécessaire de disposer de projections extrêmement précises et fiables de la manière dont va évoluer telle ou telle variable spécifique. L'exploration de scénarios possibles, l'avis d'experts sur la plausibilité d'un cas identifié comme critique, la réflexion autour des cas les plus extrêmes (*worst-case hypothesis*) peuvent constituer autant d'outils heuristiques à partir desquels raisonner. Le travail de formulation de la question permet également de mieux cibler les indicateurs sur lesquels il est utile d'opérer une veille, les seuils importants à détecter (*signposts*, qui pourraient par exemple correspondre à un changement de stratégie). La structuration de dispositifs de suivi, d'aide à la décision et d'interaction avec le monde scientifique peut ainsi constituer un première étape importante d'une démarche d'adaptation. De tels dispositifs peuvent prendre plusieurs formes, ex. :

- Système *monitoring* et d'ajustement progressif ;
- Exercice prospectifs à partir de projections et de quelques scénarios contrastés ;
- Exploration numérique systématique des scénarios de possibles pour identifier les cas critiques (cf. encadré) ⁷

Exercices 200 ans à climat constant proposés par Météo-France :

« Les domaines de l'Energie et de l'Assurance sont de grands pourvoyeurs d'études sur des problématiques liées à l'impact du changement climatique à l'échelle des 10-20 prochaines années. A partir du modèle climatique ARPEGE-CLIMAT, utilisé dans le cadre des simulations du GIEC, Météo-France a mis au point des séries météorologiques de données d'environnement, correspondant à 200 ans du climat actuel. Ces séries de données permettent ainsi d'établir des statistiques de durées de retour de phénomènes rares ainsi que des statistiques d'évènements croisés, à l'échelle de l'Europe » <http://services.meteofrance.com/etudes-consulting.html>. L'exercice a ensuite été reproduit à partir de modèles climatiques pour générer 200 ans de climats futurs correspondant à différents scénarios de changement climatique, permettant de détecter des évolutions dans les durées de retours de certains phénomènes critiques et d'éventuels phénomènes rares inédits.

⁷ Voir également à ce sujet les nombreux exemples développés aux Etats-Unis, aux Pays Bas ou au Royaume-Uni, par exemple par les participant à la DMDU Society : <http://deepuncertainty.org/>

- (ii) **Les types de réponses que l'on apporte à la « question » climatique.** Ceux-ci peuvent être multiples et varier dans le temps : attitude plutôt observatrice ou proactive, accompagnement progressif du changement (ex. gestion adaptative), démarche de gestion des risques - réduction, couverture, diversification -, ajustements - techniques et organisationnels. Au cours du processus d'exploration de la question il est possible de forger sa propre approche de la question reposant sur une certaine philosophie d'action – mettant par exemple l'accent sur la résistance et la protection ; la flexibilité des décisions ; la capacité d'apprentissage organisationnelle ; la robustesse (minimisation des regrets) ou encore la résilience face aux chocs. Il n'y en a pas une seule réponse possible et les choix qui sont faits sont le reflet d'une certaine vision du développement de son activité. Dans tous les cas, il n'est pas trop tôt pour se poser la question, y compris de manière prospective. S'aligner dès aujourd'hui sur des objectifs de transition (atténuation-adaptation) est une stratégie qui présente des avantages et permet de saisir des opportunités.

Conclusion

Se saisir de la question des impacts du changement climatique c'est intégrer spontanément ou sous la pression de parties prenantes extérieures cette dynamique dans son périmètre d'analyse stratégique. Il s'agit d'interroger dans quelle mesure et comment les évolutions climatiques peuvent devenir une variable structurante des décisions. Les gestionnaires d'infrastructures ont de bonnes raisons d'adopter dès aujourd'hui une attitude proactive vis-à-vis de cette question, d'une part pour être en mesure de répondre aux inquiétudes croissantes de leurs parties prenantes et d'autre part pour garder la capacité d'initiative et éviter de s'engager dans des impasses.

Le défi est d'arriver à penser ensemble des ruptures possibles et des continuités, et à combiner les horizons de temps. Les réponses apportées dépendent fortement de la manière de formuler les questions que l'on se pose. Elles s'inscrivent toujours dans une certaine vision du monde – et notamment une certaine appréhension de la crédibilité de différentes trajectoires de transition énergétique - et des évolutions socio-économiques qu'elles contribuent simultanément à façonner. Déployer ces réponses c'est clarifier la vision stratégique poursuivie en tenant compte des évolutions climatiques et se donner les moyens – par exemple en termes d'outils d'aide à la décision ou de partenariats - de la mettre en œuvre.

Les choix qui en découlent participent à l'adaptation et à la résilience des territoires et des économies aux changements climatiques. Au-delà des priorités que se fixent chaque acteur et des processus individuels engagés il est donc nécessaire de veiller à coordonner les stratégies en phase avec une vision commune de ce que constitue une démarche territoriale d'adaptation et quel but elle poursuit. Pour y parvenir il peut être utile de commencer par partager un certain nombre de pistes et d'hypothèses à explorer. La coordination n'est pas toujours évidente – par exemple lorsqu'il s'agit de déterminer quel est le niveau de robustesse socialement désirable ou le niveau de risque socialement acceptable et qui doit en porter les coûts - et doit faire l'objet de discussions démocratiques et d'arbitrages collectifs.

REMERCIEMENTS

L'auteur souhaite remercier les représentants des différentes gestionnaires d'infrastructures qui ont accepté d'échanger sur ces sujets ainsi que l'équipe d'I4CE pour ses retours et commentaires.

Cette note s'appuie sur des réflexions développées dans le cadre d'une [thèse cofinancée par l'ADEME, SNCF et I4CE \(2015-2018\)](#)⁸ sur l'aide à la décision et l'adaptation des infrastructures au changement climatique, mais n'engage pas ces institutions.

⁸ Détails sur www.i4ce.org/go_project/prendre-decisions-infrastructures-adaptees-aux-changements-climatiques/

Pour en savoir plus ...

- CEN-CENELEC. 2016. "CEN-CENELEC Guide 32: Guide for Addressing Climate Change in Standards." Brussels.
- CEREMA. 2015. "{PNACC}, Volet Infrastructures et Systèmes de Transport, Action 1 – Adaptation Des Infrastructures et Systèmes de Transport Au Changement Climatique."
- EEA. 2014. Adapting infrastructures to climate change
- EEA. 2014. "Adaptation of Transport to Climate Change in Europe: Challenges and Options across Transport Modes and Stakeholders."
- European Commission. 2014. "Adapting Infrastructures to Climate Change."
- European Commission JRC. (2015). Resilience of Large Investments and Critical Infrastructures in Europe to Climate Change. Publications Office.
- New Climate Economy. 2016. "The Sustainable Infrastructure Imperative." The Global Commission on the Economy and Climate.
- Garnaud, B., & Ferret, C. (2009). Adaptation au changement climatique et vulnérabilités industrielles. Liaison énergie francophonie, (OCT), 138-139.
- Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. Global environmental change, 23(2), 485-498.
- I4CE-Institute for Climate Economics. (2016). Modernisation du système ferroviaire français et changement climatique. Point Climat n°42.
- Larrivée, Caroline, Stéphanie O'Carroll, and Jean-Pierre Savard. 2014. "La Pérennité Des Bâtiments et Des Infrastructures." Vers L'adaptation: Synthèse Des Connaissances Sur Les Changements Climatiques 2014.
- IPCC. 2014. "Working Group II Contribution to the IPCC Fifth Assessment Report, Climate Change 2014: Impacts, Adaptation and Vulnerability." Ipcc AR5 (2014).
- OCDE. 2015. Climate Change Risks and Adaptation-Linking Policy and Economics. OECD Publishing.
- OCDE. 2016. Adapting Transport to Climate Change and Extreme Weather: Implications for Infrastructure Owners and Network Managers. ECD Publishing.
- OCDE. 2016. Les conséquences économiques du changement climatique. OECD Publishing.
- Rydge, J., Jacobs, M., & Granoff, I. (2015). Ensuring new infrastructure is climate-smart. Contributing paper for Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. New Climate Economy, London and Washington, DC.
- TCFD. 2016. "Recommendations of the Task Force on Climate-Related Financial Disclosure." Task Force on Climate-related Financial Disclosure.
- ToPDAd. 2014. "Overview of System Responsiveness to Climate Change Impacts in Energy, Transport and Tourist Sectors."
- UNEP 2016. The Adaptation Finance Gap Report 2016. Nairobi, Kenya
- WBCSD. Electric utilities. 2014. Building a resilient power sector.

Organisational uptake of scientific information about climate change by infrastructure managers: the case of adaptation of the French railway company

Vivian Dépoues^{1,2} 

Received: 16 January 2017 / Accepted: 15 June 2017 / Published online: 15 July 2017
© Springer Science+Business Media B.V. 2017

Abstract Future development and renewal of transport infrastructures have to take into account how the effects of climate change will affect these complex sociotechnical systems. This article aims at understanding how to raise this issue to ensure an efficient and systemic uptake of climate change by infrastructure managers. It reports the results of an in-depth case study conducted on the French railway company. This study identifies several adaptation dynamics: one is top-down and stems from climate change impacts; others are more bottom-up and focused on vulnerabilities. However, both types of approaches have, so far, yielded limited results. Building on the existing literature, this paper reveals critical bottlenecks to overcome in order to get the organization ready to adapt. It suggests key components of an enabling framework for a more proactive preparation to climate change and mainstreaming climate adaptation into major organisational decisions.

1 Introduction

In a context of climate change, the development and renewal of infrastructures is a critical challenge (European Commission 2013; Chappin and van der Lei 2014; Larrivé et al. 2015; Stecker et al. 2011; Masood et al. 2016; OECD 2015; Forziero et al. 2015; ToPDAd 2014). In the coming years, thousand billions of euros will have to be invested in transport, energy, water and telecommunication networks to preserve the connectivity, the efficiency and the resilience of the economies (The new climate economy 2014; Dobbs et al. 2013; Vallejo and Mullan 2016).¹ Those infrastructures will have lifetime expectancies of several decades and will therefore be exposed to the impacts of climate change.

¹Mc Kinsey Global Institute estimates global infrastructures needs between \$2.5 (current expenses) and 3.3 trillion per year—40% in developed countries.

✉ Vivian Dépoues
Vivian.depoues@i4ce.org

¹ I4CE – Institute for Climate Economics, 24 Avenue Marceau, 75008 Paris, France

² CEARC, OVSQ, University Versailles Saint-Quentin-en-Yvelines, 11 Boulevard d’Alembert, 78280 Guyancourt, France

Railways play a structuring role in the European economy as they ‘facilitate the production and distribution of goods and economic services, and form the basis for the provision of basic social services’.(European Commission 2013). In Europe, most of the railway managers are big companies founded in the nineteenth or twentieth century that today have to face important asset management challenges (e.g. ageing infrastructure, underinvestment in the last decades, important evolution of technologies and mobility patterns). Several research programs have analysed climate change implications in this context (UIC 2011; EEA 2014; Baker et al. 2010; Nemry and Demirel 2012; Koetse and Rietveld 2009; Armstrong et al. 2016), often focusing on infrastructures’ vulnerability. A few case-studies have been conducted at national and subnational levels, for instance in Sweden (Lindgren et al. 2009), Germany, Austria (Doll et al. 2014; Rotter et al. 2016) and the UK (RSSB 2015). They generally observed limited action in terms of large-scale investments but a reasonable level of awareness on climate change and a common focus on research and knowledge sharing. Very often, they focus on strengthening resilience to current hazards as a ‘no-regret’ option to start preparing for an uncertain future. This existing work also pointed at the increasing need to develop forward-looking thinking and to proactively integrate climate change concerns early in planning and decision processes. This literature shows how adaptation is not just a technical matter but also an institutional and organisational issue questioning values and priorities. As such, adaptive capacity relies on elements like governance, procedures or leadership (Berkhout 2012; Stecker et al. 2011).

This paper follows up with these projects and reports the results of an in depth analytical case study on the management of climate adaptation of the French railway system.

In France, the main player in the railway sector is a state-controlled group created in 1938 and called SNCF (Société Nationale des Chemins de Fer Français). It encompasses both the management of the network (with *SNCF Réseau*) and part of the operation of this network (with *SNCF Mobilités*). It is under the supervision of the transport department of the French Ministry of the Environment.

The French railway network is the second largest in Europe with more than 30,000 km of tracks and 3000 passenger terminals. Fifteen thousand trains use this network daily, in carry five million people and 32 Gt-km of freight every year. Climate change could produce severe disruptions in this network and adaptation is therefore a crucial collective concern. Nevertheless, where and how this issue should be raised and handled in such a big and complex organization is an issue without a straightforward answer. As a matter of fact, SNCF has about 150,000 employees and more than 650 branches—where decisions are distributed and shaped by various factors.

This paper, intends to understand how a big organisation such as a national railway network manager can mainstream and increase the internal uptake of the issue of climate change. It aims at explaining how an infrastructure manager (IM) can integrate scientific knowledge about climate change into its decision-making process in order to implement adaptation strategies.

First, materials and methods of the case study are introduced. Then the article describes two types of observed approaches to adaptation. These are qualified after the IPCC (IPCC 2014) as impact-first and vulnerability-first, depending on where they start and how they frame climate change and related uncertainties. The limitations of these approaches are discussed. The second part of this paper describes the critical bottlenecks to overcome in order to increase the organization’s readiness to adapt. Building on theoretical and empirical results available in the literature, it identifies key elements to build an enabling framework for a more proactive preparation to climate change and to mainstream adaptation into the decision-making process.

1.1 Analytical framework, materials and methods

Rooted in the field of science and technology studies (STS), this research adopts a descriptive approach and sees adaptation not only as an engineering issue but also as a sociotechnical concern (Latour 2006; Edwards 2003). It focuses on the interface between knowledge on climate change, the technical infrastructure and the organisation as part of its socio-economic environment. It questions how climate change is understood and how this affects such a complex system. Moreover, this approach takes into account how organisational, corporate and economic values affect how the system understands and deals with the impacts of climate change (Hulme 2009).

In the objective of analysing the way the organisation is integrating adaptation, the article does not intend to evaluate which approach could be more relevant or efficient. It identifies and describes various initiatives contributing to adaptation, going from incremental reactive adjustments to enhance resilience to current weather down to significant transformations anticipating future changes (Simonet 2009; Adger 2010; Kane and Vanderlinden 2015).

This research did not intend to be comprehensive but aimed at covering a diversity of management functions.² In order to do so, twenty-five in-depth semi-directed interviews supplemented by secondary sources analysis have been conducted. The interviews allowed to engage into discussion with:

- People working in different units of the company:
 - Transversal support units in charge of corporate sustainability, standardisations and procedures, socio-economic analysis;
 - Technical units in charge of design and engineering;
 - Units in charge of operation and maintenance planning and management.
- People intervening in the elaboration of adaptation strategies:
 - Representatives of the French Ministry for Environment;
 - Governmental technical agency (CEREMA);
 - French national meteorological service (Météo France).

1.2 Case study: where and how is the adaptation question raised?

The analysis shows there are many places within the organisation where adaptation dynamics can start. Indeed, we have observed several initiatives explicitly seeking to contribute to climate adaptation in different departments and along various processes.

1.2.1 First adaptation strategy observed: starting from projected impacts

In the last decades, concerns about climate change were raised by the publication of scientific results (five IPCC assessment reports between 1990 and 2015) and political discussions at

² Starting with people who previously demonstrated an interest in addressing climate change issues within the organization and were involved in previous work related to this topic. Interviews with weather data users inside business or technical unit most sensitive to weather and climate conditions complemented those discussions.

supranational and national levels. This led to the adoption of ‘adaptation plans’ at various levels of administration: ex. *EU Adaptation strategy to climate change*, *National Adaptation strategy* or *Subnational climate and energy plans*. In France, this topic appeared on the agenda in the early 2000s (with creation of the *Observatoire national sur les effets du réchauffement climatique* – ONERC in 2001) and then spread in a top-down way down to IMs. The Ministry for Environment and its subsidiary bodies³ piloted the French national climate adaptation plan (PNACC) released in 2011 (MEDDTL-DGEC 2011), in partnership with research centres, utilities and IMs companies.⁴ The process began with a demand to climate scientists for providing baseline scenarios of climate change in France. The mission, appointed by the Minister for the environment⁵ and by a climate scientist member of the IPCC, published several reports⁶ (Jouzel et al. 2014) describing climate projections for France based on three of the GHG concentration scenarios from the IPCC (RCP2.6, 4.5 and 8.5). Those reports established the basis for 20 sectorial action-sheets constituting the PNACC.

One of these sheets is dedicated to infrastructures and transportation systems. It highlights four actions:

1. General screening of the vulnerability of technical references and standards to climate change;
2. Analysis of the impact of climate change on transport demand;
3. Development of a common methodology for vulnerability assessment;
4. Realization of a state-of-the-art assessment of current vulnerability of the French transportation system.

SNCF’s contribution to this action-sheet was the starting point for an internal discussion on adaptation. The attention was mostly focused on the first action: the screening of technical standards containing references to climate parameters that needed to be updated according to the expected climate changes (CEREMA 2015).

This approach is representative of what IPCC’s reports refer to as an ‘impact-first’ approach or ‘top-down, science-first or standard approach’ (IPCC 2014 Chapter 2). Tasks are clearly distributed: science is an upstream activity that provides information for the decision about the future as a finished product.⁷ Climate projections are generated ‘for wide application, and thus are not tied to any specific choice’. Therefore, very little direct interaction is expected between climate scientists and the IMs who eventually use the information.

Climate change as an external constraint In accordance with this linear approach, climate change is knowable, controllable and constitutes a specific issue. Scientific information is provided in a top-down manner to fill a knowledge gap (Blanchard 2011) and can result for

³ DGITM (transport and infrastructures department), DGEC (energy and climate department)

⁴ This described process is in many ways similar to what has been observed in other European countries (AEE 2014)

⁵ The letter of appointment sent by the Ministry of the Environment to Jean Jouzel in July 2010, requested as an in-depth synthesis on climate scenarios to consider in order to implement the National climate adaptation plan.

⁶ On the basis on modelling work of two climate-science teams from CNRM-Meteo France (Aladin-climat model) and from IPSL (WRF model).

⁷ General insights have to be provided publically for free (while more tailored information might be sold as a ‘climate service’), the public sector playing a role of knowledge-broker through its public policies (giving an official mission to scientists and broadcasting the results through official channels, being an intermediary between information needs and information supply)

instance in the modification of an existing temperature threshold in a normalized procedure such as rail installation. Even though individuals may acknowledge the complexity of the climate system and how it interacts with the sociotechnical infrastructure system, the adaptation process itself reduces this complexity by making simplified assumptions (Kane et al. 2014), for instance causal links between impacts and vulnerability. Consequently, the proposed responses are direct and incremental. Missing pieces of information are identified and demanded to scientists with no dialogue on the feasibility, relevance or costs of the necessary research (CEREMA 2015).⁸ Climate uncertainties are treated independently from others components of the situation.

Limitations encountered: a limited appropriation across the IM activities At the end of the period covered by the 1st French PNACC (2011–2015), sensitive standards were identified but not yet updated (CGEDD 2015). This approach failed to produce an engagement strong enough to go beyond a formal assessment of the procedures.

According to interviewees who were involved in this process, it was not specific enough and not self-sufficient. Making it operational in the context of the railway system would have required a large amount of work with dedicated resources the PNACC did not provide. Moreover, no tailor-made climate change indicators were delivered beyond generic climate projections. Indeed, there is no link between indicators in the Jouzel Reports and much more specific parameters currently used in the industrial processes (for instance temperature thresholds in technical guidelines). This appears to be a critical sticking point, never called into question. Neither the availability of further customized information nor the possibility to decide without it (Dessai et al. 2009) were explored. Engaging in a direct in-depth discussion with climate scientists was not considered an option as interviewees consider that high-resolution climate projections should be publically produced and made available.

It is not the revision of norms and standards by itself that interviewees judge irrelevant but the process set up to do so at the national level which was not transversal enough. According to several interviewees, climate change will not just affect a few procedures or standards that could be easily listed, but will also have impacts across the whole railway system. Mere listing instances of climate parameters in technical documents are therefore perceived as a sign of poor understanding of the system's complexity. It assumes that it is possible to draw a linear causal link between climate impacts and standardization documents when there are thousands of interactions between the climate system and the infrastructure life cycle that are not always formalized. Moreover, the process described above, was conducted separately from related policy dynamics, such as European discussions on industrial standards and regulation. SNCF is associated with a European cross-sectoral group working on adaptation of industrial standards to climate change. Representatives of the company took part in drafting of specific technical guidelines that propose a step-by-step approach to address climate change in any standards (CEN-CENELEC 2016). SNCF executives perceive this logic of mainstreaming climate change questions into the general process standardization potentially more relevant and efficient. Applying this type of approach might have a significant effect on practice (e.g. Rotter et al. 2016; Rudberg et al. 2012; Ryghaug and Solli 2012), but this is not the direction followed through the PNACC implementation.

In a nutshell, this ad-hoc, impact-first approach struggles to address the diversity of business operations and its relationships with the climate system. It remains an incomplete

⁸ Cf. requests to scientists in the PNACC, deliverable 1, p91

process, depoliticized and far from the strategic concerns of the company. In practice, it did not succeed in considering climate change as a potential key element in the decision-making environment. Prescriptive approach to adaptation has left very little room for discussion and was very poorly appropriated throughout the firm. At the end of the day, impacts of climate change are still perceived internally as too ambiguous and not tangible enough compared to other priorities such as urgent renewal needs and security.

1.2.2 Vulnerability-first: context-centred alternatives

Enhancing adaptive capacity by focusing on weather sensitivity Public policy is not the only source of adaptation concerns within the company. A few people in various positions in the organisation tried to raise this question locally. They did it when providing feedback on their everyday activity, or when writing the specifications of new materials or infrastructure components. They did not refer to the institutionalised adaptation process described in the previous section.

Those ‘adaptation intrapreneurs’⁹ know very well how the system is exposed to the weather and what its main vulnerabilities are. Most of them share a common diagnosis about the French railway network being globally robust to potential climate changes. Some extreme events might produce disruptions difficult to deal with,¹⁰ but there are also large security margins: stabilized renewed railways tracks can for instance withstand temperatures up to 60 °C. Recent drainage systems and major engineering works are designed to cope with at least a 1:100-year flood event.

In addition, adaptation measures are implemented continuously in a reactive mode. After the 2003 heat wave, which caused major disruptions due to track deformations and severe deterioration of travel conditions, SNCF took important measures: release of a reinforced heat wave contingency plan, establishment of an annual heat-day for a check-up of critical equipment, adjustment of temperature class specifications for the new regional rolling-stock, modernization of decision support tools to optimize monitoring and maintenance, etc.

Willing to go beyond reaction, punctual initiatives intend to improve the understanding of the existing interactions between the infrastructure components and climatic conditions. This is perceived as a first necessary step to improve readiness and to anticipate what the consequences of climate change might be. Indeed, there is, for now, very little aggregated quantified information about the impact of weather on the French railway system.¹¹

Example 1: an improved understanding of the relationships between the railway infrastructure and weather Taking the opportunity of the renewal of weather service contracts, representatives from different SNCF departments launched initiatives to improve the understanding of the relationship between the railway infrastructure and weather. Through cross-analysis of weather data (observations and forecasts) and infrastructure data, those

⁹ Entrepreneur from the inside of a large organization

¹⁰ Rail buckling during heatwaves, fires because of droughts, flash-floods in the south of France, landslide because of heavy rain (Stamos et al. 2015). Old infrastructure and equipment are particularly vulnerable to this type of events.

¹¹ Similarly to the UK (NetworkRails 2017), understanding the impact of weather events on the railway comes a long way. There was attempts to perform economic estimations of those impacts, for instance on the cost of maintenance (Gaudry and Quinet. 2014), but this aspect has not been fully addressed yet.

initiatives pursue several objectives such as detecting current vulnerabilities, providing a better picture of the capacity of the system to absorb shocks, designing indicators directly relevant for various management operations, improving decision making tools and updating technical standards and guidelines.

One of them aims at matching the internal incident databases with weather observations. Its primary goal is to improve the understanding of individual disruptions and of the conditions associated with them. A second one is the adoption of a decision-support software to trigger and conduct heat-inspections of tracks. A robust statistical relationship was thus established and validated to replace the former empirical approach. This operation aims at reducing the number of non-useful inspections conducted and useful inspections not conducted.

Example 2: a historical approach to crisis management A research project conducted in the Engineering and projects department of SNCF-Réseau¹² is exploring the benefits of a geomatics (GIS) approach to improve knowledge about flood risks for the railway network (Saint-Marc 2013). It provides descriptions and representations of past flood episodes with detailed chronologies of the events and how they were managed. The purpose is to strengthen the institutional memory in order to mainstream the culture of risk within the company. At the moment, it is indeed very hard to understand and compare individual weather events because the relevant circumstances are not systematically recorded, especially when the damages are not exceptional (Pams-Capoccioni et al. 2013). This project may lead to further developments providing a better description of the evolution of the network vulnerability through decades and questioning how the system reacts to changes.

Continuity between weather resilience and climate change adaptation These approaches are representative of what IPCC's reports refer to as a "vulnerability-first" approach (or "bottom-up", or "context-first" approach) (IPCC 2014 Chapter 2) starting with the decision-making context before considering climate change projections. These discourses are more infrastructure-centred than climate-centred. In these examples, climate change is the exacerbation of existing stresses occurring between infrastructure and the environment. While not necessarily perfectly defined or understood, climate change provides incentives to improve the knowledge about the infrastructure itself. Detailed scientific information or climate change projections are almost never quoted or used. The general objective is to ensure a continuity of service with current and future climate conditions. It is consistent with many sectorial reports exploring how utilities are adapting to climate change (Rotter et al. 2016; EEA 2014; Lindgren et al. 2009; Ryghaug and Solli 2012). There is no rupture between current ability to deal with weather events and future adaptation; actions to be taken are the result of trade-off between risks and opportunities.

Context-centred initiatives responding to day-to-day concerns at the expense of anticipation and transversality These initiatives have a priori a stronger capacity to foster the uptake of climate challenges in infrastructure management. Still, they meet some important obstacles. First, interviewees reported the prevalence of reaction over anticipation. There is a strong ability in the organisation to deal with crisis, but no culture of prevention of events that have not been experienced yet (let alone unpredictable events). Promoters of those context-

¹² This is a national department offering engineering services to business units of the group but also conducting autonomous researches.

centred initiatives describe their action as a first step to enable future evolution towards more prevention. Indeed, an enhanced knowledge of the current infrastructure vulnerability may be used as a starting point to stress-test assets and the reliability of procedures¹³ under different climate change scenarios. However, this development is not considered at this point.

A second major limitation of those approaches is their low transversality. Most of them remain context specific and poorly interconnected. There are very few interactions between various business units, phases of the infrastructure lifecycle or decision-levels where the issue is raised.

In a nutshell, these vulnerability-first approaches remain local processes of knowledge acquisition with no institutional uptake. Proposals for more strategic approaches did not raise enough interest from the top management. For instance, a prospective analysis of the climate-induced evolution of transport demand was proposed but not marked as a priority. There is no scepticism about whether there might be changes in climate, however, IMs have not considered these evolutions as potentially disruptive or as structuring drivers for the activity (Table 1).

1.3 Discussion of observations and comparison with existing literature on adaptation to climate change: overcoming bottlenecks to build collective ownership and enable proactive adaptation

In the recent years, SNCF took some steps towards an institutional uptake of adaptation to climate change. Both company executives and public authorities recognize climate change as a concern and adaptation as a challenge. However, as of now, adaptation processes have remained incomplete and do not enable the definition of a framework to generalize the uptake of this question. While the literature states that adaptation is able to disrupt classical ways of doing business (Richard 2016), it has been very difficult until now to challenge the current infrastructure management framework and go beyond weather resilience.

As described in the first part of this article, many context-based questions related to climate adaptation are raised across the company (Table 2). However, there is no consensual vision on how to describe this phenomenon and how it affects the infrastructure and the organisation. As a result, no collective ownership of the issue is built either.

A lesson learned from STS (Rittel and Webber 1973; Hulme 2009) is that the description of a complex phenomenon like climate change as a critical issue for an organization does not pre-exist. It has to be collectively built out of the relationship between this phenomenon and the sociotechnical system. Our analysis reveals serious bottlenecks that prevent management from achieving this objective. Those are quite similar to obstacles faced in other countries that have started to address them. For instance in the UK, a dedicated program called TRACCA¹⁴ funded through the Rail Safety and Standards Board, recently led to creating an adaptation strategy (NetworkRails 2017) to address the ‘lack of ownership and governance’ of adaptation.

¹³ That is, to evaluate their ability to deal with unusual and suboptimal situation.

¹⁴ The Tomorrow’s Railway and Climate Change Adaption (TRACCA) program led to the formulation of 5 objectives ‘for a railway that is safe and more resilient to the effects of weather, now and in the future’. These objectives are (1) infrastructure which is able to withstand the impact of future weather conditions, (2) rapid recovery from the impacts of adverse and extreme events, (3) improve performance and safety during adverse and extreme weather conditions, (4) leverage financial savings through reduced compensation payments and repair costs, and (5) enhance reputation and trust in the railway’s ability to manage weather events’. (NetworkRails 2017).

Table 1 Synthesis of identified limitations of current adaptation approaches

| | General interaction between management and science | Sharing a vision of climate change across the organisation | Processes and procedures for decision-making under uncertainty |
|----------------------------|---|---|--|
| Impact-first approach | Projections of future climate remaining too far from daily concern | A top down approach with no direct contact with everyday activities. No specific resources dedicated or provided for a transversal analysis. | Classical predict-then-act instruments (such as statistics-based standards) relying on a linear, centralized and deterministic framework with no consideration of potential disruptive changes or uncertainties. |
| Context-centred approaches | Robustness of current weather sensitivity to potential future changes not questioned. Scientific information about climate change not mobilized. | Context-based initiatives do not succeed to demonstrate potential consequences across the whole infrastructure organization. | Reaction systematically preferred to prevention, potential breakdown not considered. Knowledge on the infrastructure not complete yet. |

Source: author

Table 2 Examples of concerns expressed by various interviewees during our research

| Various readings of climate change | Implications for infrastructure management, types of adaptation questions raised |
|--|---|
| Climate change as a new public concern | How to respond to regulatory and policy requirements (e.g. European and national adaptation strategies)? How to accompany and anticipate changes in regulatory frameworks? |
| Climate change as a source of perturbations for technical systems and daily organization | Which adjustments or modifications can be proposed to existing procedures, practices and standards to keep them fitted for climate conditions? |
| Climate change as a source of costs & potentially enhanced stresses | Do we know how much weather events cost; can we attribute the evolution of costs to climate change? Are management choices (for instance maintenance or renewal of selected options) robust or flexible enough to handle uncertain future climate change? How to prioritize options by considering this new constraint? What type of information is needed? |
| Climate change as an uncertainty for infrastructure planning and design | Is climate change uncertainty comparable to socio-economic uncertainties? How to deal with this deep uncertainty during planning and design phases? Are currently used decision-making tools able to take it into account? |
| Climate change as a structuring driver for the future, among others | How to articulate various undergoing transition dynamics (e.g. energy transition, digital transformation, country planning, and evolutions of competitive and institutional landscapes, climate changes)? How to deal with potentially conflicting objectives and time steps? |

Source: author

This table is an attempt to characterize the diversity of adaptation questions raised by the interviewees. It does not depict the number of times either of these questions came up during the interviews. For example, more interviewees mentioned as a new public concern than as a new structuring driver of the future of railway infrastructure. Even though all the interviewees generally perceived climate change an important concern, priorities clearly differ from one department to the other

These examples as well as recent literature suggest different levers of action to enable a more proactive preparation to climate change and to mainstream adaptation into major relevant decisions.

- i. *Lack of a consistent institutional framework*: satisfying the necessary conditions for adaptation. Some of the core elements of what would constitute a consistent facilitative framework for action appeared to be lacking. The process for a national adaptation policy launched by the government was not able to facilitate them.

Alternatives paths may be explored. Many situations may provide windows of opportunity to start building a common understanding of the climate related issues across the company. It might for instance be a response to a triggering event, an institutional initiative, a planned revision of the standards, or a catalysing R&D program (Ryghaug and Solli 2012; NetworkRails 2017; EEA 2014). In any case, it is important to structure the approach in order to ensure a strong leadership from top management, set up a clear and transparent governance, enhance engagement with external stakeholders and especially the public authorities and identify possible resources to design and implement adaptation actions (Ford and King 2015). This cannot be handled separately from other ongoing processes setting both the scientific agenda (e.g. development of climate services, new research forefronts, etc.) and the structural evolution of a sector such as transportation (e.g. asset management, energy transition of institutional evolutions).

- ii. *Poor engagement with climate science*: creating opportunities for a strengthened dialogue. With stable climatic conditions, the interactions between infrastructure management and the climate system remain most of the time invisible. Indeed, the infrastructure was designed to perform properly within a range of conditions large enough to absorb weather deviations. Weather is only an issue in some exceptional circumstances (extreme temperatures during heat waves, extreme precipitation leading to floods), rare enough to be managed ad hoc as exceptional crises. Climate change disturbs this well-established relationship. With more extreme episodes and less historical data on their statistical distribution it becomes harder to keep the infrastructure fitted to different contexts (Edwards 2003). This creates new uncertainties that could be better managed with a proper use of climate change scenarios and a sustained dialogue between climate scientists and engineers that has not yet been set up. Thus, precise knowledge about climate change—with certainties and uncertainties, the complexity of the dynamics and an enhanced variability—are never considered. Yet, these characteristics are precisely what might challenge current practices.

To build a shared understanding of what climate change is, what it means for the railway system, and how it can be addressed, an iterative dialogue with scientists might be a beneficial first step. Beyond addressing specific demands for additional information, such a relationship would allow to overcome oversimplified representations of the phenomenon and to explore possible futures (Kirchhoff et al. 2013; Cash et al. 2003; Vaughan and Dessai 2014). Different arrangements can be set up like research partnerships, common research projects, business partnerships, etc. Scientific knowledge can be integrated into management in many forms: participatory vulnerability assessments (following protocols such as the one developed by Engineers Canada (2011), prospective

work based on few contrasted possible climate futures, systematic tests to assess the vulnerability of options to worst-case scenarios, etc.

- iii. *Processes and procedures not adapted to an uncertain dynamic phenomenon:* experimenting alternative decision-making tools to mainstream adaptation. The existing processes and procedures are those of a big technical organization. Tasks are divided according to a classical, homogeneous and codified industrial model. Past experiences and standard situations play an important role in shaping up these procedures. For instance, every technical document with reference to climate parameters is based on empirical evidence of past climate records (e.g. drain systems designed according to past flood patterns, the installation of continuous welded rails is calibrated for average temperatures). These characteristics reflect a rarely challenged engineering culture. They are very different from what is usually described as a relevant approach to deal with climate change, favouring diversity, flexibility, anticipation, non-deterministic planning and continuous learning (IPCC 2014 Chapter 15).

Alternative decision-making tools and methodological frameworks might be powerful and performative instruments to foster the evolution of practices. In situations such as large project conception, maintenance budget planning or standard revisions, they can contribute to operationally mainstreaming adaptation into decision-making processes. The generalization of alternative decision-making tools is a matter of corporate strategy and moves forward alongside the revision of procedures and standards. However, a first interesting step might be to experiment this type of tools at different stages of projects analysis, from design phases (to display extended costs and benefits) down to monitoring and evaluation (to provide feedback). Many methodologies, including economic analysis, decision making under deep uncertainty techniques, multicriteria decision making, social network analysis, etc. have been explicitly developed to address climate change challenges (Watkiss and Hunt 2013; Dittrich, Wreford, and Moran 2016) but have not been mobilised yet in the French transport sector. A common property of this family of approaches is to disclose any underlying hypothesis and to make every methodological option explicit and open to discussion. These methods encourage more inclusive and participative decision making processes. They also challenge business as usual thinking. For instance, they question optimal economic efficiency as a unique decision criterion by emphasising the value of flexibility (adjustability over time) or robustness (effectiveness in a broad spectrum of possible futures) as complementary valuable characteristics and by considering possible surprises. Mobilizing these tools to design an adaptive management strategy, to stress test a new management plan or to choose between options is therefore not always straightforward. They are more than additional decision-support tools—they embody and perform a “new paradigm” in decision-making, which can be hard to switch to. Indeed, any procedure of decision-making or indicator implicitly reflects underlying values and societal choices that can change with time (Muniesa and Callon 2013; Crozet 2004; Doganova 2013; Godard 2004). The experimentation with this type of instruments can therefore only be carried out as an explicit strategy in cooperation with all the relevant stakeholders including public authorities, SNCF engineers and climate scientists.

This last point shows that the needs and levers described in this article—common vision of adaptation challenges; enabling institutional framework; strategic support; relevant partnerships; adapted tools—are tightly interrelated.

2 Conclusion

This paper, through the case study of SNCF, explores where and how large and complex organisation managing a network infrastructure may raise adaptation issues. In the first part, it described two types of approaches: first, impact-centred processes focusing on the mobilization of climate science upstream, which struggle to percolate through the organization; second, localized vulnerability-centred initiatives, which strengthen current management procedures but do not bridge the gap with future climate changes. Most of them focus on resilience to current weather and do not go so far as to question future climate.

The analysis highlighted key bottlenecks at the interface between the production and the use of knowledge on climate change. Building a shared and politically backed vision of this phenomenon and formulating context-relevant questions appear to be essential steps to set the ground for an enabling framework for adaptation.

Finally, the article presented existing tools and methodologies suggesting an alternative approach to tackling adaptation challenges. These tools have not been tested in the French context yet. How such tools can be integrated in existing decision processes, in which situations it is relevant to mobilize them, what are the conditions of their acceptance and appropriation (for example in terms of credibility, salience and legitimacy (Cash et al. 2003)) remain open research questions. Tackling them would lead to a broader question about the nature of climate knowledge for a sector like transportation potentially revealing tensions within the sociotechnical system of the infrastructure interacting with its environment.

Acknowledgements This research was funded by the French National Energy and Environment Agency (ADEME), the Institute for Climate Economics (I4CE) and SNCF. The author is especially grateful to Christian Dubost, Bernard Torrin, Antoine Rothey and Sophie Jalabert (SNCF) for their valuable support to access the relevant people and material for the case study within the company. We thank Jean-Paul Vanderlinden, Tommaso Venturini, Benoit Leguet, Alexia Leseur, Igor Shichlov, Mariana Deheza, Bruno Lafitte and the anonymous reviewers for constructive feedback.

References

- Adger WN (2010) Social capital, collective action, and adaptation to climate change. *Der Klimawandel* 79:327–345. doi:10.1126/science.11.277.620
- AEE (2014) National adaptation policy processes in european countries
- Armstrong J, Preston J, Hood I (2016) Adapting railways to provide resilience and sustainability. *Proc Inst Civ Eng Eng Sustain* 169(2). Thomas Telford:1–10. doi:10.1017/CBO9781107415324.004
- Baker CJ, Chapman L, Quinn A, Dobney K (2010) Climate change and the railway industry: a review. *Proc IME C J Mech Eng Sci* 224(3). SAGE Publications:519–528. doi:10.1243/09544062JMES1558
- Berkhout F (2012) Adaptation to climate change by organizations. *Wiley Interdiscip Rev Clim Chang*, Wiley Online Library 3(1):91–106. doi:10.1002/wcc.154
- Blanchard A (2011) Reflexive Interdisciplinarity: supporting the Dialogue on the Role of Science for Climate Change. Dissertation, University of Bergen and the University of Versailles - Saint-Quentin-en-Yvelines
- Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jager J, Mitchell RB, Gustin DH (2003) Knowledge systems for sustainable development. *Proc Natl Acad Sci U S A* 100(14):8086–8091. doi:10.1073/pnas.1231332100
- CEREMA (2015) {PNACC}, Volet Infrastructures et Systèmes de Transport, Action 1 – Adaptation Des Infrastructures et Systèmes de Transport Au Changement Climatique
- CGEDD (2015) Evaluation Du Plan National D'adaptation Au Changement Climatique. CGEDD
- Chappin EJJ, van der Lei T (2014) Adaptation of interconnected infrastructures to climate change: a socio-technical systems perspective. *Util Policy* 31:10–17. doi:10.1016/j.jup.2014.07.003

- Crozet Y (2004) Calcul économique et démocratie: des certitudes technocratiques au tâtonnement politique. *Cahiers d'économie Politique/Papers in Political Economy* 47(2):155–172
- Dessai S, Hulme M, Lempert RJ, Pielke R, Dessai S, Hulme M (2009) Climate Prediction: A Limit to Adaptation. Adapting to Climate Change: Thresholds, Values, Governance. In: *Adapting to Climate Change: Thresholds, Values, Governance.*, 64–78. Cambridge University Press. doi:<http://dx.doi.org/10.1017/CBO9780511596667.006>
- Dittrich R, Wreford A, Moran D (2016) A survey of decision-making approaches for climate change adaptation: are robust methods the way forward? *Ecol Econ* 122:79–89
- Dobbs R, Pohl H, Lin D-Yi, Mischke J, Mischke N, Hexter J, Matzinger S, Palter R, and Nanavatty R (2013) Infrastructure productivity: how to save \$1 trillion a year
- Doll C, Trinks C, Sedlacek N, Pelikan V, Comes T, Schultmann F (2014) Adapting rail and road networks to weather extremes: case studies for southern Germany and Austria. *Nat Hazards* 72(1):63–85. doi:[10.1007/s11069-013-0969-3](https://doi.org/10.1007/s11069-013-0969-3)
- Doganova L (2013) Discounted future. The conception (s) of a valuation and management device (No. hal-00875287). London School of Economics, Londres
- Edwards PN (2003) Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems. In: *Modernity and Technology*, 1., 185–226
- EEA (2014) Adaptation of transport to climate change in europe: challenges and options across transport modes and stakeholders
- European Commission (2013) Adapting Infrastructures to climate change
- Ford JD, King D (2015) A framework for examining adaptation readiness. *Mitig Adapt Strateg Glob Chang* 20(4):505–526. doi:[10.1007/s11027-013-9505-8](https://doi.org/10.1007/s11027-013-9505-8)
- Forziero G, Bianchi A, Marin Herrera MA, E Silva F, Feyen L, Lavalle C (2015) Resilience of large investments in critical infrastructures in europe to climate change. doi:[10.2788/232049](https://doi.org/10.2788/232049)
- Gaudry M, Quinet, E. (2014) Correlation within SNCF Administrative Regions among Track Segment Maintenance Cost Equation Residuals of a Countrywide Model. In *Man, Environment, Space and Time-Economic Interactions in Four Dimensions*. Nomos Verlagsgesellschaft mbH & Co. KG, pp. 207–254
- Godard O (2004) Autour des conflits à dimension environnementale. *Cahiers d'économie Politique/Papers in Political Economy* 47(2):127–153
- Hulme M (2009) *Why We Disagree about Climate Change*. Cambridge. Cambridge. doi:[10.1017/CBO9780511841200](https://doi.org/10.1017/CBO9780511841200)
- IPCC (2014) Working group II contribution to the IPCC Fifth Assessment Report, Climate Change 2014: Impacts, Adaptation and Vulnerability. *Ipcc AR5* (2014)
- Jouzel J, Ouzeau G, Déqué M, Jouini M, Planton S, Vautard R (2014) *Le Climat de La France Au {XXIe} Siècle* Volume 4 Scénarios Régionalisés: Édition 2014 Pour La Métropole et Les Régions D'outre-Mer
- Kane IO, and Vanderlinden J-P (2015) L'utilisation Du Concept Polysémique de Résilience : Une Analyse Empirique En Zone Côtière. *Vertigo*, no. Hors-série 23 (November). doi:[10.4000/vertigo.16661](https://doi.org/10.4000/vertigo.16661)
- Kane IO, Vanderlinden J-P, Baztan J, Touili N, Claus S (2014) Communicating risk through a DSS: a coastal risk centred empirical analysis. *Coast Eng* 87:240–248. doi:[10.1016/j.coastaleng.2014.01.007](https://doi.org/10.1016/j.coastaleng.2014.01.007)
- Kirchhoff JC, Lemos MC, Dessai S (2013) Actionable knowledge for environmental decision making: broadening the usability of climate science. *Annu Rev Environ Resour* 38(1):393–414. doi: [10.1146/annurev-environ-022112-112828](https://doi.org/10.1146/annurev-environ-022112-112828)
- Koetse MJ, Rietveld P (2009) The impact of climate change and weather on transport: an overview of empirical findings. *Transp Res Part D: Transp Environ* 14(3):205–221. doi:[10.1016/j.trd.2008.12.004](https://doi.org/10.1016/j.trd.2008.12.004)
- Larrivée C, O'Carroll S, Savard J-P (2015) *Lapérennité Des Bâtiments et Des Infrastructures*. In: *Vers L'adaptation*. Vers L'adaptation: Synthèse Des Connaissances Sur Les Changements Climatiques 2014
- Latour B (2006) *Changer de Société, Refaire de La Sociologie*. La découverte
- Lindgren J, Johnsson DK, Carlsson-Kanyama A (2009) Climate adaptation of railways: lessons from Sweden. *Eur J Transp Infrastruct Res* 9(2):164–181
- Masood T, McFarlane D, Oarlikad AK, Dora J, Ellis A, Scholing J (2016) Towards the future-proofing of UK infrastructure 28–41. doi:[10.1680/jinam.15.00006](https://doi.org/10.1680/jinam.15.00006)
- MEDDTL-DGEC (2011) *Plan National D'adaptation Au Changement Climatique : 2011–2015*
- Muniesa F, Callon M (2013) 8. La performativité des sciences économiques. In *Traité de sociologie économique*. Presses Universitaires de France, France, pp. 281–316
- Nemry F, Demirel F (2012) Impacts of Climate Change on Transport: A Focus on Road and Rail Transport Infrastructures. *JRC Working Papers*. Directorate growth & innovation and JRC-Seville, Joint Research Centre. doi:[10.2791/15504](https://doi.org/10.2791/15504)
- NetworkRails (2017) *Network rail weather resilience and climate change adaptation strategy 2017–2019* 1

- OECD (2015) Climate change risks and adaptation: linking policy and economics
- Pams-Capoccioni C, Coeur D, Chenier D, Chazelle B, Saint-Marc C, Lang M. (2013) Impacts Des Inondations Historiques Sur Un Réseau de Transport: Exemple Des Installations et Des Circulations Ferroviaires En France. In: *Événements Extrêmes D'inondation : De L'étude de L'aléa À La Gestion Du Risque Pour Les Ouvrages Hydrauliques*
- Richard E (2016) L'adaptation Aux Changements Climatiques Les Réponses de L'action Publique Territoriale. Presses Un, Rennes
- Rittel HW, Webber MM (1973) Dilemmas in a general theory of planning. *Policy Sci* 4(2):155–169. doi:10.1007/BF01405730
- Rotter M, Hoffmann E, Pechan A, Stecker R (2016) Competing Priorities: How Actors and Institutions Influence Adaptation of the German Railway System. *Clim Chang* 137(3–4). Springer Netherlands):609–623. doi:10.1007/s10584-016-1702-5
- RSSB (2015) Tomorrow's railway and climate change adaptation: phase 1 summary report (T1009)
- Rudberg PM, Wallgren O, Swartling ÅG (2012) Beyond generic adaptive capacity: exploring the adaptation space of the water supply and wastewater sector of the Stockholm region, Sweden. *Clim Chang* 114(3–4): 707–721
- Ryghaug M, Solli J (2012) The appropriation of the climate change problem among road managers: fighting in the trenches of the real world. *Clim Chang* 114(3–4):427–440. doi:10.1007/s10584-012-0449-x
- Saint-Marc C (2013) *Approches Cartographiques Pour Une Meilleure Connaissance Des Dynamiques Spatio-Temporelles Des Risques Naturels : Application Aux Risques D'inondation Impactant Le Réseau Ferroviaire*
- Simonet G (2009) Le Concept D'adaptation: Polysémie Interdisciplinaire et Implication Pour Les Changements Climatiques 17 (4): 392–401. doi:10.1051/nss/2009061
- Stamos I, Mitsakis E, Salanova JM, Aifadopoulou G (2015) Impact Assessment of Extreme Weather Events on Transport Networks: A Data-Driven Approach 34: 168–78. Accessed May 16. doi:10.1016/j.trd.2014.11.002
- Stecker R, Pechan A, Steinhäuser M, Rotter M, Sholl G, and Eisenack K (2011) Why are utilities reluctant to adapt to climate change
- The new climate economy (2014) Better growth better climate
- ToPDAd (2014) Overview of system responsiveness to climate change impacts in energy, transport and tourist sectors
- UIC (2011) ARISCC-Adaptation of Railway Infrastructure to Climate Change. Final Report. Nolte, R Berlin, I Z T
- Vallejo L, and Mullan M (2016) The role of government in making infrastructure investment climate resilient – draft survey of current practices
- Vaughan C, Dessai S (2014) Climate Services for society: origins, institutional arrangements, and design elements for an evaluation framework. doi:10.1002/wcc.290
- Watkiss P, Hunt A (2013) Method overview: decision support methods for adaptation. Briefing note 1. Summary of methods and case study examples from the MEDIATION project. Funded by the EC's 7FWP

A photograph of a child standing on a cracked, dry earth surface. The child is wearing a blue short-sleeved shirt, blue shorts, and a large, light-colored conical hat. To the left of the child is a wooden boat. The ground is covered in a dense pattern of irregular, polygonal cracks, indicating severe drought. The background is a flat, open landscape under a clear sky.

UNDER THE DIRECTION OF AGATHE EUZEN
BETTINA LAVILLE AND STÉPHANIE THIÉBAULT

ADAPTING TO CLIMATE CHANGE

A QUESTION FOR OUR SOCIETIES

ediSens



Corporate adaptation plans or the pressure of finance

Ian Cochran, Vivian Dépoues, Romain Hubert and
Morgane Nicol

Companies are or will be increasingly exposed to the risks associated with climate change, including the frequency and intensity of extreme events, average conditions, and shifting climate and seasonal variability. For example, as temperatures and precipitation fluctuate, the agriculture industry will have to ready itself for more frequent interruptions to production and distribution as a result of storms, floods or landslides. The energy sector will have to cope with the impact of climatic variation on demand — electricity for heating, for instance — as well as on production, especially for renewables. Ultimately, all economic actors will be affected, directly or indirectly, along their value chains by the impact of climate change and the measures taken to limit or adapt to it (Agrawala *et al.*, 2013; OECD, 2015)¹.

Concerns about these issues may emerge within individual companies, as part of management's exploratory approach to strategy, a risk audit, an R&D project or even technical questions arising from operational activities. It is relatively unusual, however, for such pre-occupations to become a strategic priority in themselves (EPE and ONERC, 2014). On the other hand, firms may be obliged to tackle

1. Climate change will have an impact on equipment, resources, transport, demand, etc.



climate change issues as a result of external pressures — exerted not just by civil society and the public authorities but also a company’s financial environment.

There is mounting anxiety in the financial sector about physical climate risks for financed counterparties and how these risks may influence future performance. It is highly likely that, in the years to come, businesses will be required to provide more information to financial players about their exposure and vulnerability to climate risk, as well as their capacity to manage such hazards. This article describes the rationale behind the growing interest shown in this subject by financial actors, together with the possible implications for developing business adaptation plans.

Financial actors waking up to the risks associated with climate change

2015 — the year of COP 21 — marked a turning point in the drive to integrate climate change into financial practices. The world of finance and financial regulators now acknowledges publicly that climate change and the transition to a low-carbon economy pose a risk to economic actors — and, as a result, to financial institutions and even the stability of the entire system. The message is becoming progressively explicit, as practitioners and regulators highlight the urgent need to anticipate the likelihood of these two types of risk becoming reality.

The physical impact of climate change will affect financial players as the consequences spread across every sector of the economy. The losses for the financial sector could be significant. Dietz *et al.* (2016) estimate that, if we extend current economic practices from 2015 to 2100, there is a 99% chance that the physical effects of climate change will result in a loss of \$24,200 billion across all financial assets worldwide.

Financial actors, who are sometimes unfamiliar with these questions, are now in a phase where they are beginning to “own” the special nature of the risks and gain a better understanding of the



issues. This step is a prerequisite for devising technical approaches and analytical methods that integrate the problems into existing risk management processes. We may now say that it is in the interest of companies to take note of these dynamics in the financial sector, which could well have considerable implications for all economic players.

Financial players likely to ask companies to substantiate their adaptation plans

Firms can at the very least expect to be held accountable to financial actors and public authorities regarding their exposure to physical climate risks, as well as the means employed to limit them; their company adaptation strategy, in other words.

The Financial Stability Board, a G20 body whose mission is to safeguard the stability of the global financial system, launched a working group in late 2015: the Task Force for Climate-Related Financial Disclosure (TCFD). In December 2016, the group issued a series of recommendations regarding the information companies need to declare on climate issues so that financial actors can manage climate risks. These guidelines are still voluntary; nevertheless, economic actors can expect financial institutions to follow the recommendations (at least in part), and to ask companies to fund reports on their exposure to physical climate risks so they can integrate climate variables into their risk management analyses.

In the case of France, requests of this nature issued by financial institutions are all the more compelling since they are backed by the state. The Direction Générale du Trésor (Treasury) asks banks to collect the necessary data from companies so that resistance tests can be performed on climate-related risks, as referred to in Article 173 of the Energy Transition Act for Green Growth¹.

1. Direction générale du Trésor (with the assistance of the Banque de France and the Autorité de Contrôle Prudentiel et de Résolution, the latter being responsible for supervising the banking and insurance sectors in France), *L'évolution des risques liés au changement climatique dans le secteur bancaire*, February 2017, <http://www.tresor.economie.gouv.fr/File/433386>



Predicted impact on finance access conditions for companies perceived to be poorly adapted

As financial players begin to perceive these hazards as being material, the financial conditions of companies that are highly exposed to physical climatic risks might be affected. This could take several different forms, given the diversity of players that make up the financial system (banks, insurance companies, investors, asset managers, etc.).

The conditions for accessing insurance coverage, for example, could become disadvantageous. The sectors most heavily impacted by the new developments linked to climate change could also find that access to insurance services becomes more costly or is even threatened (BOE, 2015). Insurers in several OECD countries have already begun to consider reducing their levels of coverage for buildings located in flood or coastal areas.

As a more general rule, direct access conditions to capital could be handicapped for such companies. This might involve the price of risk (e.g. increased risk premiums that reduce the valuation of equity securities, or raise loan rates or the cost of insurance premiums) or renegotiated contract terms and less favourable guarantee conditions for companies that struggle to adapt.

Demonstrating financial adaptability to anticipate the demands of financial players

Investors will use the information provided by companies (inter alia) to perform risk assessments. This data may pre-empt the demands of financiers by including plans that demonstrate the company's ability to adjust and adapt. Financial players will need to assess how a business is preparing to evolve in an environment marked by changing weather conditions and, more specifically, what repercussions this will have on financial performance. In addition to an activity's or asset's current and future exposure to climate change, the company's ability to manage its vulnerability over time will also be evaluated. What



will matter most for a company, therefore, will be to prove its ability to implement the right measures at the right time.

The resulting adaptation plans will, of course, be varied. They will depend on the particular context of individual companies, and may be drawn up in several stages with the inclusion of adaptation measures based on reactive and gradual adjustments and anticipatory actions, which may become more transformative. They might correspond to different adaptation strategies and visions, which will guide the proposed measures.

In all cases, these plans — if they are to be useful to financial players — must include a prospective analysis of the financial impact of climate change on the company. This requires forward-looking information on the geographical distribution of assets and their insurance coverage, as well as wider information about the company's future strategy, activities and investments.

The list of recommendations drawn up by the Financial Stability Board in 2016^{1 2}, asks companies to, inter alia, base their analyses on exploring different climate scenarios; disclose financial impact measures for climate risks and opportunities, regarding revenue by activity and on expenditure; and incorporate this data into annual reports.

Demonstrating financial adaptability today: a strategy with multiple benefits

Only some companies have begun conducting systematic prospective analyses of their exposure to climatic risk and the concomitant financial impact. Nevertheless, putting the framework in place to gen

1. Task Force on Climate-Related Financial Disclosures, Recommendations of the Task Force on Climate-Related Disclosures, December 14, 2016

2. A summary of the I4CE response to the consultation on the TCFD report is available at: <http://www.i4ce.org/apports-recommandations-tcfd-debat-risques-climat>.



erate this information is a useful and necessary first step for corporate adaptation strategies.

By considering the data needed to monitor their adaptive capacity now, companies can seize the opportunity to improve the way they are perceived by external stakeholders. Refining monitoring and reporting systems is a major first step in reassuring investors and insurers: it demonstrates that risks are being properly identified, monitored and managed by a company.

Businesses will also enhance the management of their adaptation process internally if they begin to study risks now. Adaptation is a long and iterative procedure: starting today, companies need to gear up so they can take ownership of, and prepare their response to, the challenges ahead. These explorations may bring to light key — and possibly imminent — decision-making moments that will determine the company's ability to adapt in the future. However, the capacity of individual economic actors to adjust ultimately depends on the adaptability of the economy as a whole. This is particularly true for the infrastructure sector, which is characterized by large capital investment in equipment which, for several decades, has organized production, distribution and consumption systems (EEA, 2014; NCE, 2016; and OECD 2015). It is crucial to factor in climate change, as and when such investment decisions arise, in order to lay the foundations for an adapted and resilient economy.

References

- Agrawala Shardul Carraro M., Kingsmill N., Lanzi E, Mullan M, Prudent-Richard G., 2013, *Private Sector Engagement in Adaptation to Climate Change: Approaches to Managing Climate Risks*, Organization for Economic Cooperation and Development.
- BOE, 2015, *The Impact of Climate Change on the UK Insurance Sector. A Climate Change Adaptation Report* by the Prudential Regulation Authority. Bank of England. <http://www.bankofengland.co.uk/prd/Documents/supervision/activities/pradefra0915.pdf>
- DG Trésor, 2017, *L'évaluation des risques liés au changement climatique dans le secteur bancaire?* Direction Générale du Trésor avec le concours de la



- Banque de France et de l’Autorité de Contrôle Prudentiel et de Résolution.
<http://www.tresor.economie.gouv.fr/File/433386>
- Dietz S., Bowen A., Dixon C., & Gradwell P., 2016, ‘*Climate value at risk of global financial assets*. *Nature Climate Change*, (April), 1 5. <http://doi.org/10.1038/nclimate2972>
- EPE and ONERC, 2014, “Les Entreprises et L’adaptation Au Changement Climatique.” *Entreprise pour l’Environnement & Observatoire national sur les effets du réchauffement climatique*. <http://www.epe-asso.org/les-entreprises-et-ladaptation-au-changement-climatique-avril-2014/>
- NCE, 2016, “*The Sustainable Infrastructure Imperative*.” *The Global Commission on the Economy and Climate*. <http://newclimateeconomy.report/2016/misc/downloads/>.
- OECD, 2015, *Climate Change Risks and Adaptation-Linking Policy and Economics*, OECD Publishing

CE QUE PEUT NOUS APPRENDRE LE CAS DE LA GESTION DE LA VEGETATION SUR L'ADAPTATION AU CHANGEMENT CLIMATIQUE POUR SNCF

Aux différentes étapes de notre enquête, une famille d'enjeux de l'adaptation du système ferroviaire au changement climatique, est systématiquement revenue : les conséquences pour la maîtrise de la végétation. Ce n'est jamais le premier risque cité mais c'est une préoccupation récurrente. C'est un des sujets qui fait l'objet de développements récents, s'appuyant sur les nouvelles technologies, en vue d'un meilleur suivi du lien entre conditions météo et système ferroviaire. En Languedoc Roussillon c'est une réelle problématique, notamment en périodes sèches, aux cours desquelles la végétation accroît le risque d'incendie au bord des voies. A l'échelle nationale la thématique fait l'objet d'une démarche spécifique très dynamique.

Ce texte se propose de revenir sur les problèmes soulevés par le changement climatique sur les pratiques de gestions de végétation pour SNCF et sur ce qu'ils nous apprennent des dynamiques d'adaptation dans l'entreprise.

Les éléments ci-dessous sont issus des (i) entretiens que nous avons menés en région ou au siège de SNCF Réseau avec les acteurs en charge de ces questions au sein des départements Maintenance et travaux (M&T) et Ingénierie et Projets (I&P), ainsi que (ii) des documents internes auxquels nous avons eu accès. Parmi ces derniers figurent notamment une présentation intitulée « Maîtrise de la végétation : ce qui a changé ... constat causes futur(s) » (2016) ; une note interne à diffusion publique « Maîtrise de la végétation » (2018) ainsi qu'un « Argumentaire maîtrise végétation et climat » (2018) tous trois destinés à de la sensibilisation et communication interne.

La principale préoccupation exprimée par les acteurs de la maintenance dans la région de Montpellier est la variabilité accrue du climat à l'échelle saisonnière. Celle-ci remet en question l'efficacité des techniques industrielles de gestion de la végétation. En effet, dans un souci d'efficacité et de productivité, cette activité repose aujourd'hui sur le passage, planifié plusieurs mois à l'avance de trains désherbeurs capables d'épandre à 70km/h des produits phytosanitaires (encadré 1). Cependant, pour être efficace, cet épandage doit se faire sous certaines conditions et à un certain moment du développement des espèces envahissantes. Cette organisation ne fonctionne donc que dans la mesure où il est possible de prévoir avec suffisamment de précision et de certitude la date optimale d'intervention. Or, l'effet – déjà

ressenti depuis quelques années et qui devrait s'aggraver avec le changement climatique encore à venir (Cassou & Cattiaux, 2016; European Environment Agency, 2017; Hamaoui-Laguel et al., 2015; Sippel, Zscheischler, & Reichstein, 2016) – rend cela de plus en plus difficile. A l'échelle nationale l'action conjuguée des hausses de température déjà observées (+ 1° C en 50 ans) et de l'augmentation des taux de CO₂ dans l'air : + 40 % en 50 ans (« le CO₂ étant LE matériau de base de croissance photosynthétique ») est proposée comme première explication d'une série de constats remontant du terrain et objectivés :

- « Des abords plus boisés et des pistes plus vertes » correspondant à un développement à la fois plus rapide et plus important de la végétation (Figure 1). Il s'agit d'une part d'une extension dans l'espace avec des espèces qui voient leur aire de répartition augmenter. C'est par exemple le cas de l'Ambroisie (Figure 1) qui remonte depuis la région lyonnaise vers la région parisienne¹. C'est le cas de la canne de Provence qui s'étend depuis les régions méditerranéennes. Il s'agit également d'une extension dans le temps : avec des températures plus douces les insectes pollinisateurs sont actifs sur des périodes plus longues facilitant le développement continue de la végétation : « ça pousse tout le temps, il n'y a plus de règles ». La durée de la saison de développement de la végétation se serait ainsi allongée de 15 jours en 30 ans. Enfin, ces nouvelles conditions accélèrent la croissance des plantes – certaines comme les Renouées du Japans pouvant grandir de plusieurs mètres en à peine quelques semaines.
- L'arrivée de nouvelles espèces invasives, non présentes en France jusque-là et difficilement contrôlables, par exemple les Ailanthos. Ces espèces peuvent se révéler dangereuses pour les agents (ex. de la Berce du Caucase, photo-toxique) et insensibles aux traitements classiquement utilisés.
- Le développement de nouvelles maladies qui déstabilisent les écosystèmes et rendent les zones végétalisées potentiellement dangereuses (ex. Chalarose du Frêne occasionnant un dépérissement accéléré et la multiplication des « arbres à risques », chenilles processionnaires (Figure3)).

¹ Cf. progression à la fois constatée sur le terrain et clairement visible sur les cartes de l'observatoire national de ce phénomène : <http://www.ambroisie.info/pages/envahi.htm>

Figure 1 : photos de la présence de végétation sur et aux abords des voies – mise en évidence de facteurs aggravants comme le manque de ballast



Source : présentation SNCF Réseau

Figure 2 : L'exemple de l'Ambroisie, plante allergène particulièrement bien implantée dans la région Rhône-Alpes qui envahi d'autres régions françaises

Figure 2a : « 2050 : pollen Ambroisie x4 ! » Chiffre cité dans une présentation SNCF Réseau

Figure 2b : zones infestées & zones frappées d'arrêtés de lutte pour raisons de santé publique (2004)

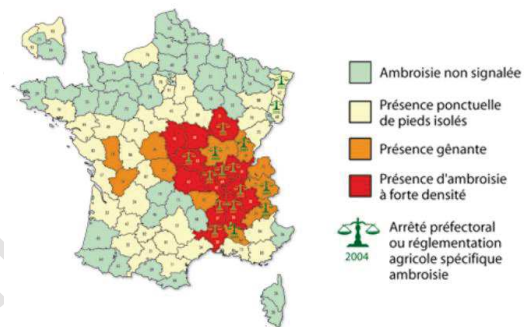
Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe

Lynda Hamaoui-Laguel^{1,2*}, Robert Vautard^{1*}, Li Liu², Fabien Solmon³, Nicolas Viovy⁴, Dmitry Khvorostyanov⁴, Franz Essi⁵, Isabelle Chuine⁶, Augustin Colette⁶, Mikhail A. Semenov⁷, Alice Schaffhauser⁸, Jonathan Storkey⁷, Michel Thibaudon⁸ and Michelle M. Epstein⁹

Common ragweed (*Ambrosia artemisiifolia*) is an invasive alien species in Europe producing pollen that causes severe allergic disease in susceptible individuals¹. Ragweed plants could further invade European land with climate and land-use changes²⁻⁴. However, airborne pollen evolution depends not only on plant invasion, but also on pollen production, release and atmospheric dispersion changes. To predict the effect of climate and land-use changes on airborne pollen concentrations, we used two comprehensive modelling frameworks accounting for all these factors under high-end and moderate climate and land-use change scenarios. We estimate that by 2050 airborne ragweed pollen concentrations will be about 4 times higher than they are now, with a range of uncertainty from 2 to 12 largely depending on the seed dispersal rate assumptions. About a third of the airborne pollen increase is due to on-going seed dispersal, irrespective of climate change. The remaining two-thirds are related to climate and land-use changes that will extend ragweed habitat suitability in northern and eastern Europe and increase pollen production in established ragweed areas owing to increasing CO₂. Therefore, climate change and ragweed seed dispersal in current and future suitable areas will increase airborne pollen concentrations, which may consequently heighten the incidence and prevalence of ragweed allergy.

would provide changes in disturbed land areas) and the efficient ragweed eradication policies. Climate change may further in the spread of ragweed by altering the climatic niche determined by physiological thresholds or affecting cropping patterns⁵. Ragweed airborne pollen concentrations depend not only on j fertilisation, but also on phenology, pollen production, rd dispersion and atmospheric transport. Recent modelling effort have led to increasingly successful simulations of airborne p concentrations. Although previous work was mostly devoted short-term forecasts to inform sensitised populations, the mat of the modelling tools are now becoming satisfactory for engi in long-term projections. Here, we present the first integrated modelling frame that incorporates ragweed phenology, pollen production, re and atmospheric transport to assess future changes in air pollen concentration under scenarios of climate and land changes and seed dispersal. The framework is based on explicit representation of plant phenology⁶, pollen producti and release to the atmosphere⁷ (see Methods and Supplement Information). We implemented two model suites that differ in atmospheric processing and in the driving climate models. First model uses the chemistry-transport model (CTM) CHM model⁸, forced by recent regional climate simulations from WRF model⁹ downscaling of the IPSL-CM5A-MR model¹⁰.

Source : (Hamaoui-Laguel et al., 2015)

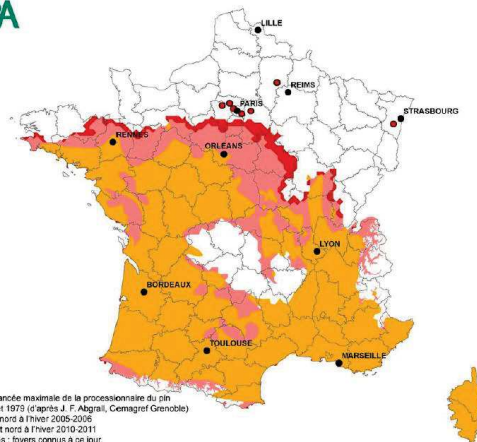
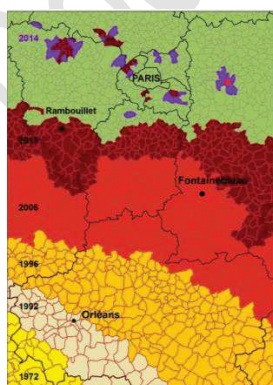


Source : observatoire de l'Ambroisie

Figure 3 : Progression de la chenille processionnaire du pin

Figure 3a : Progression vers le Nord en Régions Centre et Ile-de-France entre 1972 et 2014

Figure 3b : Progression en France entre 1980 et 2014



Orange : avancée maximale de la processionnaire du pin entre 1960 et 1970 (d'après J. F. Abgrail, Cemagref Grenoble)
 Rose : front nord à l'hiver 2008-2009
 Rouge : front nord à l'hiver 2010-2011
 Points rouges : foyers connus à ce jour.

Source : présentation SNCF Réseau

Ces constats – quoi que parfois très visibles - ne sont pas toujours simples à quantifier par manque de chiffres historiques. Les spécialistes s'accordent cependant sur leur réalité et sur le fait qu'ils devraient s'aggraver avec la poursuite de l'augmentation des températures moyennes (Figure 4). Les conséquences attendues pour la végétation sont une remontée d'espèces vers le nord encore accrue, une déstabilisation des groupements actuels et une fragilisation des écosystèmes.

Figure 4 : le scénario de changement climatique retenu, qualifié « d'inquiétant »

Les températures moyennes vont continuer d'augmenter :

- + Le réchauffement à +2°C en 2100 n'est déjà plus crédible, il faut s'attendre à + 4 ou 5°C.
- + Ceci induit que nous verrons le +2°C dans les prochaines décennies.
- + Le chiffre du réchauffement est une moyenne, qui masque des épisodes caniculaires de plus en plus fréquents.
- + Les climatologues annoncent aussi un plus grand nombre d'événements extrêmes.
- + C'est un effet de l'augmentation des émissions de gaz à effet de serre, qui va se poursuivre pendant les décennies à venir.

« Dans 25 ans, à Bordeaux il fera le même climat qu'à Séville aujourd'hui. »

Source : présentation SNCF Réseau

Ces phénomènes constituent de réels enjeux de gestion pour SNCF Réseau et notamment les Infrapôles (M&T) qui interviennent dans ce domaine en tant que gestionnaire d'infrastructure et responsables de sa sécurité.

La gestion de la végétation est le 4^{ème} poste de coûts de SNCF Réseau (devant l'entretien des ouvrages) et représente 125M€/an aujourd'hui². Ce sont 53 000 ha qu'il s'agit d'entretenir et qui font de l'entreprise le 2^e propriétaire foncier de France. Ces espaces comptant notamment les voies et leur emprise, présentent une géométrie particulière avec peu de grandes largeurs. Ils n'en sont pas moins des éléments souvent structurants des paysages traversés par les trains. Jouant le rôle de barrières ou de couloir écologiques ils ont un effet significatif sur la biodiversité³.

² « 25M€ pour le désherbage des voies par traitement phytosanitaire et 100M€ pour l'entretien mécanique des dépendances vertes ».

³ SNCF peut ainsi être perçue comme un élément perturbateur de dynamiques locales (notamment lors de la création de lignes nouvelles) ou comme un acteur intéressant dans la création d'écosystèmes stables. Une [thèse a été réalisée il y a quelques années avec le MNHN \(Caterina Penone\)](#) - habitat, refuge ou corridor pour biodiversité ordinaire.

La végétation est utile à l'infrastructure ferroviaire elle-même, par exemple en stabilisant les talus. Mais elle est aussi une source d'incidents : ce sont ainsi entre 300 et 400 000 minutes de retards par an qui lui sont imputables.

Encadré 1 : COMMENT EST GEREE LA VEGETATION ?

La gestion de la végétation chez SNCF Réseau est un métier très encadré, tant du point de vue de l'usage de traitements chimiques (SNCF est le premier acheteur de glyphosate en France en volume⁴) que de la protection des espaces et de l'eau.

Elle fait l'objet d'un cadrage national reposant notamment sur une logique de zonages (parmi lesquelles des zones règlementées particulièrement problématiques, par exemple aux abords des captages d'eau) avec des principes généraux et des spécificités locales.

Elle repose sur une gestion chimique des voies et des pistes et une gestion mécanique et chimique des abords. Les traitements chimiques sont réalisés avec des produits homologués par l'ANSES et suivant des dosages de références établis de manière empiriques par SNCF au fil du temps. Ils sont opérés à l'aide de trains désherbeurs (6 trains nationaux à haut rendement pouvant opérer jusqu'à 70km/h + 25 trains régionaux) et de camions. Ces différents véhicules sont équipés de technologies (ex. GPS agricoles, applications SIG⁵) permettant à la fois d'optimiser les passages et de garantir une traçabilité des opérations. L'introductions de ces nouvelles technologies a ainsi permis de réduire sensiblement les quantités de produits utilisées. Gérer au plus près les interventions permet ainsi à la fois de minimiser les coûts et de respecter les contraintes environnementales.

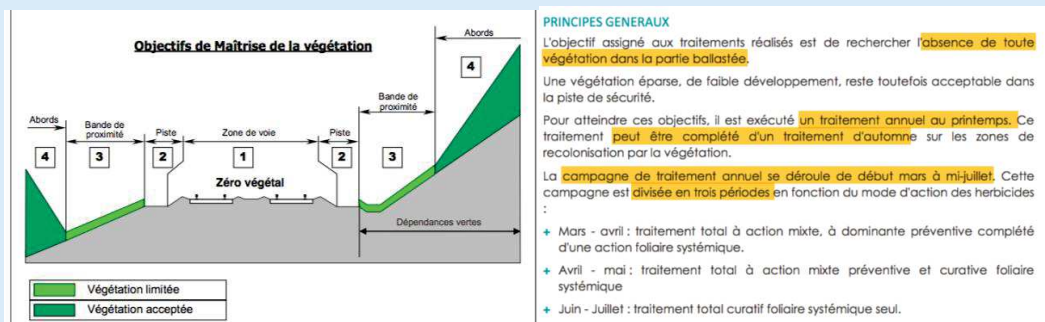
L'ensemble de ces pratiques fait l'objet de référentiels et de standards définissant par exemple les périodes de traitement. Les objectifs de gestion de la végétation sont clairement établis : ils répondent à des impératifs de sécurité (zéro végétation sur la zone de ballast par exemple (Figure 5) et à des obligations de traitement nationales pour prévenir la propagation de certaines espèces.

La gestion de la végétation reste une activité principalement réalisée en interne bien qu'elle soit occasionnellement déléguée à des sous-traitants agréés. Elle peut en revanche être menée en partenariat avec les autres acteurs locaux (collectivités, associations environnementales), notamment pour minimiser les problèmes de voisinage qu'elle engendre parfois ainsi que les risques induits par de la végétation hors-emprise SNCF.

⁴ Bien que son usage par m² traité soit relativement faible.

⁵ Application SIGMA : premier Système d'Information Géographique de maintenance à avoir une couverture nationale et accessible via l'intranet à l'ensemble des acteurs de la production depuis 2012 ; principal outil de gestion du métier, fournit de nombreuses informations sous forme de cartographie que l'utilisateur peut enrichir avec des éléments qu'il juge utile (arbres dangereux, plaintes riveraines, zone de patinage, obstacles, accès routier...). Objectifs : respecter la réglementation et organiser la traçabilité de toutes les interventions pour en optimiser leurs planifications, donc leur coût. + depuis 2013, SIGMA fournit les informations en 3G à une soixantaine de GPS Pro embarqués sur les trains et les camions désherbeurs régionaux. Ces GPS asservissent automatiquement les rampes de traitements chimiques. La traçabilité de l'intervention est renvoyée directement dans SIGMA via la 3G », explique Vincent Auriat, responsable de la division environnement à l'ingénierie. Permet d'avoir un usage raisonné des herbicides et de le prouver.

Figure 5 : Objectifs et procédures de maîtrise de la végétation telle que codifiés par SNCF Réseau



Source : note interne SNCF Réseau

Dans ce contexte, le rapport aux conditions climatiques et météorologiques est double. D'une part, la présence, la profusion et la phénologie des plantes est dépendante de ces conditions. D'autre part, les incidents liés à la végétation sont la plupart du temps corrélés à certaines conditions météorologiques : sécheresses, vague de chaleur et vent pour les feux, tempêtes pour les chutes d'arbres, précipitations intenses pour les risques d'inondation, etc.

L'évolution de ces conditions est source de multiples risques :

- Des risques à venir pour la géométrie des plateformes déstabilisées par les racines ;
- Des risques de visibilité réduite pour les conducteurs perturbant des manœuvres comme les essais de freinage ainsi que la visibilité des signaux (le droit de retrait a d'ores et déjà été invoqué par des agents) ;
- Des risques pour les mainteneurs qui ont plus de mal à accéder aux sites à entretenir et à surveiller les alentours et sont exposés aux dangers que présentent les certaines plantes. Les risques de chute et de heurt ainsi que la pénibilité augmentent.
- Des risques pour la circulation des trains exposés par exemple à des phénomènes de patinage-enrayage en automne avec la chute et la décomposition des feuilles sur les voies.
- Des risques d'obstruction des voies et de mauvais drainage lors d'épisodes pluvieux.

Ces différents phénomènes sont particulièrement intéressants à étudier car ils posent des questions qui nous paraissent caractéristiques de la situation actuelle de l'entreprise vis-à-vis du changement climatique.

1. Le changement climatique y apparaît comme une dynamique problématique parmi d'autres – dans une situation de gestion perçue comme de plus en plus complexe par les acteurs

Les évolutions constatées sont en effet attribuées à la combinaison d'une pluralité de causes à la fois exogènes et endogènes à l'entreprise. Du côté des causes exogènes sont notamment citées : l'évolution des pratiques agricoles dont les effluents (azote, phosphates, etc.) ruissellent et fertilisent les emprises SNCF ; l'importation volontaire ou involontaire de végétaux « exotiques » liée à l'intensification des flux à l'échelle globale ; l'interdiction des produits à forte rémanence au profit de composés moins nocifs pour l'environnement mais également moins efficaces ; le changement climatique. Du côté des causes endogènes, c'est un certain nombre de caractéristiques du systèmes ferroviaire et d'évolutions des pratiques qui sont mentionnées :

- Le manque de souplesse des modes de traitement industrialisés qui sont privilégiés. Les anti-germinatifs par exemple ne sont efficaces que si appliqués au bon moment du développement des plantes, dans des conditions appropriées. Or,
 - Il n'est pas possible de passer partout en même temps.
 - Il n'est pas possible de prévoir et de s'ajuster suffisamment finement aux conditions extérieures (météo, état réel de développement de la végétation) comme le ferait par exemple un agriculteur.
 - Il est très compliqué de réorganiser le planning d'intervention des engins, la programmation des sillons est figée plusieurs mois à l'avance. En cas d'annulation pour cause météo par exemple, le traitement peut être différé de plusieurs mois. Dans certains contextes comme le réseau francilien ces contraintes sont encore plus fortes avec des traitements réalisables uniquement de nuit.
- Des décennies de traitement ont amené à une sélection involontaire d'espèces résistantes.
- Les retards d'entretien de certaines portions du réseau – faute de moyens mobilisables – qui entraînent par exemple un mauvais drainage des eaux de pluies ou l'insuffisance de ballast (Figure 1) et favorisent ainsi le développement de la végétation.
- Des décennies de vidange des toilettes, fertilisant les alentours.

- Une évolution des pratiques depuis l'électrification des lignes. Comme nous l'expliquait un des experts végétation de SNCF Réseau « Il y a eu une dérive d'embroussaillage pendant des années ». Tant qu'il y avait encore des trains à vapeur le risque incendie était très prégnant. La végétation était donc gérée au plus près avec des référentiels très exigeants stipulant par exemple que tous les talus devaient être fauchés et nettoyés avant le 14 juillet de chaque année. « Avec la disparition des locomotives vapeurs, on a laissé totalement dériver la végétation, les talus parfois sont devenus des boisements de 40 ans. »

2. Les changements apparaissent comme avant tout subis

Comme sur d'autres impacts climatiques (Dépoues, 2016) les acteurs ont surtout l'impression de subir ces changements, d'y être confrontés et de devoir réagir sans les avoir anticipés, sans s'y être préparés.

Ils sont donc d'abord gérés au fil de l'eau selon les manières de faire habituelles. Le poids des héritages et la « culture ingénieur » de la SNCF, régulièrement mentionnée par les acteurs, prennent alors beaucoup de place.

Comme beaucoup d'autres enjeux de maintenance, la maîtrise de la végétation est ainsi cadrée comme un exercice d'optimisation sous contraintes : garantir des conditions de circulation et d'intervention acceptables notamment en termes de sécurité, en minimisant les coûts, en respectant la réglementation et en tenant compte des rigidités du système. En ce sens une gestion attentive des évolutions en cours – parmi lesquelles figure le changement climatique – s'inscrit dans la logique de « management de la performance » de plus en plus présente chez SNCF notamment dans un contexte de libéralisation des activités.

Le changement climatique et d'autres pressions semblent aller dans le même sens d'une complication du contexte de lutte. De nouvelles interdictions de molécules (interdiction du glyphosate qui se profile), l'élargissement ou l'apparition de nouveaux espaces protégés⁶, de nouveaux arrêtés d'obligation de lutte (pour des raisons sanitaires ou de lutte contre le risque incendie) sont autant d'incitations à chercher de nouvelles solutions.

Les solutions peuvent être de nature organisationnelle mais sont souvent technologiques, à l'image des dispositifs de GPS+SIG généralisés à bord des véhicules désherbeurs (Encadré 1).

⁶ « En 2018 une augmentation de 17% des zones en interdiction totale (74 km) a été enregistrée par rapport à l'année 2017. »

3. Des spécificités du défi de maîtrise de la végétation qui font émerger des stratégies nouvelles pour SNCF

A côté de ces enjeux largement partagés avec d'autres questions auxquelles SNCF est confrontée aujourd'hui, cette problématique présente cependant certaines spécificités notables :

- La « gestion » de la végétation est le seul domaine de la maintenance du système ferroviaire, où celui-ci est en contact direct et visible avec du vivant⁷. Elle constitue donc une interface originale entre un système technique et des dynamiques d'écosystèmes naturels qui présentent des comportements, « imprévisibles » bien différents des logiques d'ingénierie classique. Elle est un cas déjà perçu et décrit comme problématique d'interaction entre le système ferroviaire et son environnement « naturel » qui n'est plus totalement maîtrisé, ni maîtrisable.
- Pour des raisons historiques d'organisation et de construction des outils de gestion internes il est plus facile d'identifier les conséquences de la végétation sur l'activité de l'entreprise. Les bases de données incidents comportent par exemple des catégories idoines qui permettent d'attribuer des incidents à des « causes végétation »⁸. Cette capacité à objectiver l'impact de la végétation et donc à la détecter comme un problème réel au-vue des indicateurs qui comptent pour SNCF (ex. minutes de retard, coûts de maintenance, nombre d'incidents, etc.) est un élément clé de sa prise en charge, qui fait défaut sur d'autres sujets.

Encadré 2 : INCIDENCES CHIFFREES DE LA VEGETATION SUR L'EXPLOITATION FERROVIAIRE

Les incidents liés à la végétation peuvent avoir des causes directes :

- Les chutes d'arbres et de branches : 228 000 min de retard de train (annuellement).
- Les patinages/enrayages de train (feuilles mortes) : 67 000 min de retard de train (annuellement).

Ou des causes indirectes (où la végétation est considérée comme un vecteur d'incidents) :

- Les incendies aux abords des voies : 156 000 min de retard de train (annuellement).
- Heurts d'animaux sauvages : 127 000 min de retard de train (annuellement).

⁷ Un détour par les travaux des STS nuancerait cette affirmation un peu simpliste en constatant par exemple le caractère sociotechnique du réseau ferroviaire et les multiples interactions entre acteurs humains et non humains : par exemples les usagers (Abramovici, 2011) les personnels de maintenance (Denis & Pontille, 2015).

⁸ Ce qui est beaucoup plus compliqué par exemple pour les cause « météo » comme l'ont montré des initiatives récentes comme celle citée par (Dubost, 2017) visant à « procéder à l'état des lieux précis de l'information disponible en interne, puis de proposer une méthode d'évaluation / suivi des impacts climatiques sur l'activité [pour] identifier et construire des indicateurs physiques et des indicateurs économiques (KPIs) pour aider à la prise de décision ».

- La fonction de maîtrise de la végétation comme métier dédié chez SNCF Réseau est récente. Elle est donc moins tributaire du poids d'habitudes passées et moins rigidifiée.

La démarche mise en place au sein de SNCF Réseau pour répondre à cette problématique donne à voir une dynamique originale par rapport à ce que l'on a pu observer ailleurs ou sur d'autres sujets dans l'entreprise. Elle semble démontrer par l'exemple que lorsque les réponses techniques classiques et l'optimisation sous contrainte ne sont pas suffisantes il est possible, dans certaines conditions, de faire autrement.

Nous décrivons ci-dessous cette démarche telle qu'elle nous a été présentée par une des personnes qui y a pris part depuis le début.

Mise en place d'une cellule transverse maîtrise de la végétation chez SNCF Réseau

En 2013, SNCF Réseau (alors RFF) a exprimé à SNCF - qui assurait alors l'entretien du réseau (selon l'organisation de l'époque) – sur la base des indicateurs incidents-régularité⁹ sa non satisfaction vis-à-vis de la gestion de la végétation. Le propriétaire de l'infrastructure a indiqué qu'il souhaitait imposer à SNCF un maître d'œuvre extérieur pour gérer cet aspect de la maintenance à sa place.

Pour répondre au problème, un « plateau technique SNCF-RFF¹⁰ » a été mis en place. La première solution étudiée a été celle d'une délégation de l'entretien. Elle a cependant été rapidement minimisée face au double constat que (i) la gestion de la végétation était une problématique de temps long qui devait être étroitement liée aux interventions sur l'infrastructure et nécessitait une réelle expertise ferroviaire, et (ii) que le tissu professionnel de prestataires potentiels n'était pas disponible partout. Quelques expérimentations de délégation ont bien été menées mais pour finalement revenir à une réorganisation interne de cette fonction.

Les experts SNCF et RFF ont alors commencé à travailler en mode projet en créant en 2013 une « cellule végétation » qui a pu assoir un constat et développer une stratégie. Le constat a été celui du nécessaire basculement d'une maintenance corrective ou d'urgence, vers une

⁹ Des limites ont cependant été constatées dans l'utilisation des bases de données généralistes pour l'utilisation spécifique dans ces métiers. Un travail a donc été conduit –dans le cadre d'un projet de maintenance prédictive –pour qualifier des zones de vigilance et de priorisation sur le réseau pour tous les types d'impact. La 1^{ère} phase, a consisté à améliorer le traitement des bases existantes (BREHAT, REXEA, REX4, EXCALIBUR) en collaboration avec des *data-scientists*, pour consolider un outil en cours de déploiement. 4 types de problèmes liés à la faune, aux chutes d'arbres, aux incendies et patinage/enrayage sont corrélés au nombre de minutes perdues.

¹⁰ Il a eu un plateau commun Nouveau Partenariat Industriel et Commercial pour mettre des sujets à problème entre les deux structures sur la table – « la végétation a eu la chance d'être ans la liste ».

maintenance raisonnée, pluriannuelle, positive tant pour la préservation de l'environnement que pour le maintien de la performance de son réseau. L'objectif défini a alors été de généraliser une gestion mécanique, et de diminuer peu à peu le recours aux produits phytosanitaires : « la réduction d'un enrichissement excessif vis-à-vis de la sécurité de l'exploitation ferroviaire est aujourd'hui engagée avec l'objectif de maintenir une végétation prairiale et arbustive [...] pour satisfaire la performance du réseau comme la préservation des fonctionnalités naturelles des milieux ». Il s'agit d'un processus qui se déploie sur plusieurs années, avec une première phase de « remise à niveau » des dépendances vertes pour retrouver des peuplements végétaux en équilibre avec les contraintes de l'exploitation ferroviaire. Cette phase consiste en « une série rapprochée d'interventions (sur 2 à 3 ans) après des opérations de coupe visant à contrôler les recrues de ligneux ; soit par l'apport de débroussaillants (herbicides sélectifs) utilisés en dévitalisation de souche ou de repousses, et en contrôle des espèces invasives ou envahissantes ; soit en zones protégées, par des reprises annuelles par moyens mécaniques ».

L'élaboration et la mise en œuvre de cette stratégie a été rendue possible par la mobilisation conjointe et volontaire de quelques experts et d'une direction pilote (la direction Sud-Est de Maintenance et Travaux). Cette dernière a fait le choix stratégique de créer 7 postes, un par établissement, dédiés à ce sujet, sans appui extérieur pour cela. La diffusion de ces principes n'a pas toujours été facile – chaque établissement ayant ses propres habitudes – mais les responsables de la cellule constatent que « la sauce est en train de prendre ».

Petit à petit les responsables ont été convaincus. Selon les pilotes de cette initiative plusieurs arguments l'ont emporté. D'abord l'effet visible sur les coûts de maintenance qui pourraient être multipliés par 5 ou 6 selon les évolutions : face à un poste de plus en plus important il apparaissait de plus en plus nécessaire de faire évoluer les pratiques. Ensuite, le risque bien identifié car médiatisé lié à l'interdiction probable du glyphosate dans les prochaines années.

Un important travail de sensibilisation a été conduit dans une optique de « professionnalisation des acteurs » sous la forme de notes circulées aux agents, de présentations en établissements et de films (réalisé par la WebTV de l'entreprise). Lors de récents séminaires, des cadres dirigeants se sont emparés du sujet dans leurs interventions.

C'est bien de la structuration d'un nouveau métier qu'il s'agit avec :

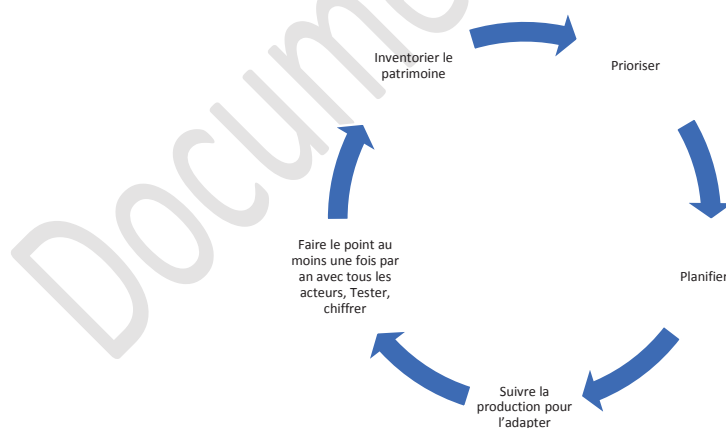
- Une dimension nationale : définition d'une politique de maintenance globale, animation du réseau d'experts, veille technique et réglementaire, développement d'une ingénierie de maintenance en support des régions ;
- Une dimension locale : création de postes d'experts en pôle maintenance de nombreux établissements (démarche toujours en cours).

De l'avis des acteurs de ce processus, ce métier présente de réelles spécificités par rapport aux autres métiers de la maintenance. De par son caractère récent il se structure avec un héritage léger et à une échelle réduite (« une chance ») : « on n'avait que de la maîtrise d'œuvre travaux, des gens qui savaient faire couper des arbres, on savait appeler des entreprises mais pas faire de la gestion de la végétation » [...] « on n'avait pas ni d'ingénierie de maintenance avec une maîtrise d'œuvre compétente ».

Il s'articule autour d'une communauté d'experts « passionnés » et très dynamiques. Des échanges réguliers sont organisés sous la forme de séminaires (un séminaire national annuel et des séminaires régionaux) et se prolongent toute l'année en ligne via le réseau social interne de l'entreprise (Yammer) dont le groupe dédié à la végétation est un des plus actifs.

L'activité se déploie sur autour d'un processus itératif et apprenant (Figure 6) :

Figure 6 : organisation « nouvelle situation, nouvelle façon de travailler »



Source : auteur à partir d'une présentation SNCF Réseau

Les enjeux étant nouveaux et demeurant souvent problématiques, cette communauté de travail est en recherche permanente de solutions et favorise donc des dynamiques d'innovation multiples. Un groupe de travail a par exemple été mis en place sur l'après-

glyphosate (interdiction du Roundup) autour de 6 pistes à explorer. Ce travail s'organise en interne mais aussi avec des industriels, des start-ups qui proposent leurs solutions (Figure 7), des laboratoires (par exemple du CEA) et des universités, des opérateurs comme l'ADEME ou l'ONF ainsi que d'autres entreprises ferroviaires européennes. Il prend des formes variées parmi lesquelles des concours, des « marathons de l'innovation » (mars 2017), ou encore le financement de thèses CIFRE.

Alors que ce n'est pas toujours évident sur d'autres aspects du système ferroviaire, la gestion de la végétation est un sujet sur lequel un certain nombre d'expérimentations in-situ sont réalisées : « des dispositions constructives expérimentales pour limiter l'infestation de la voie et des pistes par la végétation ont été mises en œuvre par sur plusieurs sites expérimentaux : Parc Naturel Régional des Etangs de la Narbonnaise (11), captages d'Eaux de Paris de La Joie et Chaintréauville à Saint Pierre lès Nemours (77) et des Sources du Dragon à Saint Loup de Naud (77)... ». Parmi les techniques testées sur ces sites ou ailleurs, on peut citer le test d'une moquette végétale sur les pistes à Villeneuve St George¹¹, des pratiques d'écobuage dirigé avec les SDIS (efficace mais compliqué à organiser), la pose de géotextiles. Les champs explorés sont assez divers allant par exemple de nouvelles technologies numériques (télé-détection et indicateurs de maintenance prédictive, utilisation de drones) à de l'ingénierie écologique. Comme c'est souvent le cas dans les dynamiques d'innovation ouvertes comme celles-ci, un certain nombre des idées proposées s'avérant au final de « fausses bonnes idées » (par exemple le désherbage thermique, extrêmement gourmand en combustibles fossiles). A côté de ces démarches pilotées en interne, une politique de participation active aux instances institutionnelles (par exemple les Comités Régionaux d'Orientement et de Suivi du Plan Ecophyto 2018) et à des projets externes est menée.

A ce jour toutes les questions sont loin d'être réglées : les alternatives efficaces – dont les coûts et bénéfices sont analysés - se révèlent par exemple plus coûteuses (les coûts actuels moyens sont de 8€/m²/an avec train national, le passage à de la gestion différenciée par exemple multiplierait le coût par 20).

¹¹ « Cela apparaît comme totalement fou en interne mais démarche soutenue : planter la voie plutôt qu'éradiquer la végétation est totalement novateur »

Figure 7 : exemple de communication externe d'une Start-up – Vitirover – soutenue par SNCF Réseau



Source : LinkedIn (J.J Thomas, directeur Innovation SNCF Réseau)

Conclusion : pour nourrir une posture d'adaptation

Cette dynamique nous semble éclairante à plusieurs titres pour nourrir une réflexion sur les postures d'adaptation possibles dans l'entreprise, qui pourraient différer des attitudes les plus communément observées sur d'autres sujets. Il met bien en évidence à la fois le poids des héritages et les possibilités d'évolution face à des problématiques nouvelles :

- Le point de départ de cette démarche de refonte de la politique de maintenance de la végétation a été un constat avéré, visible et chiffrable. La mise en avant des coûts induits et la capacité à suivre les progrès sont des éléments apparemment fondamentaux de la réussite du processus. Cela va dans le sens d'une meilleure objectivation des liens entre la météo, son évolution et la performance du système ferroviaire pour mieux piloter l'adaptation. Cet exemple spécifique de la végétation tend donc à renforcer la crédibilité des démarches privilégiée sur le climat aujourd'hui.
- Le choix de gérer cette problématique sur le temps long en intégrant pleinement la dynamique et des trajectoires de transformation étalées sont des perspectives qui pourraient se révéler intéressantes et utiles pour faire face à des changements des conditions climatiques.
- La mise en place d'une dynamique « chemin faisant », avec un fonctionnement itératif et apprenant se révèle possible et adaptée à des situations complexes comme celle-ci pour lesquelles il n'y a pas de solution préexistantes. L'articulation entre le local et le national, le choix d'allouer des ressources à cette question, et la constitution d'une

communauté professionnelle autour apparaissent comme des facteurs clés de succès. Tous les services de SNCF ne présentent pas le même contexte favorable mais les enjeux que pose le changement climatique militent en faveur de ce type d'organisation.

- C'est une logique d'innovation ouverte, en écosystème, articulant une vision de ce qui est recherché avec une posture d'accueil des solutions possibles qui se dessine. En l'absence de réponse a priori SNCF favorise la circulation de l'information, une veille active, le tissage de partenariats, l'exploration et l'expérimentation. Cela ne va pas sans l'intégration dans l'entreprise de compétences nouvelles, allant jusqu'à une forme radicalement inédite d'ingénierie qui se développe autant par auto-formation en interne que par recrutement de nouveaux profils hybrides (par exemple des paysagistes).
- La stratégie adoptée constitue un basculement d'une logique de gestion à une autre, très différente qui a été acceptée ici et pourrait encore être nécessaire sur d'autres sujets. Cette logique, assez différente des projets d'ingénierie très balisés auxquels l'entreprise est plus habituée peut également constituer un point de référence pour l'adaptation au changement climatique.

Les évolutions ne se passent pas toujours sans heurts : « il peut être compliqué de comprendre que le vivant est imprévisible – on n'en ai pas totalement sorti ». Les responsables de la démarche végétation témoignent parfois de certaines réactions « condescendantes » entendues vis—à-vis d'un domaine d'expertise nouveau et parfois difficile à faire reconnaître comme tel.

On remarquera enfin qu'une grande partie des pistes explorées restent de nature technologique dans une perspective de continuer à opérer le système sans changements majeurs de ses fondamentaux. Il s'agit toujours de garantir ou d'améliorer la performance en optimisant les coûts, pas d'imaginer d'autres formes d'interactions que la « maîtrise » entre la végétation et le système ferroviaire, comme le changement climatique pourrait y obliger (Lonsdale, Pringle, & Turner, 2015).

PRINCIPALES REFERENCES ET RESSOURCES

Internes SNCF

- Entretiens SNCF Réseau, Responsable régional environnement et développement durable, Spécialiste maîtrise de la végétation, M&T, Responsable Maîtrise de la Végétation, I&P
- Présentation. (2016). « Maîtrise de la végétation : ce qui a changé ... constat causes futur(s) ». [M.Hamon](#)
- Argumentaire. (2018). « Maitrise végétation et climat ». JP.Pujol
- Note SNCF Réseau. (2018). « La maîtrise de la végétation ». I&P

Bibliographie

- Abramovici, M. (2011). Attention, un client peut en cacher un autre » Gérer les clients en situation perturbée. *Gérer & Comprendre*, 105(3), 71.
<http://doi.org/10.3917/geco.105.0071>
- Cassou, C., & Cattiaux, J. (2016). Disruption of the European climate seasonal clock in a warming world. *Nature Climate Change*, (April), 1–6.
<http://doi.org/10.1038/nclimate2969>
- Denis, J., & Pontille, D. (2015). Material Ordering and the Care of Things. *Science, Technology, & Human Values*, 40(3), 338–367.
<http://doi.org/10.1177/0162243914553129>
- Dépoues, V. (2016). *Modernisation du système ferroviaire français et changement climatique Oser penser des transformations profondes pour des réseaux robustes et adaptés*. Paris.
- Dubost, C. (2017). L'entreprise SNCF confrontée au changement climatique. In B. Laville, A. Euzen, & S. Thiébault (Eds.), *Adaptation au changement climatique, une question de sociétés* (CNRS Editi).
- European Environment Agency. (2017). *Climate change, impacts and vulnerability in Europe 2016*. (H.-M. Füssel, A. Jol, A. Marx, M. Hildén, A. Aparicio, A. Bastrup-Birk, ... P. van der Linden, Eds.) (Vol. 1/2017). Retrieved from <http://dx.doi.org/10.2800/534806>
- Hamaoui-Laguel, L., Vautard, R., Liu, L., Solmon, F., Viovy, N., Khvorostyanov, D., ... Epstein, M. M. (2015). Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe. <http://doi.org/10.1038/NCLIMATE2652>
- Lonsdale, K., Pringle, P., & Turner, B. (2015). *Transformational adaptation: what it is, why it matters and what is needed*. UK Climate Impacts Programme. UK Climate Impacts Programme. Retrieved from <https://ora.ox.ac.uk/objects/uuid:d06e03fa-ecfc-4901-9041-059ba0215436>
- Sippel, S., Zscheischler, J., & Reichstein, M. (2016). Ecosystem impacts of climate extremes crucially depend on the timing. *Proceedings of the National Academy of Sciences*, 113(21), 5768–5770. <http://doi.org/10.1073/pnas.1605667113>

Titre : De l'information scientifique sur le changement climatique à l'analyse économique pour l'adaptation des infrastructures : le cas de SNCF

Mots clés : changement climatique ; adaptation ; infrastructures ; ferroviaire ; organisations ; connaissance scientifique

Résumé : Cette thèse analyse *in situ* ce que SNCF fait de la connaissance disponible sur les impacts du changement climatique et ce que cette connaissance lui fait. Elle cherche à contribuer à la compréhension de la manière dont les grandes organisations se transforment face au changement global décrit et annoncé. L'enquête, ancrée dans une méthodologie inductive, s'attache dans un premier temps à décrire en détails l'adaptation telle qu'elle se fait aujourd'hui chez SNCF, principalement de manière réactive et incrémentale, au niveau du siège et au niveau régional (en Occitanie). Elle explore ensuite les conséquences possibles des changements les plus disruptifs anticipés par les études scientifiques et le rapport des différents acteurs à d'éventuelles transformations plus profondes de leurs visions et de leurs pratiques.

Le dispositif mis en place montre que l'accroissement de la variabilité et des extrêmes climatiques est effectivement à même d'interroger les politiques internes et les choix stratégiques de l'entreprise. Au-delà des enjeux techniques, l'adaptation pose des questions de gouvernance qui débordent largement SNCF. Face à ces problématiques, une diversité de postures d'adaptation et de configurations des jeux d'acteurs est possible. Ce résultat amène à préciser les questions économiques pertinentes pour mieux répondre à ce défi. Cette thèse défend que c'est en tant que science de la gouvernance que l'économie, aux côtés d'autres heuristiques, a un rôle clé pour déployer les implications du changement climatique, explorer les pistes et ouvrir des espaces où mettre en débat les choix d'adaptation sur le long terme.

Title: From scientific information on climate change to economic analysis for adaptation of infrastructure: the case study of SNCF

Keywords: climate change; adaptation; infrastructure; railways; organizations; scientific knowledge

Abstract: This thesis describes and analyzes *in situ* how SNCF, the French national railway company, deals with the scientific knowledge on the impacts of climate change. It intends to improve our understanding of how large organizations adapt to multifaceted changes and address wicked environmental problems. Based on an inductive inquiry, the research describes how adaptation happens for now at SNCF, mostly on a reactive and incremental mode, first at the corporate level then in one specific region (Occitanie). In a second step, it explores possible consequences of the most disruptive changes announced by science and how various actors consider more transformative adaptations of their world-views and practices.

The device set up showed that increases in climate variability and evolutions of extreme events might actually question current policies and strategical choices. Beyond technical stakes, adaptation raises important governance challenges. Different sub-entities of SNCF but also local authorities, traffic authorities or other mobility providers can make contrasted adaptation choices. Following these observations, this research identifies salient research questions to improve adaptation decisions. It defends that, along with other heuristics, economics have a major role to play to unfold critical consequences of climate change, explore adaptation options and display controversies regarding long-term adaptation.

