“We drive until the last vehicle is stuck”

How resilient is Hamburg’s Public Transport system to Climate Change effects?

Christoph Aberle

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A thesis submitted in partial fulfillment of the requirements of Lund University International Master’s Programme in Environmental Studies and Sustainability Science (30hp/credits)

LUCSUS
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Content

Abstract

Climate change consequences are forecasted to severely affect urban life. Already in the past years, extreme events such as heat-waves, cloudbursts, and storm surges have strained cities' infrastructures and inhabitants.

In this thesis I investigate the impact of extreme weather events on Public Transport (PT) in Hamburg/Germany. As a framework I apply the resilience concept with the four key dimensions *Anticipation*, *Reaction*, *Monitoring*, and *Learning*. By evaluating seven qualitative PT stakeholder interviews and sector-specific publications I assess the current system's resilience as well as chances for and barriers to resilience building. By applying the resilience concept to the PT system in Germany's second-largest city, I investigate how a sustainability science concept translates to a practical context and how this practical application relates to sustainability goals.

Hamburg's PT system has already been affected by extreme weather, particularly by storm and flooding. So far, the short-term adaptation has been successful, as operators could respond to and learn from adverse incidents. Although they do not explicitly refer to them in their daily practice, most interviewees are familiar with resilience elements. However, there is no strategic tool of monitoring and evaluating extreme events and forecasting challenges. Overall, the key dimensions *Reaction* and *Learning* are covered, whereas *Anticipation* and *Monitoring* are not.

A major chance for climate change adaptation is timely mainstreaming of resilience properties into existing and new infrastructrues and processes; Barriers are financial constraints and a lack of political awareness. For adapting the PT system to climate change effects, I propose a cross-sector strategy hosted by HVV as the PT association.

Most of the interviewed stakeholders do not expect social inequality as a result of adaptation. However, it cannot be ruled out that resilience building, embedded into a neo-liberal agenda, happens at the cost of marginalized people. Framed in the Brundlandt Sustainable Development taxonomy, the *social sustainability* dimension needs to be further investigated.

Keywords: Public Transport, Resilience, Urban, Climate Change, Adaptation

Word count: 13,888

Abstract auf Deutsch

Die Auswirkungen des Klimawandels werden das Leben in der Stadt voraussichtlich ernstlich beeinflussen. Bereits in den letzten Jahren haben Extremereignisse wie Hitzewellen, Starkregenfälle und Sturmfluten urbane Infrastrukturen und Einwohnende stark belastet.

In dieser Arbeit untersuche ich den Einfluss von Extremwetter-Ereignissen auf den Öffentlichen Personennahverkehr (ÖPNV) in Hamburg. Als Rahmen wende ich das Konzept der Resilienz mit den vier Schlüsselfunktionen Vorhersage, Reaktion, Monitoring und Lernen an. Auf der Grundlage sieben qualitativer Stakeholder-Interviews und sektorspezifischer Publikationen bewerte ich die derzeitige Resilienz des Systems sowie Chancen und Barrieren für Resilience Building. Indem ich das Resilienzkonzept auf den ÖPNV in Deutschlands zweitgrößter Stadt anwende, ergründe ich, wie ein Konzept aus den Nachhaltigkeitswissenschaften in einen praktischen Zusammenhang übertragen werden kann und wie es sich gegenüber Nachhaltigkeitszielen verhält.

Hamburgs ÖPNV-System ist bereits von Extremwetter betroffen gewesen, insbesondere von Sturm- und Flutereignissen. Bis jetzt war die kurzfristige Anpassung erfolgreich, nachdem ÖPNV-Betreiber auf negative Ereignisse reagieren und von ihnen lernen konnten. Obwohl sie im operativen Alltag nicht explizit auf die Idee der Resilienz zurückgreifen, arbeiten die meisten Interviewpartner mit Teilelementen. Sie verfügen allerdings nicht über ein strategisches Werkzeug, um Extremwetter-Ereignisse zu überwachen und auszuwerten und Herausforderungen vorherzusagen. Insgesamt werden die Schlüsselfunktionen Reaktion und Lernen umgesetzt, wohingegen Vorhersage und Monitoring nicht erfüllt werden.

Eine wesentliche Chance für die Klimawandel-Anpassung ist ein rechtzeitiges ‚Mainstreaming' von Resilienzfunktionen in existierende und neue Infrastruktur und Prozesse; Barrieren sind mangelnde finanzielle Ressourcen und ein Mangel an Bewusstsein auf Seiten der politischen Entscheider. Um den ÖPNV an Klimawandelfolgen anzupassen, schlage ich eine sektorübergreifende Strategie vor, die vom HVV als Vertreter der Aufgabenträger angeleitet wird.

Die Betreiber erwarten keine negative Auswirkung der Klimawandel-Anpassung in Form sozialer Ungleichheit. Es kann allerdings nicht ausgeschlossen werden, dass Resilience Building, eingebettet in eine neoliberale Agenda, auf Kosten einkommensschwacher Menschen geschieht. Ausgedrückt in der Brundlandt-Taxonomie der Nachhaltigen Entwicklung, ist Forschung in der Dimension der Sozialen Nachhaltigkeit angebracht.

Stichwörter: Öffentlicher Nahverkehr, Resilienz, Stadt, Klimawandel, Anpassung

List of abbreviations

AG	Aktiengesellschaft *Public Limited Company*
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety*
BSU	Behörde für Stadtentwicklung und Umwelt Hamburg *EPA / City of Hamburg, Ministry of Urban Development and Environment*
BWVI	Behörde für Wirtschaft, Verkehr und Innovation Hamburg *City of Hamburg, Ministry of Economy, Transport and Innovation*
DB	Deutsche Bahn *German Railways*
DMI	Danmarks Meteorologiske Institut *Danish Meteorological Institute*
DRR	Disaster Risk Reduction
DWD	Deutscher Wetterdienst *German National Meteorological Service*
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GmbH	Gesellschaft mit beschränkter Haftung *Limited Company*
HVV	Hamburger Verkehrsverbund *Hamburg's Public Transport Association*
IPCC	Intergovernmental Panel on Climate Change
LSBG	Landesbetrieb Straßen, Brücken und Gewässer *Municipal Agency for Streets, Bridges, and Water Bodies (subsidiary of BWVI)*
NAP	National Adaptation Plan for the NAS
NAS	National Climate Change Adaptation Strategy
NATO	North Atlantic Treaty Organization
NDR	Norddeutscher Rundfunk *Northern German Radio and TV Broadcaster*
PT	Public Transport
TEN-T	Trans-European Transport Networks
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
VHH	Verkehrsbetriebe Hamburg-Holstein *Bus operator associated in HVV*

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1 Introduction

1.1 Public Transport discovering the field of Climate Change Adaptation

In the last decades, unprecedented global warming has been observed. Among scientists and practitioners it has become consensus that it is induced by humankind, and that it is going to tremendously alter the global environment (Cook et al., 2013; IPCC, 2013). Global warming will particularly affect urban agglomerations as the effects – more and stronger extreme events, hotter summers, precipitation shifts – coincide with an ongoing urbanization trend. 73 per cent of Europeans live in cities, with a forecasted share of 82 per cent in 2050 (UN, 2014).

In the near future, cities will need to cope with increasing climate change-related hazards. Since the global climate system reacts inertly to the increase of atmospheric carbon dioxide, global warming, induced by anthropogenic emissions during the last decades, will continue – resulting in higher temperatures, rising sea-levels, and more extreme weather events (IPCC, 2014).

In Northern European cities, these effects culminate to a multi-dimensional threat scenario for human livelihoods: On the one hand heat-waves, fortified by the Urban Heat Island effect[1], threaten lives; The 2003 European heat-wave, e.g., carried off 70,000 people (Robine et al., 2008). On the other hand stronger storm surges and increased precipitation strain urban inhabitants and infrastructure. The July 2011 Copenhagen cloudburst, e.g. flooded wide parts of the capital and induced insured loss of 6bn Danish Crowns, ca. 800 million Euro, within few hours (Leonardsen, 2012, 2014; Strøbæk & Nielsen, 2013).

The urban transport sector represents a crucial function for urbanity: A growing number of people depend on the supply of goods and, in the case of Public Transport (PT), on reliable means of daily mobility. Simultaneously, transport systems are vulnerable to aggravating extreme weather events (heat-waves, precipitation, storm) that strain infrastructure and passengers (EEA, 2014a).

PT operators throughout Europe have recognized their climate change *mitigation* potential long time ago. The sector's *adaptation* to climate change effects, however, has hardly been subject to strategic planning (EEA, 2014a; Eisenack, Stecker, Reckien, & Hoffmann, 2012). As recently as in the last few years, the topic has been considered, as operators and public bodies recognized the need to replace outdated infrastructures. While their current adaptation focus lies on the design of facilities and vehicles, the transport operations in terms of, e.g., service schedules are given little attention (EEA, 2014a).

[1] The feature of urban areas to be significantly hotter than nearby rural areas due to the built infrastructure and a relatively low plant density (Santamouris, 2001).

Although practitioners acknowledge climate change as a key challenge for the PT sector, they have gained little adaptation experience yet. Accordingly, current efforts are rather fragmented and lack a systematic approach. As the uncertainty among decision-makers is high, there is a need to investigate sector-specific adaptation opportunities (EEA, 2014a; Pechan, Rotter, & Eisenack, 2011).

1.2 The aim of this thesis

In this thesis I investigate Hamburg's Public Transport system's coping capability towards adverse climate change effects. The concept used by academics and practitioners to achieve this goal is resilience. It describes a system that is able to resist, absorb, accommodate to and recover from external shocks (UNISDR, 2009). By applying the resilience concept to the PT system in Germany's second-largest city, I study how it translates into operation practice, how useful it proves successful for making Hamburg's PT more able to cope with adverse effects, and how it relates to equality and sustainability goals.

The research questions for this thesis are as described in Box 1.

Research questions

RQ1:	How has Hamburg's Public Transport system been stressed by direct climate change effects? Which indirect climate change effects have influenced Hamburg's PT?
RQ2:	How resilient is Hamburg's current PT system against climate change effects? What measures have PT operators and/or the municipality implemented to increase resilience? What do they plan?
RQ3:	What are social implications of resilience building in a PT context? Does a resilient PT exclude certain groups?
RQ4:	How can Hamburg's PT system be improved towards resilience? What are chances for resilience building, what are barriers?
RQ5:	Is the resilience concept appropriate to frame the adaptation of Hamburg's PT sector? To what extent is a resilient PT system in line with sustainability goals?

Box 1: Research questions investigated for this thesis

In chapter 2, I introduce the resilience concept as it has developed from ecosystem science. After operationalizing it for the case of a Hamburg's PT, I derive desirable attributes of a resilient PT.

Chapter 3 describes the methods I use to investigate the applicability of the resilience concept for Hamburg's PT. In chapter 4, I describe Hamburg's historical relationship to water, its unique PT system and the key challenges that come along with a changing climate. Furthermore, I introduce adaptation policies on the EU, national, and regional levels.

In chapter 5, I describe the results structured around the research questions introduced above to discuss them and derive implications for transport planning in chapter 6. The conclusion narrows the results down to answer the question the title poses: How resilient is Hamburg's Public Transport, how can we make it become so – and is it in line with sustainability goals?

2 Resilience: A developing concept in Sustainability Science and disaster risk reduction

In recent decades, the resilience concept has been used to frame coping capability towards adverse environmental impacts. Initially used in ecology, resilience theory has migrated to sustainability science and disaster risk reduction studies (J. Walker & Cooper, 2011). To approach a working definition, I summarize the development of the concept and critique towards it in the following section.

2.1 Initial definitions: Ecosystems 'absorbing changes' and 'returning to equilibriae'

From investigations of predator/prey relationships, the ecologist Holling (1973) derived a resilience definition that applies to ecosystems. His popular definition describes resilience as "the ability of systems to absorb changes of state variables [...] and still persist" (p. 17). Also focusing on ecosystems, Pimm (1984) describes resilience as the time that is needed for "[system] variables to return towards their equilibrium following a perturbation" (p. 322). The underlying assumption is that each complex system holds a certain capacity to compensate for significant changes.

According to Holling and Gunderson (2002), these two definitions represent dominant paradigms in conceptualizing resilience. They attribute the first definition (Holling) to an *engineering resilience* school that assumes one globally stable equilibrium and presumes "the dangerous myth that the variability of natural systems can be controlled [and] that the consequences are predictable" (p. 28). In contrast, they consider the second definition (Pimm) as an *ecological resilience* idea that conceptualizes several potential equilibriae and the capability of systems to change from one to another stable state.

2.2 Adding a Social Dimension

In the recent decades, the resilience understanding has been extended. Adger (2000) applies the initially ecological concept on social relations, concluding on a definition of resilience as the "ability of communities to withstand external shocks to their social infrastructure" (p. 361). As external shocks for a society, Adger names environmental impacts (e.g., agricultural pests, climate variation), further "social, economic and political upheaval" (p. 361).

Gaining in relevance, the uprising social resilience research resulted in a dimension supplementing *engineering* and *ecological resilience*: *Social-environmental resilience*. The unit of investigation are socio-ecological systems that are seized regarding (1) the amount of disturbance they can absorb while staying in their stable state, (2) their ability to re-organize themselves (in distinction to be organized from external forces), and (3) their capacity to develop learning and adaptive capacity (Carpenter, Walker, Anderies, & Abel, 2001; Folke, 2006).

Key features of the three resilience paradigms are shown in Table 1.

Resilience Paradigm	Characteristics	Focus on
Engineering resilience	Return time, efficiency	Recovery, constancy
Ecological/ecosystem resilience *social resilience*	Buffer capacity, withstand shock, maintain function	Persistence, robustness
Social–ecological resilience	Interplay disturbance and reorganization, sustaining and developing	Adaptive capacity transformability, learning, innovation

Table 1: Three paradigms of resilience. Adopted from Folke (2006, p. 259).

2.3 Disaster risk reduction and crisis management adopting the resilience concept

In the 1990s, the resilience concept began to migrate into the DRR field. By stressing the need for "resilience and self-confidence of local communities to cope with natural disasters" (UN, 1994, p. 11), the 1994 World Conference on Natural Disaster Reduction in Yokohama/Japan coined the term that should be used by important actors in the subsequent years (Galderisi & Ferrara, 2012). Parallelly, resilience ascended to a key term in governmental crisis management that, besides natural impacts, applies the concept to terrorist attacks and diseases (J. Walker & Cooper, 2011).

The United Nations International Strategy for Disaster Reduction (UNISDR), founded in 1999, defined resilience in 2004 as "[t]he capacity of a system, community or society potentially exposed to hazards to *adapt, by resisting or changing* in order to reach and maintain an acceptable level of functioning and structure." (UNISDR, 2004, p. 6, accentuation added).

The 2009 definition complements the previous one: "The ability of a system, community or society exposed to hazards to *resist, absorb, accommodate to and recover from* the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR, 2009, p. 24, accentuation added). The 2009 amendment manifests a focal shift from the *change* notion of the 2004 definition to the *resistance* and *recovery* quality.

2.4 Resilient systems are not static systems

It is important to point out that a system's resilience does not equal stagnancy. Ecosystems do not remain in a single equilibrium but move between several functionally stable states. Similarly, complex systems do not alter only in case of an external impact, but undergo a constant transformation (Holling & Gunderson, 2002).

Accordingly, the Stockholm Resilience Centre's current working definition reads:

> Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds. (Stockholm Resilience Centre, 2015)

For politics and system management, this dynamic conceptualization implies that the goal changes: From stabilizing a socio-ecological system's *productive efficiency* in a command-and-control manner to maintaining its *existence* by enhancing adaptive capacity (Holling & Gunderson, 2002). The aim is not to secure a seemingly-stable human society at any price – but to maintain the preconditions for its continuance.

2.5 Four operative capabilities of resilient systems

Investigating the potential for societal resilience to be enhanced and maintained, Hollnagel (2011) names four essential features of a resilient system Supplementing the UNISDR definition above, his categories apply on an operative level, i.e., deliver concrete links to improve a system's resilience: Hollnagel considers a socio-environmental system resilient when it is able to...

(1) ... *respond*	Knowing how to react to variability, disturbances, and opportunities	Addressing the *actual*
(2) ... *monitor*	Knowing which internal and environmental indicators to observe	Addressing the *critical*
(3) ... *anticipate*	Knowing what developments, threats and opportunities to expect	Addressing the *potential*
(4) ... *learn*	Knowing what has happened, draw the right conclusions from the right experience	Addressing the *factual*

Table 2: Four capabilities of resilience. Adopted from Hollnagel (2011, p. 279).

From Holling's 1973 predator/prey relations to Hollnagel's 2011 categories, the resilience concept has evolved from an ecosystem-modelling construct to a theory that is commonly applied to socio-environmental systems. Sustainability scientists as well as DRR and urban development agents refer back to it to assess and improve the situation of urban agglomerations exposed to environmental hazards (Becker, 2014; Wamsler, 2014).

2.6 Resilience: Working definition for this thesis

Any resilience assessment is highly context-related, as B. H. Walker (2002, p. 187) emphasizes: "Any discussion of resilience [...] must be prefaced by the question, 'The resilience of what to what?'. The system needs to be defined in terms of (1) the variables that describe the state, and (2) the nature and measures of the external shocks".

In my case, the subject of analysis is Hamburg's Public Transport system as described in section 4.1. Thus, I operationalize resilience as follows:

Resilience describes the capability of Hamburg's Public Transport system to resist, absorb, accommodate to and recover from Climate Change-related external shocks in a timely and efficient manner. It entails the capabilities to *anticipate* and *respond to* external shocks, to *monitor* appropriate indicators and to *learn from* past and present.

Main actors are the 30 PT operators, whereof three operators provide 72% of PT service. Furthermore, the PT association HVV and municipal agents have key influence.

External shocks are climate change-related extreme events, e.g., heat-waves, strong precipitation, storm surges.

Box 2: Working definition of resilience, referring to UNISDR (2009) and Hollnagel (2011).

2.7 Societal resilience as capitalism's resilience?

The resilience concept has not been uncontested. Particularly the application of ecosystem science to social systems is controversial. To metaphorically frame a city in ecosystem terms like *metabolism*, *self-organization*, or *competition* is criticized as one-sided: Environmental threats are constructed as inevitable and used to legitimize certain forms of urban development. The normative obligation to make the *city ecosystem* resilient is blamed for technically optimizing urban space, while disregarding the social production of urbanity. Governmental agencies and entitled experts are accused of reproducing undemocratic top-down decision making processes (Gandy, 2002; MacKinnon & Derickson, 2012).

This critique goes hand-in-hand with a general accusation of stabilizing unequal power relations. MacKinnon and Derickson (2012) blame resilience not only for masking the fundamental social question of how a society shall look like. They also accuse it of serving capitalist systems at the expense of others: "[T]he resilience of capitalism is achieved at the expense of certain social groups and regions that bear the costs of periodic waves of adaptation and restructuring" (p. 254).

On a political level, resilience is accused of promoting inter-regional competition following neo-liberal principles: Cities and metropolitan areas, feeling urged to take part in a global struggle for investment, would "increasingly [link] resilience [...] to urban marketing strategies, [...] stressing the 'safety' and 'security' of cities as places to conduct business" (Coaffee & Wood, 2006; MacKinnon &

Derickson, 2012, referring to Coaffee & Wood, 2006)[2]. Similarly, global capitalism, is taken for granted as "immutable external force", as MacKinnon and Derickson (2012, p. 261) criticize.

Copenhagen's attempt to couple its adaptation plan with *Green Growth* and to export the strategy to other cities (Københavns Kommune, 2011, p. 63f) exemplifies the interplay between resilience building and urban marketing. According to the critics, this interplay would take place at the cost of local social relations (MacKinnon & Derickson, 2012). Accosted with the former critique, Copenhagen's agent for climate adaptation indicated not to know about adverse impacts on social relations: Increased inequality, e.g. in terms of gentrification, had not been observed[3].

2.8 Resilience: An adequate framework to describe a public sector's adaptation?

The conceptual critique hardly aims at the resilience model as such, but rather on its application to cities that has in many cases become intertwined with a neo-liberal agenda. In an increasingly globalized environment, city governments feel urged to promote their qualities to potential dwellers and investors (MacKinnon & Derickson, 2012). That their pursuit of urban resilience necessarily results in social inequality, is, nevertheless, questionable. Particularly Public Transport as public service is supposed to provide a service that is accessible for all societal groups (Gegner, 2007).

I share the critique that resilience building can, when co-opted by neo-liberal ideas, jeopardize social equity. That critique, though, is not to direct to the analytical concept as such but to the agents using it. In other words, a climate-resilient but extremely exclusive PT would not be owing to the framework but by those who interpret the results without considering social questions. However, admitting that it is not exempt from social conflicts, I adhere to the resilience concept for my analysis.

[2] Coaffee and Wood (2006, p. 504) follow the UK resilience definition as "ability to detect, prevent and if necessary handle disruptive challenges", in a context of, e.g., terrorist attacks. Their argument is, however, transferable to climate change-related impacts.

[3] Reply at a Q&A during a presentation (Leonardsen, 2014) that was part of a LUMES excursion on March 14, 2014.

3 Method: Case Study and Qualitative Interviews

To investigate the research questions introduced in section 1.2, I chose a case study design and a mixed method approach. The analysis of peer-reviewed and grey literature and qualitative interviews with experts are the key methods. Using the term "Triangulation", Bryman (2012, p. 417) refers to the combination of complementary methods as a strong tool that allows to cross-check findings.
Below, I describe my research design and methods.

3.1 Conducting research in a real environment: Case study

The case study research design provides the basis for my research. It is useful to examine a subject in its particular context, and in-depth investigate specific questions (Gerring, 2007). My unit of analysis is Hamburg's PT with its local context. The PT system has grown with the city throughout more than a century, and it is closely intertwined with Hamburg's urban fabric both in built and in administrative regards (Krause, 2012). The system's specifications are unique. Lacking a tram system, Hamburg is, e.g., an exception among large German cities[4]. Instead, feeder lines for metro and rail are covered by bus, which leads to one of Hamburg's bus line 5 being the most frequently used one in the EU (Welt Online, 2010). Furthermore, the structural specification of running Hochbahn and VHH as two municipal bus operators is unique (VHH interviewee).
With its sensitivity for specific conditions, the case study design is suitable to answer my research questions. As my purpose is to in-depth investigate Hamburg's PT and its unique features, the research approach is idiographic: The primary aim is not to generalize results, but to derive results that specifically apply to the unit of analysis (Bryman, 2012). This focus on Hamburg's specifications does, however, not exclude the potential to transfer results to other cities.

3.2 Gaining insights from practitioners: Semi-structured interviews

3.2.1 The semi-structured interview as flexible instrument

One of my core methods is the semi-structured interview. The reliance on a structured questionnaire holds the potential to compare the interviewees' replies, while it leaves room for the interviewer to complement or change interview questions if appropriate (Bryman, 2012). In my case, this quality turned out particularly important, as the seven interviewees work in different fields. Accordingly, their focuses are distributed among my research questions. With the leeway the method provides I could adjust the respective interview focus to the respective interviewee's profession.

[4] Until 1978, Hamburg had a wide tram network that was then replaced by buses (Krause, 2012).

3.2.2 Purposive sampling as tool to identify experts

For the interviewee selection I chose purposive sampling, as described by Bryman (2012): My intention is not to generalize from the interviews to a wider population (e.g., from three PT operators in Hamburg to the 300 organized in the national transport association VDV) but to gain insight into a context-specific case. Target institutions were the City of Hamburg, the three most important PT operators (see Table 4), a transformation research institute, and the Right to the City movement. All interviewees should either work with or at least have a decent knowledge about Hamburg's PT strategy or about climate change adaptation, which made probability sampling unfeasible.

I approached the interviewees directly via email, respectively via their institutions' headquarters. The seven interviewees and their positions are described in Table 3.

Name	Position	Category
EPA*	Hamburg's Ministry of Urban Development and Environment, Department *Coordination Centre for Climate Issues*	Public Administration
BWVI*	Hamburg's Ministry of Economy, Transport and Innovation, Department *Traffic Planning*	Public Administration
Hochbahn*	Hamburger Hochbahn, Department *Occupational Safety and Environmental Management*	PT Operator
S-Bahn*	S-Bahn Hamburg, Department *Passenger Marketing*	PT Operator
VHH*	Verkehrsbetriebe Hamburg-Holstein, Spokesperson	PT Operator
Transformation researcher*	Norbert Elias Center for Transformation Design & Research, Department *Climate, Culture, Sustainability*	Science
HVV Umsonst*	Right to the City initiative *HVV Umsonst* ("HVV for free")	Civil Society

Table 3: Interviewees, their positions, and the categories they belong to.
* Due to privacy considerations, I do not provide the interviewees' names in this publicly accessible version.

I conducted the semi-structured interviews between March 23 and April 02, 2015, following the questionnaire in Annex A1. The interviews were recorded and varied in length between 35 and 75 minutes. My qualitative evaluation followed theoretical analysis (Kvale & Brinkmann, 2009), aiming at the research questions introduced in chapter 1.2.

3.2.3 Methodological limitations

Three methodological limitations concern my interviewee sampling. Firstly, it included PT stakeholders from different departments. Among the three operators, a difference in professions showed evident: One interviewee is employed at the environmental department, while the others work in distribution and customer relations. Correspondingly, the former's responses were rather environmental-technical, while the latter replied in a conceptual-administrative manner. This mismatch of interviewee professions was beyond my control. I explicitly asked the companies to assign a partner from the environmental department. At least one operator, however, does not have an environmental department.

The second limitation concerns the interviewee number. From a pool of 30 operators, I chose only three. As described in section 4.1, I took this decision since they provide 72% of Hamburg's PT service.

Thirdly, I did not include an interviewee from a ferry operator. I took this decision since the ferries account only for 4.2% of PT service (HVV, 2014b).

4 Adapting a Metropolis to an altering Climate: The Case of Hamburg

In chapter 2, I introduced the resilience framework used for my analysis. In theory, the desirable outcome is clear: Hamburg's Public Transport system shall be able to resist, absorb, accommodate to and recover from climate change-related adverse effects. Subject of this chapter are the conditions that embed resilience building in Hamburg.

Firstly, I briefly introduce Hamburg and its historical DRR focus to water-related extreme events. Secondly, I briefly outline forecasted changes in Hamburg's climatic conditions and the adverse impacts that may result. Thirdly, I summarize existing climate change adaptation strategies on EU, national, and local level.

4.1 A growing city at the shore line of a huge river

Hamburg is Germany's second-largest city with a population of 1.8 million people, located 108 km upstream from the North Sea along the Elbe river. Due to the proximity to the sea, the climate is oceanic, with an average daily maximum temperature of 12.8°C and 129.4 rainy days per annum (DWD, 2015). As such, Hamburg's average weather is a little less rainy than in the Öresund region's (Copenhagen: 11.1°C t_{max}, 168 rainy days; DMI, 2015).

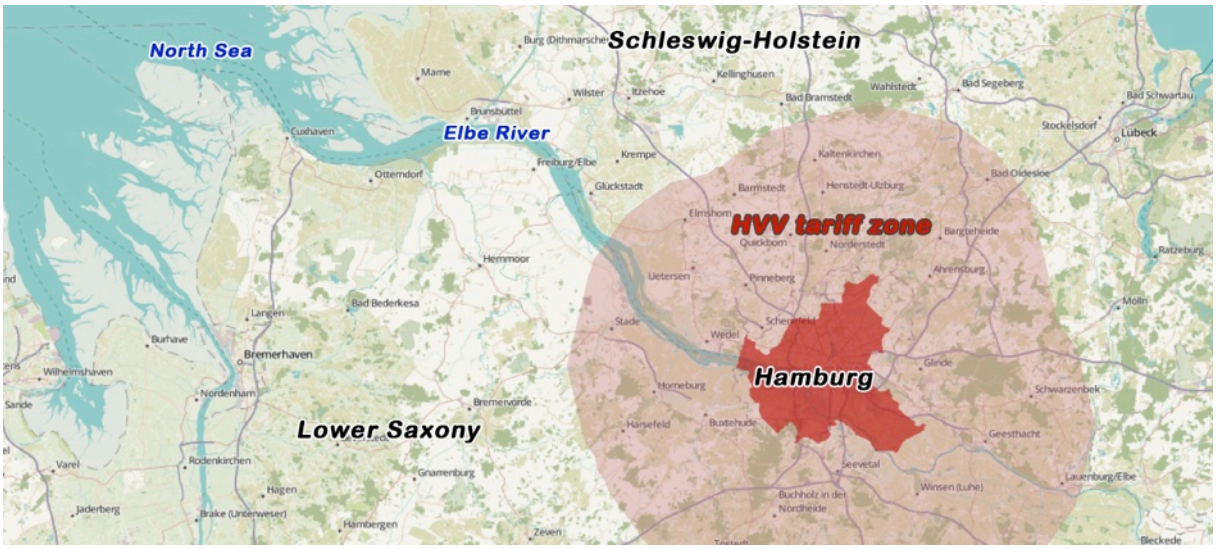

Fig. 1: Map of the Hamburg metropolitan area. The city (dark red) is located 108 km upstream the Elbe river between the federal states Lower Saxony and Schleswig-Holstein. Politically, Hamburg is counted as own federal state. The HVV tariff zone (bright red) covers whole Hamburg and parts of the other states. Map: OpenStreetMap contributors / CC license BY-SA 2.0

Historically, Hamburg's relationship to water has played a central role; it was one of the key cities of the Hanseatic League that dominated Northern European waterways between the 13th and 17th century. Industrialization allowed Hamburg to become a hub of maritime trade and industry, and the city kept this status throughout the two World Wars. Nowadays, the harbour is still an important base for international trade. As measured by turnover volume, Hamburg's harbour was ranked number two of Europe and number 15 worldwide in 2013 (World Shipping Council, 2015).

As freight vessels have been constantly growing in size and in draft[5], the Elbe river waterway has been adjusted at least seven times, from the 1850 depth of < 5 m to the current depth of 14.50 m, referring to the average low tide (Gaumert & Bergemann, 2007). After the last deepening was conducted in 1999, one more aiming for 19 m is pending at a federal German court, as the plan is highly contested. While Hamburg's government argues for the intervention as being essential for the local economy (carriers with huge vessels could evade to the deeper harbours of Wilhelmshaven/Germany, or Rotterdam/The Netherlands), environmentalists and smaller downstream cities deny further deepening referring to adverse consequences for ecosystems and flood safety (NDR, 2014a).

Although artificial deepening is only one out of several variables for rising water levels, an extra adjustment is forecasted to reinforce climate change effects in the whole lower Elbe catchment area. An increased tidal range would increase flood risk and make it necessary to improve flood protection (Graßl, 2007).

An improvement of flood protection is necessary in any case. In 2012, the municipality defined a new reference tide level that includes climate change effects. As a consequence, dikes and flood walls along the lower Elbe are going to be raised throughout the next 30 years (LSBG, 2012; BWVI interviewee).

4.1.1 Hamburg's Public Transport system

Hamburg's first metro was launched in 1912 and has been successively expanded throughout the last century. As first European city, Hamburg established an integrated tariff system. The model of one common tariff covering different operators was implemented in 1965 and has been adopted in many cities throughout the world (Krause, 2012). Nowadays, 30 operators are organized in the regional Public Transport association (HVV) and transport three million persons per day over a distance of 98.4 million place-km[6] (HVV, 2014b). 72% of service is provided by the operators Hamburger Hochbahn, S-Bahn Hamburg, and Verkehrsbetriebe Hamburg-Holstein (Table 4).

[5] The nautical term for the range between the waterline and a vessel's keel. The draft determines the minimum water depth required to navigate. To arrive in and depart from Hamburg, huge vessels *surf* on the incoming, respectively outgoing tidal wave to ensure a sufficient depth.

[6] Place-km: Quantitative indicator for transport service, describing the product of the place number (seats/standing) and the distance covered in km.

Operator	Modality	Owner	2013 Service / billion place-km	2013 Service / %
Hamburger Hochbahn AG	Metro, Bus	Hamburg City	Metro 8.1 Bus 3.5 11.6	32.4
S-Bahn Hamburg GmbH	Rail	Deutsche Bahn AG /DB Regio	11.6	32.4
Verkehrsbetriebe Hamburg-Holstein AG (VHH)	Bus	94% Hamburg City 6% Pinneberg Municipality	2.5	6.9
All 30 Operators	*Rail, Metro, Bus, Ferry*		*35.8*	*100.0*

Table 4: Hamburg's three most important Public Transport operators. In the text body, operators are referred to as indicated by the underlined names. Source for service index: HVV (2014b)

After the HVV association had held operative PT competencies in the first 30 years – it controlled, among others, the common product development, pricing, and marketing – a mid-1990s reform allocated responsibility back to the operators. As a result, HVV's task has been reduced to an administrative scope of contracting out the regional PT service. Although it formally is a limited company (German GmbH), HVV effectively operates as an agency for the share-holding municipalities in three federal states. As such, it coordinates PT as a public service[7] (Krause, 2012). As each operator is responsible for their own strategy, the topic of resilience and climate change adaptation is – if at all – addressed on the operator level[8].

4.1.2 The 1962 storm surge: Shaping Hamburg's DRR understanding

In February 1962, a North Sea high tide in combination with strong western winds pressed water into the Elbe river that soon flooded dikes up to Hamburg. Whole villages were devastated, 340 persons lost their lives, and around 20,000 people lost their homes (NDR, 2012). In Hamburg, particularly the waterside districts Wilhelmsburg and Veddel were hit. Public Transport infrastructures in forms of tram tracks were heavily damaged (Krause, 2012).

The 1962 flood had a huge impact on subsequent disaster risk reduction measures. Whereas coastal protection had historically been part of regional responsibilities, a 1969 law lifted it to the federal level. An unprecedented governmental program was set up to retrofit existing dikes and to partly build completely new infrastructures (Junge, 2012). Moreover, the flood went down into the citizens'

[7] In Germany, PT has the status of a public service. Municipalities are obliged by constitution to provide a decent level of service. According to established interpretation that includes, e.g., water supply, waste disposal, and Public Transport (Franz, 2005).

[8] According to HVV's reply to an interview request in March 2015.

collective memory. Even five decades later, the date 1962 stands for an extreme event that, due to neglected preparation, destroyed thousands of livelihoods.

4.2 Regional climate forecast: Warmer, rainier, wetter

According to a multi-scenario analysis, Hamburg's regional climate is forecasted to undergo significant alterations. Box 3 shows a summary of PT-related changes.

Forecast of Hamburg's regional Climate Change

- An increase of hot summer days, heat-waves and droughts
- A seasonal precipitation shift from summer to winter, a fortification of rainfalls
- An increase of the Elbe river's water levels

Box 3: Hamburg's regional climate change forecast after Daschkeit and Renken (2009). Summarized are the essentials in the Public Transport context.

The forecast relies on five regional climate models (Daschkeit & Renken, 2009) and is in line with global climate forecasts that describe future warming, shifts in precipitation patterns and a global sea-level rise (IPCC, 2013). Hamburg has already been affected by extreme weather, particularly heavy precipitation (Schulze et al., 2012); Trying to assess the economic impact induced by to a cloudburst in June 2011 (four days after the Copenhagen cloudburst mentioned above), Schulze et al. (2012) calculate a damage between 27.3 and 46.1 million Euro.

4.3 Existing Climate Change adaptation strategies

4.3.1 EU level

Within the last decade, political decision-makers' awareness of adaptation requirements has risen. This manifests in the EU members' national adaptation strategies approved throughout the last decade. Since 2005, 21 European countries have adopted a national adaptation strategy (NAS), whereof nine strategies explicitly mention the transport sector (EEA, 2014b). However, "transport modes are considered differently, depending on the specific conditions of each country. No country reports about an integrated, trans-modal approach to adaptation." (EEA, 2014a, p. 23)

The EU pursuit to set up a cross-national adaptation framework started in 2007 with the Green Paper[9] *Adapting to climate change in Europe – options for EU action* (EC, 2007) and was supplemented by a 2009 White Paper[9] *Adapting to climate change: Towards a European framework for action* (EC, 2009) that proposes concrete steps for resilience building in five societal fields. Public Transport is not explicitly mentioned, but fits into the *physical infrastructure* field.

As a framework strategy, the European Commission adopted the EU climate adaptation strategy in 2013. One of the three core objectives is to "[p]romot[e] adaptation in key vulnerable sectors"; One of the eight action fields is, again, to "[e]nsur[e] more resilient infrastructure" (EC, 2013, p. 2).

[9] A *Green Paper* is a EU-wide discussion paper published by the European Commission. In some cases it is followed by a *White Paper* that proposes concrete EU action (EU, 2015a, 2015b).

Overall, adaptation strategies on the EU have no legislative but a consultative character. Via EU institutions like the EEA and the adaptation database *Climate-ADAPT*[10], member states share their adaptation knowledge. Furthermore, members can retrieve EU funds: the 2014-2020 EU budget dedicates at least 20% for climate change mitigation and adaptation projects (EEA, 2014a).

4.3.2 National level

The key document on the national level is the *German Strategy for Adaptation to Climate Change (NAS)* adopted by the parliament in 2008. According to the United Nations Framework Convention on Climate Change (UNFCCC), each country is supposed to develop adequate domestic adaptation policy (UN, 1992). This requirement is put into national legislation by the NAS, on the purpose to provide a framework for adaptation strategies on various levels (The Federal Government, 2008).

The NAS describes forecasted climatic long-term alteration for Germany. Furthermore, it summarizes specific adverse effects and adaptation opportunities for 14 societal fields. Subsuming PT as part of *transport and infrastructure*, the NAS contemplates potential threats and opportunities with a focus on infrastructure, while operational processes are not regarded (The Federal Government, 2008). In 2012, the environmental ministry published the *Adaptation Action Plan for the Strategy for Adaptation to Climate Change (NAP)*. As the purpose was to complement the conceptual NAS by a roadmap for climate change adaptation, the NAP specifies responsibilities and summarizes ongoing and planned adaptation activities throughout Germany (BMU, 2012).

Although the NAS and NAP were initiated by the federal parliament, neither of them has a legislative character. Instead, they are supposed to provide a basis for several actors' adaptation strategies.

Neither NAS nor NAP does explicitly refer to resilience as adaptation framework. However, their conceptual starting point of reducing societal vulnerability by increasing adaptive capacity (The Federal Government, 2008) is closely related to the resilience concept (Becker, 2014; Wamsler, 2014).

4.3.3 Local level

In 2013, Hamburg's government decided to develop an adaptation strategy. In 2013, it published the *Adaptation Action Plan* that describes nine fields of action. None of them explicitly refers to Public Transport, whereas the traffic infrastructure adaptation to rainwater impacts is mentioned in the water management section (Bürgerschaft der Freien und Hansestadt Hamburg, 2013).

The *Adaptation Action Plan* is planned to be updated In 2015. It shall serve as a starting point for the *Adaptation Strategy* that is supposed to follow up in the same year. In preparation for the *Strategy*,

[10] *http://climate-adapt.eea.europa.eu* (Retrieved on May 08, 2015)

the EPA is currently developing a monitoring index for climate change effects (EPA interviewee; Umweltbundesamt, 2014).

On behalf of the city's EPA, Schulze et al. (2012) evaluate Hamburg's climate change adaptation options. For their economic analysis they investigate existing research in seven societal fields. They do not explicitly analyse PT, but refer to in the *infrastructure* and *urban development* fields. Furthermore, the authors name "a safe and reliable (public) transport" as beneficial (p. 66).

Referring to the complexity of the topic, Schulze et al. do not give a singular recommendation. However, they conclude that Hamburg should prepare an adaptation strategy, and make processual recommendations like the timely inclusion of stakeholders and the increase of cross-administrative communication regarding adaptation.

5 Results: A day-to-day resistant Public Transport System

The following section describes results of the semi-structured interviews and the analysis of peer-reviewed as well as grey literature. The structure follows the research questions.

RQ1: How has Hamburg's PT system been stressed by direct climate change effects?

- **All operators have been affected throughout the last years.**
- **The central problems for rail and metro have resulted from storms and frost, for buses from flooding events and warming.**
- **The operators expect to be affected in the future.**
- **They cannot quantify overall damage in monetary terms. Losses are not considered significant as long as the extreme events do not increase.**

Which indirect climate change effects have influenced Hamburg's PT?

- **Indirect impacts have been building regulations, tendering conditions, adaptive passenger behaviour, and societal macro trends.**

Box 4: Result summary for research question 1.

In general, Public Transport can be affected by climate change in different ways. Rotter, Glahe, and Hoffmann (2011) distinguish between *direct* and *indirect* impacts.

Direct impacts are factors that influence PT in a physical way, i.e., by shortening the lifespan of infrastructure and endangering safe operation (Rotter et al., 2011) (Fig. 2). Examples are a higher prevalence of hot days and higher temperature, resulting in stressed infrastructures (e.g., melted tarmac, buckled rails) and distressed persons (e.g., passengers in a coach with faulty air condition) (Metroeconomica Limited, 2006). Particularly in autumn and winter, extreme precipitation events stress facilities (e.g., flooded tunnels) and may cause transport interruptions. Falling trees due to storm can be a threat, especially for railway networks with overhead electrification (EEA, 2014a).

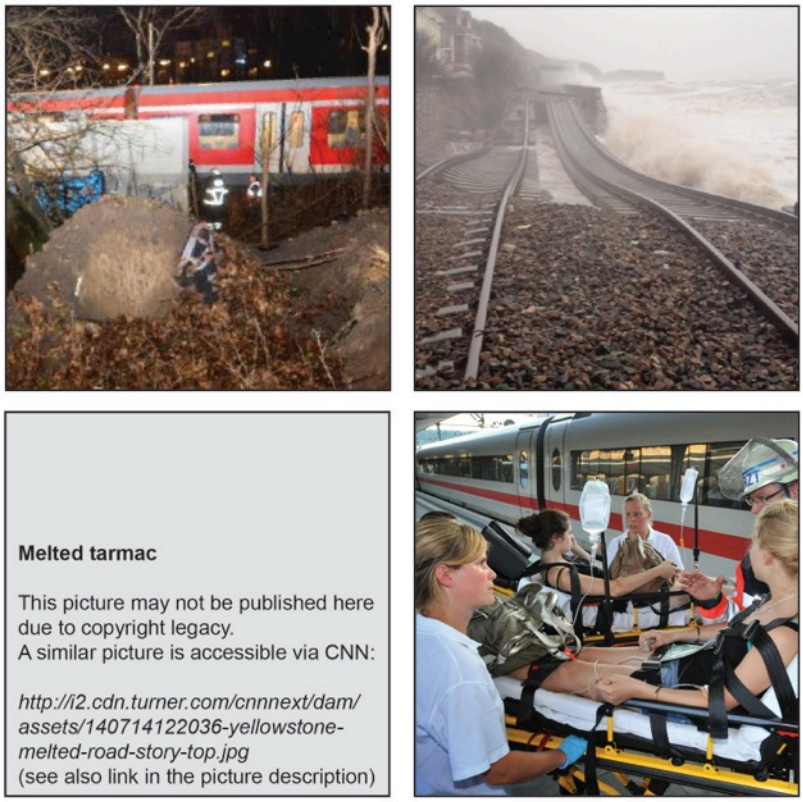

Fig. 2: Climate change-related direct impacts to Public Transport:
(a) S-Bahn train blocked by a fallen tree in Hamburg,
(b) Rails washed away by a storm surge in Dawlish, Devon/UK,
(c) Melted tarmac in Yellowstone National Park/US,
see *http://i2.cdn.turner.com/cnnnext/dam/assets/140714122036-yellowstone-melted-road-story-top.jpg*,
(d) Dehydrated passenger treated by paramedics after the AC in a German high-speed train has collapsed.
Photos: (a) © Lars Ebner, (b) © NetworkRail UK, (d) © dpa/picture-alliance

Heat-related incidents have not been critical for the German PT sector. Only one of 26 operators surveyed by Pechan et al. (2011) indicated severe past impacts (Fig. 3). However, a series of incidents raised the heat issue: In July 2010, air-condition systems in 50 Deutsche Bahn high-speed trains collapsed. Passengers inside were exposed to temperatures up to 50° C, unable to open any windows. As a result, dozens dehydrated and several had to be hospitalized (Zeit Online, 2010).

According to the 26 German operators, storm and cold spells have been the most severe impacts (Fig. 3), particularly on railway systems. In Hamburg, frost has been a central issue for S-Bahn. Particularly in the outskirts, the electrical supply rails at the vehicle sides are more prone to freeze than conventional overhead lines.

However, climate change is forecasted to reduce the prevalence of frost periods. Thus, the pressure to adapt to frost is forecasted to ameliorate (Bräuer et al., 2009; Daschkeit & Renken, 2009).

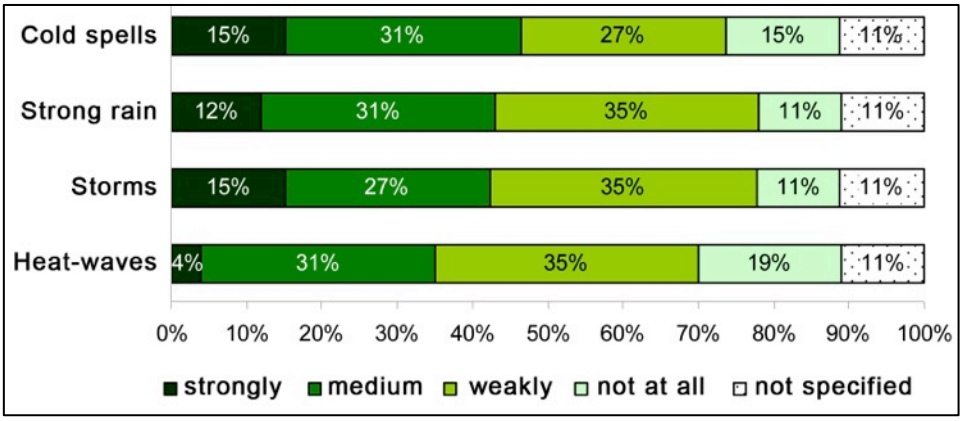

Fig. 3: Impacts of extreme weather events on PT operation (short- and long-distance) as assessed by German operators (N=26). Adopted from Pechan et al. (2011, p. 21).

5.1.1 Direct impacts on Hamburg's PT: Rails blocked by trees, flooded streets

Hamburg's three interviewed PT operators indicated that their business has been affected by direct impacts throughout the last years. For rail and metro operation, the most evident problem has been induced by trees blocking the tracks and damaging overhead lines[11] during storm events. Whereas S-Bahn (rail) reported rather low financial damage, Hochbahn (metro) referred to a significant impact: In December 2013, a train hit a fallen tree and dragged it along, which damaged a bridge and made the train partly derail (Fig. 4). No persons were hurt, but the incident induced costs of two million Euro (Hochbahn interviewee; Hamburger Abendblatt, 2013a; 2013b). Hamburg municipality does not reimburse the operators for damage resulting from extreme weather. Hochbahn and VHH are insured, while S-Bahn has to bear the losses itself (respective interviewees).

Fig. 4: Hochbahn metro coach derailed by a fallen tree in Großhansdorf close to Hamburg.
Photo: © Monika Veeh / ahrensburg24.de

[11] An issue only in-between nine outskirt S-Bahn stations. In-between the other 59, trains are supplied by contact rails below the train doors. (HVV, 2014b; S-Bahn interviewee).

Although the rail and metro operators run underground stations (S-Bahn 9 of 68 stations, Hochbahn 45 of 91), none of them reported flood-related problems. However, a news portal reported water intrusion into the main station during a thunderstorm in June 2011. As a consequence, the station had to be partly closed as rainwater spilled on long-distance rail overhead lines (Redaktion Blaulicht, 2011). Other news portals reported that several metro tunnels had been flooded due to the same incident and that inner-city bus traffic was interrupted (Focus Online, 2011; Hamburger Abendblatt, 2011).

For bus operation, the central issue mentioned has been flooding of street infrastructure in Lauenburg city upstream the Elbe river. However, as they are independent of tracks, buses are flexible to adapt, which has enabled VHH to avoid any damage. The major challenge has been "to keep our vehicles out of reach of the flood".

Higher summer temperature was named as a past issue only by VHH, whereas all operators expect future adverse impacts. These can emerge, e.g., in the form of parched scarps along the infrastructure and as physical strain for passengers (Hochbahn; S-Bahn). The technical infrastructure is not expected to be strained by the forecasted warming in Hamburg. Accordingly, there has not been experience with infrastructure damaged by extreme heat (S-Bahn).

It was difficult for the operators to quantify specific climate-related damage. Beyond the singular costs of certain incidents (e.g., the metro tree accident mentioned above) none of them is systematically registering weather-induced loss. The S-Bahn representative estimated that each storm event causes a one-day disruption, amounting to 34,900 person-kilometres not provided. He called the translation into financial damage difficult, since the pooled tariff system would not allow for it. However, the representative indicated that the losses are not significant – "assuming [the climate] stays like it is".

Indirect impact on Hamburg's PT: Regulation, local political agenda, tendering

Indirect impacts are factors that affect transport networks and operators through political and societal adaptation pursuits. According to Rotter et al. (2011), governmental strategy on different levels, as described in section 4.3, has a significant influence on how, and how timely, operators take adaptation steps. In Germany, these indirect impacts are mediated by the PT systems' structural conditions: In many cases, operation and infrastructure maintenance are run by separate organizations[12], and cross-cutting issues take place in an environment of entangled state, private,

[12] E.g., S-Bahn:
The trains are owned and run by *S-Bahn Hamburg* (subsidiary of *DB Regio*), while the rails and the energy grids are owned and maintained by *DB Netze*. The stations are owned and run by *DB*

and hybrid responsibilities (Gegner, 2007). Accordingly, climate change adaptation attempts need to include a variety of actors.

Hochbahn named operational regulations[13] as important indirect factor that prescribe, e.g., certain flood protection measures for the metro infrastructure. Furthermore, the ownership structure might be important. As a publicly-owned limited company running a subsidized service, Hochbahn is directly subject to political decisions: "As the city requests a certain cost-efficacy, our financial capacity [to adapt to climate change effects] is low". Moreover, Hochbahn referred to regulations that might antagonize adaptation: The public obligation to reduce energy consumption, e.g., collides with plans to climatize vehicles in response to heat-waves.

S-Bahn referred to the tendering preconditions that oblige the company to exactly provide the service prescribed by a 15-years contract. This static planning could impede adaptive capacity (see *RQ5/Barriers* below). VHH has been affected indirectly in the flooding case, as an agreement with the municipality obliges the operator to support emergency services by, e.g., evacuating affected districts.

A potential indirect factor named by BWVI and HVV Umsonst is passenger behaviour. Already now, the weather would lead to adaptive mobility behaviour, e.g., a higher ridership on rainy days.

In contrast to Rotter et al.'s (2011) assessment, EU and national influence seems to be of minor relevance. Only Hamburg's EPA representative referred to European and national policy; She did not attest influence on Hamburg's adaptation[14]. As conceptual framework strategy, Germany's national adaptation strategy (NAS) would not exert influence on local adaptation. Neither did the EPA representative attest EU institutions' influence, who mainly act "by coordinating transnational reporting"[15].

Station&Service. Interactions take place as business transactions: For each train stop-over of a train, S-Bahn pays a fee to *DB Station&Service* (Interview S-Bahn).

The split structure is characteristic for lines that have been run by DB's predecessor Deutsche Bundesbahn until 1994. The fundamental structural reform ceased the stately railway monopoly.

[13] In the Hochbahn case prescribed by the *Regulation regarding the construction and operation of tram lines* (Verordnung über den Bau und Betrieb der Straßenbahnen).

[14] Several interviewees related to legislation aiming at climate change *mitigation*. As my thesis focuses on *adaptation*, I do not consider these statements.

[15] An example for EU-level reporting is EEA's data collection: By agreement, member countries are obliged to provide certain data, e.g., regarding their carbon emissions (EEA, 2015).

RQ2: How resilient is Hamburg's current PT system against climate change effects? Which measures have PT operators and/or the municipality implemented to increase resilience? Which do they plan?

- ***Response***: **The operators have established response processes for known impacts.**
- ***Monitoring***: **One operator has a monitoring process that is not specifically sensitive to climate change effects.**
  The municipality is about to start a 20-years monitoring process.
- ***Anticipation***: **The operators do not systematically anticipate climatic changes.**
  Hamburg cooperates closely with neighbouring federal states to improve anticipation quality.
- ***Learning***: **The PT sector's Learning is coupled with concrete adverse impacts.**

Box 5: Result summary for research question 2.

For assessing the PT system's resilience, I use Hollnagel's (2011) four functions as introduced in section 2. Fig. 5 shows the illustration that I used for the interviews.

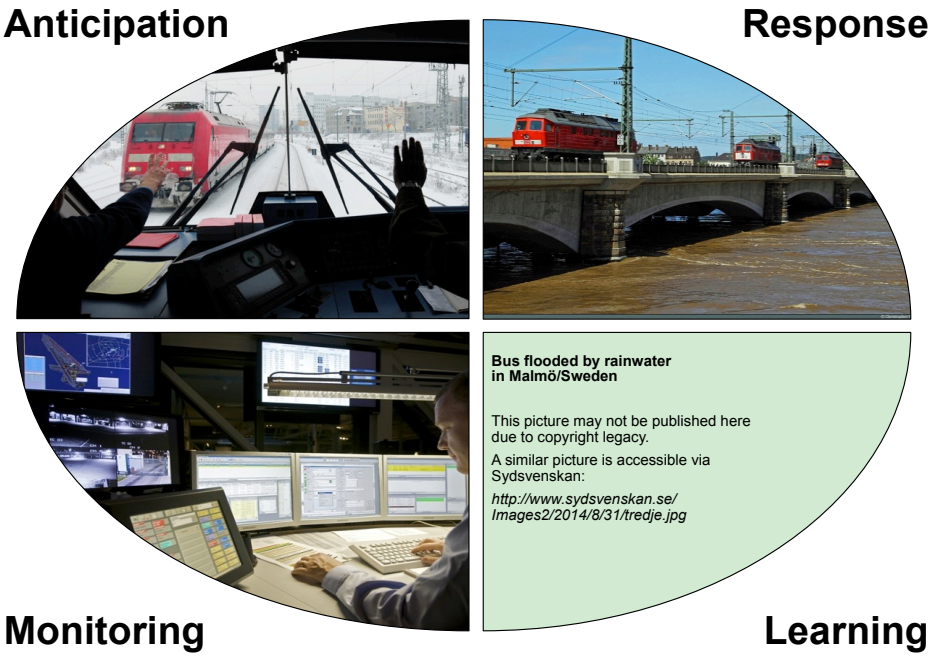

Fig. 5 Hollnagel's (2011) four resilience functions, as illustrated for the questionnaire. Photos: *Anticipation*: Ralf Roletschek/Wikipedia, CC-Lizenz BY-NC-ND 3.0; *Response*: © Christopher Pätz; *Monitoring*: Rusty Solton/Wikipedia, CC-Lizenz BY-SA 3.0; *Learning*: accessible via http://www.sydsvenskan.se/Images2/2014/8/31/tredje.jpg

5.1.2 Response: Established processes to cope with short-term impacts

The *Response* dimension describes the capability "to respond to [...] disturbances either by adjusting the way things are done or by activating ready-made responses" (Hollnagel, 2011, p. 279). Simply put, it is about "knowing what to do" and "being capable of doing it" (p. 279).

For weather impacts that have already impacted them, Hamburg's operators have established coping processes, e.g., to hold available replacement vehicles, reduce the number of trains in a storm situation to ease evacuation, or drive *on sight* (as opposed to normal, signal-guided operation) to prevent collisions with fallen trees. Overall, the goal is to at least provide partial PT service – as the S-Bahn representative framed it, "we drive until our last vehicle is stuck".

For the immediate reaction to a disaster, the rail and metro operators have contingency plans available. They participate in crisis management groups and cooperate with police and emergency services. The contingency mechanisms assume, however, rather "conventional" (S-Bahn) scenarios such as fire or terrorist attacks. Accordingly, there is no specific heat-wave, storm surge, or cloudburst contingency plan. The bus operator VHH does not have a comprehensive contingency plan either. In case of a disaster, the coordination is delegated to civil protection agencies and Hochbahn as the largest operator. The VHH representative described past responses as well-coordinated.

In general, the operators described their response measures as reactive. As the S-Bahn representative stated: "Our reaction is plainly led by incidents". Some proactive adaptation takes place on the basis of changing weather patterns; Hochbahn referred to the opportunity to enlarge sewage systems in newly-built metro infrastructure. That measure has, however, not been implemented yet.

The operators acquire air-conditioned (AC) vehicles to be able to respond to heat impacts. While AC buses have been standard for Hochbahn and VHH for at least ten years, AC metro trains were firstly launched by Hochbahn in 2012, and S-Bahn will follow with rail trains in 2016. Due to financial constraints, S-Bahn is going to run the air-condition system at a low level.

5.1.3 Monitoring: Unspecific operational monitoring, municipal monitoring under progress

Hollnagel (2011, p. 279) describes the *Monitoring* capacity as "knowing what to look for [...] that which changes [...] so much in the near term that it will require a response", including both system and external variables.

In response to the fatal 1962 flood, Hamburg has set up a monitoring system that assigns the port authority to compare each observed flood level with the forecasted scenario. Furthermore, once in ten years the federal states along the lower Elbe river (Lower Saxony, Schleswig-Holstein, and

Hamburg) jointly assess the flood protection effectivity and set the indicators for the next five decades (BWVI interviewee).

Among the surveyed operators, only Hochbahn named a monitoring process – one that is, however, unspecific to climate change effects. In the daily reports that have been established at least since 2003, only incidents affecting operation are documented. Operationally *harmless* effects (e.g., high underground water levels that do not affect train operation) are therefore not considered. Neither are the existing data mined to learn about past impacts.

The representative considers the idea to adjust the daily report to cover climate change effects reasonable – though it, as he stated, would require the awareness and the company's managing board's willingness. Like Hochbahn, the other two operators do not specifically monitor climate change-related indicators.

A municipal monitoring process for climate change effects is under progress. It relies on a set of indicators that are classified as *state*, *impact*, and *response indicators*. The monitoring process shall deliver information about climatic changes in the next two decades, but is not specified for certain urban functions like, e.g., transport (Umweltbundesamt, 2014; EPA interviewee).

5.1.4 Anticipation: Delegated to established institutions

According to Hollnagel (2011, p. 279), *Anticipation* describes the capacity to "expect [...] developments [...] such as potential disruptions or changing operating conditions" – to "address the potential".

For short-term planning, all surveyed operators rely on the national weather forecast. Regarding long-term climate change effects, only the Hochbahn representative has gathered some knowledge about future impacts. Due to resource constraints, however, he has not been able to follow-up on the topic: "[Unfortunately], adaptation is one project among many in our environmental management department." In line with their practice of not monitoring, the other two operators do not strategically anticipate climate change impacts either.

A particular case of anticipative action was reported by VHH: By planning the new radio system, the operator is keeping the current analogue technology running parallelly to the new digital radio. In a disaster case, the digital communication is subject to external crisis management, which would possibly hamper bus transport coordination[16]. The resulting risk to not be able to communicate is considered big enough to invest extra money in redundant technology to uphold the capacity to act.

[16] In an emergency case, digital radio licenses are ranked: Police and emergency services are prioritized, while other nodes (e.g., private mobile phones, transport operators) can be disconnected to enable prioritized communication. In contrast, analogue radio is hosted by the operators themselves and cannot be interrupted by regulation (VHH interviewee).

Overall, a climate-specific anticipation strategy that would sufficiently cover Hollnagel's recommendation to "address the potential" (p. 279) does not exist in Hamburg's PT system. As the S-Bahn representative put it, "we explicitly do not consider climate change adaptation, not even indirectly".

5.1.5 Learning: By experience

Hollnagel (2011, p. 279) describes *Learning* as "knowing what has happened" and "learn the right lessons from the right experience".

As described in *Response* above, the adaptation of Hamburg's PT is experience-based: Each improvement follows a respective adverse impact. Partly, the operators have established learning processes, e.g. assessing the previous winter's frost impacts to improve responsive capacity (S-Bahn). Hochbahn and VHH described their learning processes similarly.

Hence, the operators fulfil Hollnagel's *Learning* category.

RQ3: What are social implications of resilience building in a PT context? Does a resilient PT exclude certain groups?

- **Most interviewees do not expect social injustice as a result of PT adaptation in Hamburg.**
- **Several interviewees acknowledge the potential for inequality. They see the cause, however, not in the resilience concept but in the societal context.**

Box 6: Result summary for research question 3.

Resilience critiques, as mentioned in section 2.7, blame the concept of reinforcing social inequality (MacKinnon & Derickson, 2012). Applied to PT, the primary way of socially excluding people is via ticket pricing: Climate change adaptation of Infrastructure and operation could happen at the cost of higher ticket fares and thus disregard poor citizens.

The EPA representative called this polarity of *a resilient PT vs. an affordable one* being "constructed".

Resilience building would not necessarily exclude persons, but the context might:

> Technically speaking, building up resilience does not by any means induce marginalization. [...] It could, however, appear that way: When in the course of refurbishing public space with private financing, certain groups of citizens are excluded from using the space. The society should, however, be careful to avoid this effect.

Similarly did the transformation researcher argue:

> It is imaginable that the resilient PT excludes certain groups. It does, however, not do so as a result of the resilience policy, but of the society in that it takes place. When a society marked by inequality tries to make certain systems resilient, that will be achieved unequally. [...] It is therefore not a weakness of the concept per se, but of the social context that resilience is pursued in.
>
> Inequality can of course emerge in the PT as well, or does already: In a crowded train with defect air-conditioning it is probably still more comfortable in the first class than in the second. The different comfort hence influences the experience of weather events[17].

Similarly to the class segregation, he sketched a hierarchy between high-speed and low-speed connection: "Certain [long-distance] high-speed trails are probably built very resiliently, while a small line in the countryside is affected much faster".

Except of HVV Umsonst, all interviewees stressed PT's current success at delivering an accessible public service that they expect to continue. They do not expect a marginalization of certain groups. The HVV Umsonst representative, however, does "of course [...] see a relationship between resilience building and ticket fares." Assuming that PT operators bear the necessary investments, he is concerned about potential fare increases at the cost of lower-income groups.

Referring to public cost pressure (see *RQ5/Barriers* below as well), the Hochbahn representative disagreed: "I rather expect no climate change adaptation than an adaptation that leads to higher ticket fares."

[17] That separation applies to very few cases in Hamburg's inner-urban PT system. Except of few surchargeable express buses there is no class discrimination any more.

RQ4: How can Hamburg's PT system be improved towards resilience?
What are chances for resilience building, what are barriers? Who has the agency?

- **As chances for adaptation, timely beginning and mainstreaming are considered.**
- **The potential of a Copenhagen-like *wake up disaster* is disputed.**
- **Perceived barriers are financial pressure, long-term contracts, and a lack of political awareness.**
- **The operators allocate the adaptation agency to the municipality.**
- **All interviewees consider long-term political thinking as key for resilient urban PT. With a quarterly stakeholder meeting, BWVI tries to establish it.**

Box 7: Result summary for research question 4.

5.1.6 Chances for adaptation: Mainstreaming, and a 'wake-up disaster'?

As chance for infrastructure adaptation, the mainstreaming of resilience building into already planned interventions is promoted (Schulze et al., 2012; Wamsler, 2014). Huge parts of the German rail and road infrastructures are about to be modernized in the near future, which entails the opportunity to incorporate climate-specific requirements: New vehicles can, e.g., be outfitted with air-condition, while newly-built facilities can benefit from increased water drainage capacity. Particularly for long-lasting infrastructures, timely adaptation investments are considered useful to prevent later adaptation costs that would be significantly higher (Rotter et al., 2011).

Similarly did the interviewees argue. The EPA interviewee emphasized that a timely start of the adaptation process could "virtually completely avoid surplus spending". Her assessment is in line with Hochbahn's and VHH's conclusion. Accordingly, the BWVI representative referred to mainstreaming: Hamburg's road surface is planned to be completely retrofitted throughout the next two to three decades. In combination with ongoing federal research on tarmac robustness against heat and on road drainage, the representative diagnosed the opportunity for a resilient renewal.

EEA (2014b) refers to extreme weather events as effective trigger for adaptation policy. Out of 30 surveyed European countries, 28 named those events as motivation to set adaptation on the political agenda (Fig. 6).

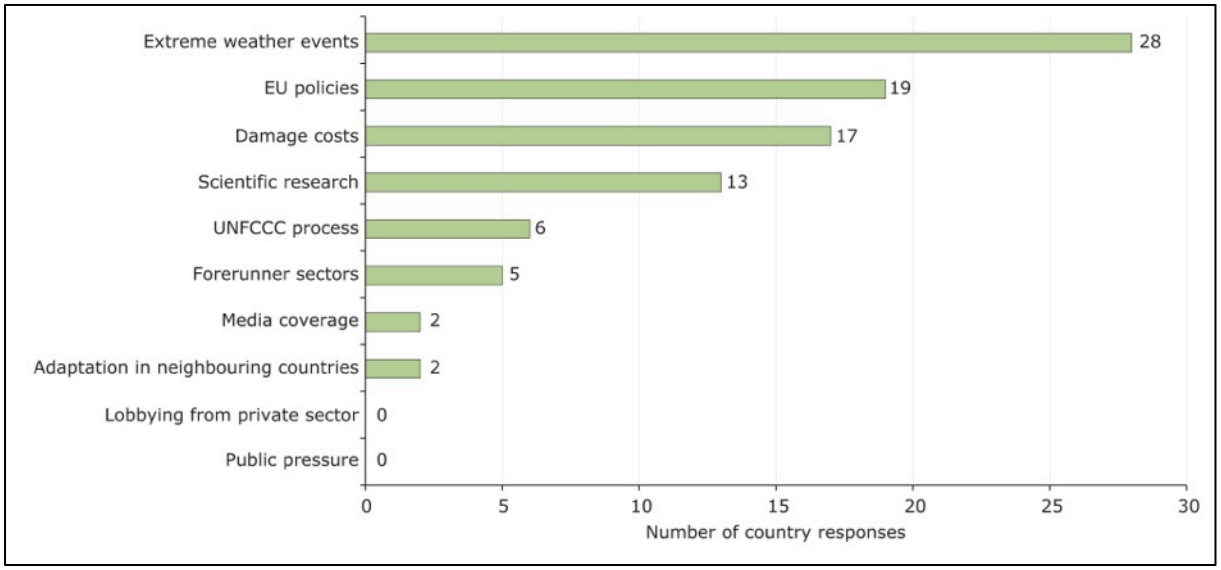

Fig. 6: Triggers to adopt climate change adaptation policy, as indicated by 30 European countries. NB: The survey investigated not the PT sector's, but the countries' overall adaptation. (EEA, 2014b, p. 24)

Regarding the question whether a disaster like the 2011 Copenhagen cloudburst could be *helpful* to trigger eager adaptation policies, the interviewees were at odds with each other. As the BWVI representative stated, "I [assume] that such a severe event could mobilize stronger than many expert arguments". HVV Umsonst agreed, referring to the 1962 flood's persisting strong narrative that "could indeed trigger PT planning, e.g., to question an underground metro system that is not accessible in case of a flood event". Here he referred to the government's strategy of developing the PT system by expanding the metro system (NDR, 2014b).

The S-Bahn representative agreed to the potential of a disaster as well, referring to "human nature" reacting to, particularly adverse, incidents.

The Hochbahn interviewee acknowledged the chance of an extreme event to raise awareness: "When you can table costs like the 800 million Euro Copenhagen damage, that is a strong basis for argumentation in fiscal realms." However, he was sceptical of the *wake-up disaster* notion: "That would imply that Hamburg remains asleep – I would not say so. In my perception, the EPA [that is also in charge of urban development] is already paying attention to climate change effects."

The VHH representative questioned the necessity of an ambitious adaptation policy resembling the Copenhagen one. Referring to Hamburg's sewage system, he called the municipal monitoring and communication already sufficient "to prevent extreme situations like the 2011 Copenhagen cloudburst from the outset".

As runner-up trigger to adapt, the countries surveyed by EEA (2014b) named EU policies[18], which is not at all reflected in the interviewees' responses for Hamburg. Only Hamburg's EPA representative referred to EU influence. However, she does not recognize legislative influence, but rather an influence via reporting processes from the national to the EU level[19].

5.1.7 Barriers to adaptation: Money, static contracts, lack of political awareness

As surveyed by EEA (2014b), the major barriers to overall climate change adaptation are a lack of human and financial resources, uncertainties, and unclear responsibilities (Fig. 7). Similarly, a 2013 survey among 23 European transport reference centres (usually the national EPA or another authority) names a lack of financial resources as central problem, followed by a lack of awareness (ETC/CCA, 2013). Stecker et al. (2011, p. 26) identify "missing availability of information and the cross-cutting nature of adaptation" as reasons. All publications acknowledge the high coordination effort.

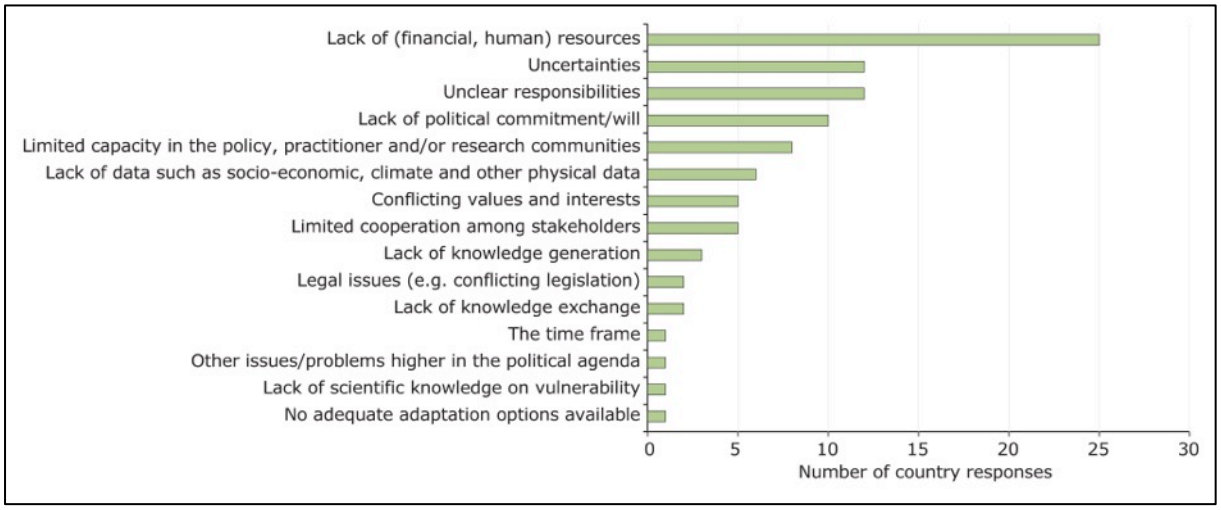

Fig. 7: Barriers to adaptation, as indicated by 29 European countries (EEA, 2014b, p. 26).

The results from the Hamburg case reflect these findings. Among the interviewees, the lack of financial resources is the most-named barrier. As Hochbahn stated, "proactive planning is costly. As

[18] The respondents mainly referred to trans-boundary projects, e.g., common flood-water management, EU Interreg cohesion projects, ICI projects, and research partnerships (EEA, 2014c, survey question 36).

[19] Here, the interviewee sampling might be relevant: While EEA's self-assessment survey was addressed to national institutions responsible for adaptation (EEA, 2014b), the practitioners in my sample work on a municipal level. They might be not as aware of EU-wide environmental policy as a respective national agent.

we don't operate cost-effectively anyway[20], we needed to justify that to the municipality and to the passengers".

Similarly, S-Bahn referred to their mandate: Bound by a contract with the municipality, the company is obliged to strictly follow a service schedule. Any service beyond this schedule (e.g., to run fully air-conditioned trains) is not reimbursed. Thus, S-Bahn has no financial incentive to adapt. The long contract period can be an additional barrier: "In 2013, we agreed on the operation conditions for 2019-2033. Therefore, we deal with a 20-years period that is relatively static."

The NEC researcher named austerity policy as potential barrier:

> In Spain, the government cut back emergency services, which compromised the reactive capacity to the severe 2012 forest fires. Generally spoken, austerity cutting back DRR infrastructure is a condition that influences climate change adaptation. As Germany enacted the *brake on debt*[21], that will probably be the case in the long run.

BWVI attested a mismatch between the municipal departments' knowledge and the political adaptation will: "In the administration, [we] are aware of the topic. But when it comes to implementing [adaptation policy], [...] we need to pitch it to the politicians". Similarly, the Hochbahn representative was concerned about the long-term climate change effects as being "below the [decision-makers'] detection threshold", which, in turn, could lead to inert reaction.

The EPA representative named citizen protest as potential barrier to public adaptation. She referred to a current case in Hamburg's Walddörfer district, where affluent inhabitants resist against the designation of flooding areas that might depreciate of their properties. For this case, she acknowledged that future flooding events would probably increase acceptance for public adaptation measures.

Another barrier commonly named by interviewees in Hamburg is a lack of continuity in the city's traffic policy; See *Roadmap* below.

5.1.8 Agency for Climate Change Adaptation: Municipality, supported by non-state actors

The operators Hochbahn and S-Bahn allocate responsibility to the municipality, referring to past, current, and future activities:

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[20] As virtually each PT operator in Germany, Hochbahn runs on deficit. The 2013 revenue-to-cost ratio amounted to 90.3%, whereas the 2012 German average was 77.1 % (Hochbahn, 2014; VDV, 2014b).

[21] The federal *brake on debt* was enacted by the parliament in 2009 as constitutional amendment. From 2016 on, it will forbid the federation (Bund) to run into net debts higher than 0.35% of GDP. The 16 federal states (Länder) will be forbidden to run into net debts at all. Exceptions are legal in case of natural disasters and major recessions (Finance, 2014).

> For all topics of higher quality, the HVV [on behalf of the municipality] needs to find an answer, and contractually instruct us how to act. [...] Of course we are open to change [the contract conditions] if necessary [...] – However, the impulse must come from HVV.
> (S-Bahn)

Similarly, VHH, BWVI, and EPA named state institutions, furthermore non-state actors: BWVI named motorist and cyclist associations and *Friends of the Earth* as stakeholders, and EPA named public-private partnerships. Accordingly, the transformation researcher referred to Deutsche Bahn as (formally) non-state key actor on a national level. Overall, however, the interviewees allocate the primary agency to the municipality.

5.1.9 Roadmap to Hamburg's Future Public Transport: Continuity as key request

Regarding Hamburg's transport development, all interviewees referred to the necessity of a continuous political steering.

For achieving a resilient PT, the Hochbahn representative requested a decided, long-term political steering: "We need a clear political statement that outlasts the election periods and allows long-term measures". Similarly, though not specific on adaptation, the BWVI representative emphasized the need for an integrated mobility development. Remembering two failed tram systems[22], she asked politicians to mandatorily commit to one project and "not to suspend it as soon as the government changes". She named continuity as central characteristic and added that her authority pursues this quality, hosting a quarterly stakeholder meeting to outline the next decades' mobility development. In a political realm, their diagnosis aligns with HVV Umsonst's diagnosis of a societal vicissitude that leads to a lack of politicians' awareness: "[The climate debate] is not permanent yet. It is only a hot topic [...] after a singular extreme event. [...] Public pressure [to make the politicians adopt ambitious climate agendas] is not high enough."

For future mobility development, the S-Bahn representative highlighted the need to avoid technocratic planning: "Primarily it is not about applying a transportation technique, but about incorporating people's expectations, horizons, and feelings. The question is: What is acceptable?"

[22] After Hamburg's tram system had been torn down in the 1970s, there were two attempts to re-establish it in 2001 and 2010. Both systems were already planned in detail, when the newly-elected government decided to abandon the plans. These decisions were not only costly, but also very frustrating for the planners (Hochbahn and BWVI Interviewees).

RQ5: Is the resilience concept appropriate to frame the adaptation of Hamburg's PT sector? To what extent is a resilient PT system in line with sustainability goals?

- **The resilience concept is considered useful. One interviewee attests a lack of capacity to model inner-system dynamics.**
- **From an *economic* sustainability standpoint, PT adaptation appears useful. The *ecological* dimension is fulfilled in comparison to the passenger car, but remains open without the comparative advantage. The *social* quality depends on the distribution of implementation costs.**

Box 8: Result summary for research question 5.

5.1.10 The Resilience concept: A suitable framework?

All interviewees indicated their general consent to apply the resilience framework with its long-term perspective. They acknowledged the necessity to react to changing climate conditions.

However, the transformation researcher underlined that a static understanding of resilience might fall short in properly modelling the transport system:

> To statically express resilience by one certain function – e.g., continuous mobility service – makes sense. However, assuming stable systems might be problematic, as the whole system undergoes a constant transformation. [...] The resilience concept falls short in describing systems' dynamics beyond external shocks.

The researcher's remark is in line with Holling and Gunderson's (2002) distinction between the aim of maintaining a seemingly-stable state at any cost and the aim of maintaining its dynamic endurance (section 2.4). Applied to the Hamburg case, an example for the former practice would be to assume a stable state, equip vehicles and facilities against adverse effects, and literally *drive until the last vehicle is stuck*, regardless of the consequences and of intra-system dynamics. When the aim is to uphold the 2015 operation throughout decades (as it is assigned, e.g., by the 15-years S-Bahn contract), effects like skyrocketing maintenance costs, or the exclusion of certain groups, might be conceded. The latter practice, in opposite, would observe the internal and external conditions under that PT operation takes place, and be aware of their inherent dynamics. This awareness is actually the core of Hollnagel's (2011) *Monitoring* and *Anticipation* functions.

Indeed, the resilience concept, as modelled here, might be blind on constant dynamics that are not as tangible as a cloudburst that keeps a metropolis in an emergency state for several days. The express train example described in section 5.1 represents such silent dynamics: The trains' AC systems, built in the mid-1990s, had been designed for temperatures up to 32°C. For two decades, no problems had occurred as the outside temperature had not exceeded been higher. During these decades, however, the summer temperatures increased, and at the same time the passenger numbers rose constantly (Deutsche Bahn, 2011). The combination of three dynamics, whereof one was definitely an internal dynamics (passenger increase has been a central part of DB's strategy; Deutsche Bahn, 2011) lead to adverse consequences in terms of passengers who had to be hospitalized.

It arises the question is whether such disregard of internal dynamics is attributable to a general blindness of the resilience concept. From a conceptual point of view, this question can be negated: The theory delivers *Monitoring* and *Anticipation* functions that apparently were not met properly. From an incident perspective, however, and this is the important perspective when passengers are stuck in a train at 50°C, the model would definitely fail[23].

As the case with any model, the resilience concept's quality depends on the context in that it is applied. In the described case, my conceptualization as introduced in section 2.6 would perhaps fall short, as it aims at external shocks. However, if complemented by a monitoring process for internal dynamics, the concept can be useful in a PT context.

5.1.11 Resilient PT: In line with sustainability goals?

The most prominent framework to describe sustainability goals is delivered by the Sustainable Development framework. With its three dimensions of *economic*, *ecological*, and *social sustainability* (Brundtland, 1987), it delivers categories that I use to assess the potential performance of a resilient PT.

From an *economic* perspective, resilience building in the PT sector seems useful. Timely infrastructure adaptation is considered beneficial in the long-term as it is less expensive than ex-post adaptation (Rotter et al., 2011). Furthermore, a resilient PT can economically benefit societies, e.g., by avoiding losses induced by gridlock traffic (Schulze et al., 2012).

In *environmental* regards, a resilient Public Transport appears perfectly in line with sustainability goals: Each inhabitant that undertakes their mobility by PT instead of car improves Hamburg's carbon performance, thus contributes to the central sustainability goal of reducing greenhouse gas emissions (VDV, 2014a).

Via this detour of its *relatively* low emissions compared to the passenger car, the (resilient) PT can easily be legitimized. However, this argument does not question the *absolute* high transport capacities. Each day, Hamburg's operators consume tremendous amounts of energy to transport three million passengers, with a rising tendency (HVV, 2014a, 2014b). Without its comparative advantage to the *dirty* car traffic, PT's legitimation remains in the duty to provide resource-intense personal mobility.

This duty of personal mobility is critical for a society that is marked by a high division of labour (EEA, 2014a; Schulze et al., 2012). Capitalist societies promote "individual hypermobility" (Transformation researcher; see also Rosa, 2013) – a mobility that can indeed be provided by PT and that can be

[23] I use the conjunctive as I do not know which model of adaptation and/or disaster prevention Deutsche Bahn applied when the AC incident happened.

made resilient against climate change impacts. This does, however, stabilize the same trajectory that continuously *induces* rising resource consumption and a changing climate. Figuratively speaking, how sustainable can the climate-resilient PT mobility become in a society that is overall resource-intense? This question regarding the *environmental* sustainability performance remains open at this point.

In *social* regards, the PT system's resilience appears to be beneficial for socially marginalized people, as most of the PT captives[24] belong to low-income groups (S-Bahn interviewee). Accordingly, a resilient PT system would, by enabling societal participation, have an inclusive effect especially for them (HVV Umsonst interviewee). This benefit, however, depends on affordable ticket fares, and might be endangered by resilience building (see *RQ3*).

Furthermore, it is important to reflect for whose interests resilience building happens: Using the example of the 2007 US *National Strategy for Homeland Security*, J. Walker and Cooper (2011) describe how resilience was completely adopted by military trajectories. Along with an "intense reprivatization", they attest a "transfer of regulatory authority from the civil sectors of public transport, health and safety, environmental protection and emergency response to a logistics and security sector newly organized around counter-terrorism" (p. 153).

At the first glance, the resilience concept appears as appropriate tool to reconcile growing mobility needs with Sustainable Development goals. However, when it is embedded in a neo-liberal security paradigm as described by J. Walker and Cooper, the outcome might not be desirable. It is, here referring back to B. H. Walker (2002, p. 187), not sufficient to define „the resilience of what to what" (section 2). Resilience agents have to legitimize their endeavour that might include capitalist agents. To meet *social sustainability* questions of equity, they have to be particularly transparently communicate on whose behalf they act.

[24] Widely-used term for people who cannot afford PT alternatives.

6 Discussion: Implications for the path towards a resilient Public Transport

6.1.1 The results and their relevance for Hamburg's Public Transport

Hamburg has already been adversely affected by climate change-related extreme weather events, particularly storm-related ones. This observation is in line with the forecasted increase both in number and severity (Schulze et al., 2012).

As central function of Hamburg's urbanity, the PT sector has not been spared. Particularly storms have heavily impeded operation. One fallen tree alone can block railway services for several days. Hitting the rail modality that has the largest passenger carrying capacity, the incident combines a minimal cause – one fallen tree among thousands along the tracks – with a maximal impact.

Although Hamburg's adaptation focus has been historically sensitive to flooding, the PT sector has not been significantly disrupted. Underground railway and metro stations have been affected by water intrusion only in singular incidents, and the buses have been flexible enough to drive around affected areas. The preparation for water impacts might be a result of the severe 1962 flood that is described as the impetus for Hamburg's DRR strategy by all interviewees.

Capability of a resilient system	**Assessment of Hamburg's PT system**
1 Response	• Comprehensive responsive knowledge available
2 Monitoring	• Widely delivered by external institutions (e.g., weather forecast) • Partly operational monitoring that is unspecific to climate change effects • Specific monitoring started by EPA, though unspecific to PT
3 Anticipation	• Generic knowledge that is rather unspecific to PT
4 Learning	• Takes place, based on adverse experience

Table 5: Hamburg's PT assessed against Hollnagel's (2011) four essential resilience functions.

Table 5 shows Hollnagel's (2011) four resilience dimensions applied to Hamburg's PT system. While the dimensions *Response* and *Learning* fulfil the definition introduced in section 2, action is required regarding *Monitoring* and *Anticipation*. To achieve a resilient PT system, it is not sufficient to respond to external impacts and to learn *by doing*; it is necessary to systematically supervise appropriate indicators and to draw the right conclusions about future adverse impacts.

6.1.2 Hamburg's PT: A system that is about to realize upcoming threats

As the operators indicated, their adaptation policy fed by past experience has proven successful so far. The S-Bahn representative explicitly stated that the financial losses are insignificant, assuming that the adverse impacts do not considerably increase. However, according to global and local forecasts, the adverse impacts will increase. Climate change *is* about to further aggravate extreme weather in Hamburg. Whereas the operational *learning by doing* strategy has succeeded up to now, this approach will probably be insufficient in the future.

The interviewees consistently acknowledged these prospects, and each one indicated their awareness and concerns. However, system-specific conditions, like the commitment to long-term contracts and the omnipresent lack of financial resources, impede the sector's capacity to proactively adapt. While climate change concerns are present for the specialists in PT and public administration, they have not made it to the decision-makers' level. The steering boards and political bodies do not pay the attention they could – and should – pay.

Fig. 8: Fed by past weather experience, Hamburg's operators have developed response strategies. The picture shows a maintenance coach removing leaves from the S-Bahn rails. Wet leaves impede braking effectivity in autumn.
Photo: Torsten Bätge / Wikimedia, CC license 3.0 Unported

6.1.3 Fundamentals and agency for an integrated adaptation strategy incorporating PT

While the interview partners referred to plenty of measures of Hamburg's climate change *mitigation* strategy (that are not covered by this thesis), the sector is not as advanced in *adaptation* realms. This finding corresponds with Eisenack et al. (2012) and EEA (2014a), who draw the same conclusion on the national and EU level, respectively. To tackle this problem, EEA (p. 49) proposes to prioritize adaptation as strongly as mitigation. To "plac[e] transport adaptation higher on the political agenda [...] would generate more awareness and foster more action." For such an umbrella strategy, EEA emphasizes the crucial role of cooperation between and among the different state and non-state partners. The challenge is "to overcome the fragmentation that exists in what is – ironically – a highly connected sector" (p. 51).

Applied to Hamburg's PT system, with 30 associated operators and numerous other stakeholders, this challenge translates into a constructive recommendation: Come together and plan adaptation.

Currently, adaptation takes place on the operational level and within institutional boundaries. Cornerstones for an integrated strategy are, however, observable.

Firstly, cross-actor adaptation measures have already been implemented. As of now, they either have a regulative character (e.g., municipal building regulation forcing operators to incorporate flood protection) or are unspecific to climate change effects (e.g., the generic cross-operator preparation for major events like football games).

Secondly, knowledge fragments are already existing on different places. Hamburg's EPA is preparing an index to monitor climate change impacts, although it does not incorporate particular PT indicators. Furthermore, the municipal adaptation strategy is planned to be developed from 2015 on. The operators, in turn, have developed practical knowledge to cope with extreme weather. Moreover, Hochbahn's operational monitoring process, though unspecific, dates back to at least twelve years. Merging these three knowledge clusters would open up potential for an umbrella strategy.

Thirdly, Hamburg's PT association has been established for half a century. When HVV started in 1965, the goal of uniting numerous operators under one common tariff was ground-breaking. Similarly, the 2015 HVV affiliates could, supported by the associated municipalities, aim for finding a common response to climate change.

Fourthly, the traffic authority BWVI has already started a process involving representatives of stakeholders to design Hamburg's traffic development for the next decades. According to the BWVI representative, the first meetings have been very promising. Moreover, the other interviewees indicated their willingness to find a common solution.

With these four cornerstones, main preconditions to systematically adapt Hamburg's Public Transport to climate change are given. What lacks is the critical step of lifting the adaptation imperative from the specialist to the political level. The fragmented adaptation has to become a united strategy. Such a strategy will undoubtedly be costly. However, the costs for *business as usual* instead of proactive adaptation are likely to be disproportionately higher (EEA, 2014a; Rotter et al., 2011).

Another potential reason to re-think Hamburg's PT system was named by the HVV Umsonst representative. Although not explicitly referring to adaptation, he described the potential Olympic Games in 2024[25] as a chance to "radically change the preconditions for the debate." He made this remark not in regards of adaptation but of preconditions for a ticket-free PT. However, as a topic that

[25] The interview took place a few days after the German Olympic Sports Confederation publicly declared to support Hamburg's bid for Olympic Games in 2024. The final decision will be taken by the International Olympic Committee in 2017.

is debated loudly (Deutsche Welle, 2015), the Games could trigger a reflection process about millions' urban mobility and its resilience to adverse effects.

6.1.4 Resilience: a useful concept for Hamburg's PT?

From an operational perspective, the resilience concept appears useful to frame adaptation efforts. Although none of the operators explicitly applies resilience concept, and only one indicated to be familiar with the terminology, the key components *Reaction* and *Learning* are reflected in their processes.

This *implicit* application of resilience elements brings up the question whether the theory is needed, given the fact that the operators have actually managed to widely safeguard PT operation against adverse impacts. The answer from a resilience standpoint would be 'Yes – because the current system does not suffice regarding *Anticipation* and *Monitoring*'. This straightforward answer, however, is tautological, as it justifies the need for a concept based on the concept itself.

To properly assess the necessity of resilience for Hamburg's PT, the overarching purpose is relevant: To adapt the PT system to changing conditions. If that is missed, PT becomes outdated, i.e., remains designed for conditions that no longer apply. In physical terms, the system cannot provide its service anymore, because it is impeded by weather extremes (EEA, 2014a).

If the agents stick to *business as usual*, this might happen in Hamburg. Operators act under the assumption that "[the climate] stays like it is" (S-Bahn), and under the same assumption the service is stipulated in 15-year contracts. Meanwhile, the physical conditions for a safe and attractive PT change significantly, proving the responsive adaptation insufficient.

Particularly in PT planning, as signified by long-term thinking, resilience strategy needs to incorporate long-term forecasting. Thus, to adapt the sector to climate change, the resilience framework with its qualities *Anticipation* and *Monitoring* is useful.

7 Conclusion

I started my thesis process with the assumption that climate change-related extreme events have an adverse impact on Public Transport operation. My purpose was to investigate how Hamburg's PT system has been affected, and how key actors, namely municipality and operators, can strategically prepare. My framework of choice was the resilience concept with its key functions *Anticipation*, *Response*, *Monitoring*, and *Learning*.

As the results of seven qualitative stakeholder interviews indicate, Hamburg's PT system is somewhat prepared for extreme weather events. From impacts that already have induced problems – storms, frost, precipitation – operators have gained coping knowledge. Therefore, the categories *Response* and *Learning* are fulfilled. On the contrary, *Monitoring* and *Anticipation* are not sufficiently covered. Climate change-related incidents are neither monitored nor evaluated with regards to the PT system's potential adaptation need.

As both the interviewees and the literature indicate, a key challenge is to find a common solution in a highly fragmented sector. Fragments of a suchlike greater adaptation strategy are conceivable. The operators' functional knowledge and the EPA's planned monitoring process could provide the basis for a cross-sector endeavour. As HVV is the body that has coordinated Hamburg's PT for 50 years, the competency to coordinate adaptation lies within the association's scope. To initiate adaptation, the key step is to lift the topic from the operator to a cross-actor level.

As my key conclusion, this demand could be seized by further research to develop an adaptation blueprint for Hamburg's Public Transport. Furthermore, the relationship between resilience building and social inequality could be an interesting subject for further investigation: For my research, I narrowed the inequality notion down to social exclusion through ticket fares. However, other forms of inequality are imaginable. Urban dwellers could, for instance, suffer from disturbing infrastructure, e.g., concrete flood walls, or the noise of air-conditioned buses in a five-minute cycle.

As noted by the critics and acknowledged by the interviewees, resilience is no silver bullet to technically safeguard PT against adverse impacts. Resilience building requires efforts, and it cannot be ruled out that it happens at the cost of higher ticket fares, i.e., at the cost of the socially marginalized. However, consciously applied, the framework can help to conceptualize a city's PT adaptation.

At the end of my investigation, there is an insight about the Public Transport system in Germany's second-largest city. It has already been affected by adverse climate change effects, and it is virtually certainly going to be severely affected in the future. Similarly to their colleagues on the national and the EU level, the interviewees named financial constraints and political ignorance as main barriers to adaptation. On the other hand, timely mainstreaming of resilience attributes into facilities and processes appears promising to avoid unnecessary ex-post adaptation efforts.

Cloudbursts, storm surges and heat-waves are going to increase both in number and in severity in the next decades. As extreme events do not consider institutional boundaries, an effective response can only be a common one. Accordingly, Hamburg's traffic and PT stakeholders are well advised to continue on their path towards a common agenda – so that "the last stuck vehicle" may remain the exception and not become the rule.

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9 Annex

9.1 Interview questionnaire

9.2 Illustration of the four resilience dimension used in the interviews

How resilient is Hamburg's Public Transport to Climate Change effects? Questionnaire

Thanks a lot in advance for participating in my interview. Some remarks regarding privacy:
If you want, you can remain anonymous. After audiotaping our interview, I will transcribe it and delete the audio file. The transcript will be stored safely and is *not* going to be published. After the defence of my thesis, I will send you a digital copy of it, if you wish so. My thesis (without transcripts) will be available online. If you have any concern, feel free to ask.

A Introduction

1 Please briefly introduce yourself. What is your profession, what is its relationship to urban climate change adaptation?

B Regional Climate Change Effects in Hamburg

According to the German EPA, Hamburg's future climate is forecasted to be signified by:

- An increase of hot summer days, heat waves and droughts
- A seasonal precipitation shift from summer to winter, with stronger rainfalls
- An increase of the Elbe river's water levels
  (current flood protection probably effective until 2030)
  Daschkeit and Renken (2009)

2 Has your organization already been affected by the effects summarized above?

3 Do you remember a recent extreme weather event? How was your business affected? How severe was the damage?

4 Had your organization prepared beforehand to mitigate potential damage?
If yes, how? If not, why?

5 Did a particular incident surprise you?

C Key Concept: Resilience

To prepare cities for extreme events, the UN use the resilience concept. It was initially used to measure ecosystem stability. Applied to Hamburg's PT, the definition is:

> **Resilience** describes the capability of Hamburg's Public Transport system to resist, absorb, accommodate to and recover from Climate Change-related external shocks in a timely and efficient manner.
>
> It entails the capabilities to *anticipate* and *respond* to external shocks, to *monitor* appropriate indicators and to *learn* from past and present.
> *Hollnagel (2011); UNISDR (2009)*

6 Have you already been confronted with this term?

7 In the illustration attached, the four key features of a resilient PT system are sketched. Can you name a respective measure for each feature?

8 What is your opinion on the concept? Do you consider it useful? What does it lack?

D A resilient Public Transport System in Hamburg

9 Do you have a tool to systematically monitor and classify extreme events?
If so, who in your organization is responsible?

10 Do you have a contingency plan to coordinate the response to an extreme event?
How does it look like?

11 What indirect factors affect the adaptation of Hamburg's PT system?
(e.g., legislation on Hamburg/Germany/EU level, market changes, passenger demand alterations)

12 What are chances for the PT system's climate change adaptation? What are barriers?

13 In June 2011, Copenhagen suffered from a massive cloudburst which destroyed property worth 800 million Euro. As a consequence, the municipality adopted the hitherto most eager European adaptation plan. It entails, e.g., retrofitting big part of the city to mitigate damage caused by flooding.
Do you think that Hamburg 'needs' such an event to adopt a similarly ambitious policy?

E Adaptation and Social Justice

14 The concept of resilience is strongly criticized. It is accused of fostering social injustice and disregarding democratic access to public space. Sustainable urban development like in Malmö's Västra Hamn or Hamburg's HafenCity is accused of creating segregated quarters for affluent inhabitants.

Do you expect a similar development in Public Transport? Will the resilient PT exclude people? Who will be the excluded?

F Miscellaneous

15 How do you imagine Hamburg's PT in 2040?

16 What steps need to be taken to achieve this vision? What should city developers and PT planners avoid?

17 Do you have anything to add?

G Literature

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Illustration for question 7: Four key dimensions of a resilient PT system

Anticipation

Response

Bus flooded by rainwater in Malmö/Sweden

This picture may not be published here due to copyright legacy.

A similar picture is accessible via Sydsvenskan:

http://www.sydsvenskan.se/Images2/2014/8/31/tredje.jpg

Monitoring

Learning

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