10
Europe's Infrastructure Vulnerabilities: Comparisons and Connections

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This book has investigated the historical shaping of critical transnational infrastructure in Europe, its associated vulnerabilities, and its intertwinement with broader processes of European integration and fragmentation. The chapters in the three parts have scrutinized these issues from different thematic angles and in a broad range of geographical and temporal settings. While each study has generated intriguing insights in its own right, the range of empirical cases has also set the stage for comparative and connecting observations. This final chapter sets out to harvest from our case studies by focusing on a number of such cross-cutting issues.

Differing interpretations of vulnerability

Recent constructivist research on risk and vulnerability stresses the importance of studying vulnerability not as a given, objective phenomenon that can be defined precisely and unambiguously but as something that is constantly reinterpreted, contested, and negotiated by stakeholders and analysts alike.[1] Our findings confirm that such a view of vulnerability as socially constructed is indeed crucial when seeking to grasp the making of transnational infrastructure vulnerabilities. Our case studies are largely consistent with insights from cultural studies of risk, in which the "ways in which individuals – including experts – interpret risks can be seen as an expression of socially located beliefs and world views that to a large extent stem from the individual's situated position and experiences within social hierarchies, institutions and groups."[2]

As argued in several chapters of this book, however, this is not the whole story. Rather, our results point to the importance of studying not only *vulnerability* but also *reliability* as socially and culturally interpreted and negotiated. For example, the "European blackout" of November 4, 2006, was interpreted by some as an illustration of the extreme vulnerability of electric power networks leading to a disruption of economic life in Europe. This perception went hand in hand with calls for more centralized governance and coordination of Europe's electric power grid, not least from the side of Europeanist politicians. To electricity sector spokespersons, however, the event instead suggested the high reliability of Europe's electricity supply: since the 1960s the sector had installed and continuously upgraded security measures, which had made cross-border cascading failures extremely rare and allowed fast reparation of the rare failures that did occur – in this case the sector fully restored Europe's power supply within just two hours. Overall the damage of rare and rapidly repaired breakdowns was negligible compared with the daily security gains of cross-border collaboration in the form of joint instant frequency stabilization. Importantly, this high-reliability perception, too, had implications for governance: since the sector's vulnerability management system was based on well-working decentralized response (each transmission operator repaired its own transmission area, which it knew best), European Union (EU)-level governance constituted a new threat rather than a solution to system stability.[3]

Next to such interpretations of a particular critical event, another discussion that has persisted for a longer time concerns the argument that the main problem with Europe's power grids is not its vulnerability but, on the contrary, its excess reliability; that security investments far exceed the economic costs of incidental breakdown. As emphasized in Chapter 8, the very early liberalization of the Norwegian power sector was partly intended to counteract what was seen as a huge overinvestment in excess capacity. The liberalization was indeed followed by a sharp decrease in investments in the grid, without any corresponding increase in the number of outages. This was interpreted by the proponents of liberalization as a confirmation of the old regime's excessive focus on reliability.[4] An identical discussion took place in the Netherlands a few years ago.[5] These examples illustrate how perceptions of overly vulnerable and overly reliable infrastructure may coexist in the field. It should inspire researchers to question the dominant discourse on vulnerability by simultaneously examining infrastructure vulnerability and reliability.

Our book contains many examples of situations in which actors have been forced to make choices between alternatives that imply very different kinds of vulnerabilities and thus weigh certain risks against others. The Finns discussed the pros and cons of Soviet nuclear technology, scaled up electricity imports, or increased reliance on Soviet natural gas, Polish coal or Middle Eastern oil, before concluding that Soviet nuclear technology was to be imported. But they made this choice only after tough negotiations with the Soviet nuclear establishment, in which Moscow had to give in to Finnish security demands.[6] The Greeks similarly faced a delicate choice between installing nuclear power on seismically active ground, importing electricity from beyond the Iron Curtain, or accelerating the exploitation of domestic, polluting lignite resources. In contrast with the Finns, those who regarded the risk of nuclear accidents as too great had the final say.[7] But each option was linked to a certain kind of vulnerability, and there was no objective way of deciding which of these vulnerabilities was the most problematic: nuclear accidents, pollution stemming from the burning of lignite, or import dependencies.

Our book has shown that such vulnerability trade-offs informed several lines of conflict between stakeholders. They have sometimes led to opposition between different social groups within a given country. For example, the 1995 earthquake in Greece discussed in Chapter 5 was interpreted very differently by engineers and journalists. According to the journalists, the earthquake showed the resilience of Greece's national electric power network to the devastating blackout that could have resulted from the major earthquake. For the other group, the engineers, the Greek network was resilient because of its transnational connections: "the Greek national power network proved reliable because its vulnerability was shared with the national power networks of some of Greece's neighbors." In this latter interpretation, connected countries become more resilient because vulnerabilities were shared in a transnational network.[8]

In other cases these trade-offs led to opposition between stakeholders on different sides of a border. Previous studies of risk have noted the tendency of different social groups to agree internally on certain perceptions of vulnerability and risk.[9] Yet national borders might divide them. The Finnish case illustrated different interpretations of vulnerability within the social group of engineers in Finland and the Soviet Union. According to the Soviet engineers, risks were calculable: "If calculations showed that no risk existed there was no need to build expensive backup systems and redundancy." The Finnish engineers also made calculations but did not consider this sufficient when seeking to manage nuclear risks. The two approaches clashed when transnational connections between Finland and the Soviet Union were planned, and even more when discussing the design of nuclear power plants.[10]

Such vulnerability trade-offs might set countries against international organizations. When Bulgaria negotiated its accession to the EU, the EU considered several blocks at the Kozloduy nuclear power plant unsafe and made their decommissioning a condition for Bulgarian EU membership. The International Atomic Energy Agency, however, found safety in these blocks comparable to older, Western European nuclear units that were still in operation. But the EU kept up its demand in the treaty negotiations, and the units were then actually shut down. Remarkably, when the 2009 Russian-Ukrainian gas crisis caused a disruption to Bulgaria's gas supply, the Bulgarian government suggested reopening the decommissioned blocks to counter the unexpected energy shortage. In this case, nuclear power was perceived as a potential savior rather than as a source of vulnerability. Behind these conflicting perceptions, however, lay Bulgaria's interests in retaining its position as a major electricity exporter on the Balkans.[11]

Finally, such vulnerability trade-offs may change over time. The *evolution of vulnerability perceptions over time* is a theme that has been much neglected in previous social studies of risk. Our explicit historical focus sheds light on this issue. In particular, many of the chapters demonstrate that the perceived vulnerabilities related to energy infrastructures have changed profoundly over time. For example, Bulgaria's vulnerability in the field of electricity was initially defined in terms of shortage. Having overcome the basic shortage by constructing coal-fired power plants, actors began to point out a new form of vulnerability: dependence on the Soviet Union for adequate coal supplies. The Bulgarians then sought to reduce this dependence by constructing a vast nuclear power plant. This led to a further shift in vulnerability perception, toward an emphasis on nuclear risks, and on the instability of the grid and the risk of major blackouts, which was handled by increasing storage capacity in dams and building more transmission lines.[12]

Critical events

Often, changes in the perceptions of vulnerabilities and vulnerability trade-offs have been triggered by what we call "critical events." One well-known example is the nuclear accident at Three Mile Island in April 1979, which suddenly changed the general perception of the vulnerability of nuclear power, not only in the United States but also in Western Europe. Nuclear risks, which had been abstract and hypothetical, became much more tangible, and many countries changed their nuclear policies in response. In the Balkans, two earthquakes had an even stronger role in influencing the perceptions of nuclear vulnerability. In Bulgaria a major earthquake occurred in 1977, which had its epicenter only 30 km from the nuclear power plant in Kozloduy. Even though the plant was not damaged, the government started a process to improve its safety. And in 1981 an earthquake 200 km from the site of a planned nuclear power plant led to the abandonment of nuclear power as an option in Greece. Similarly, the vulnerability of airplanes having reached their cruising altitudes was perceived as low before two actually collided over the Grand Canyon in 1956. Although this accident happened in the United States and not in Europe, it formed the point of departure for a discussion in Western Europe about air-traffic security. This led the key actors to eventually reinterpret air-traffic risks, paving the way for a new transnational infrastructure for air-traffic control.[13]

Critical events have thus been crucial to how vulnerability perceptions have changed over time, and this is why such events play a prominent role in this book. Indeed, all chapters analyze critical events of different kinds. We have found the analytical significance of critical events to be threefold: they are useful sites for analyzing the nature of infrastructure vulnerabilities; they reveal how different actors respond to crises; and they give rise to fierce discussions affecting infrastructure's further evolution. Although the critical events studied here are very diverse in terms of causes, geographical location, and impacts, they have in common that they generated new societal and political debate about how to cope with infrastructure vulnerabilities.

One interesting finding from our analysis of critical events is that many of these in fact did not affect users but "only" the systems. This underlines the importance of the distinction we made in Chapter 1 between "system vulnerability" and "user vulnerability." A telling example is the fire in the Eemshaven converter station in April 2009, which led to a sudden interruption of the electricity flow through the NorNed cable between Norway and the Netherlands, lasting for a month. No electricity consumers in either country were directly affected by this interruption because the power companies were able to avoid a blackout. However, the power companies and grid operators lost millions of euros during the month and became aware of the vulnerability of the converter stations.[14]

In the current policy debate it has been popular to distinguish between "intended" and "unintended" causes of critical events between "internal and external sources of failure"[15] and between "internal and external threats."[16] Our results, however, show that such distinctions can rarely be defined objectively. Rather, the extent to which a critical event comes to be regarded as intended or unintended (or internal or external) is the outcome of debates and negotiations – and often no agreement is reached. The European blackout discussed above, for example, has politically and popularly been interpreted as an unintended event. As we have seen, however, the way in which certain regions were disconnected from the grid and others were not followed predefined and detailed so-called emergency load-shedding plans. From this perspective the course of the blackout can be viewed as intentional. Similarly, the European gas crises of 2006 of 2009 can be interpreted either as external events caused by political decisions taken in the Kremlin power struggle with the government in Kiev, or as an internal event in which the main problem was the failure of gas managers in Russia and Ukraine to renegotiate the terms of export and transit contracts.

All in all, our book shows that the ways in which vulnerability perceptions have changed over time, not least in response to major critical events, have reshaped Europe's transnational infrastructure in decisive ways. The struggle to make certain vulnerability perceptions rather than others dominant can be seen as a struggle to influence infrastructure's future. In particular, as emphasized in much of the policy literature, reducing vulnerability is often expensive, and actors therefore often have an interest in de-emphasizing vulnerability for economic reasons. De Bruijne and Van Eeten, for example, note that infrastructure nowadays, following the liberalization and privatization of many critical infrastructures, operate "closer to the edge" than before restructurings since actors have stronger incentives to maximize their profits.[17]

As our book has shown, however, the trade-off between economy and vulnerability did not start with liberalization and privatization. Transnational integration has often been pursued for economic reasons despite anticipated increases in vulnerability. The first plans for Western European imports of natural gas from the Soviet Union and Algeria, for example, were immediately contested due to anticipated implications for energy security. Western Europe could very well have managed without natural gas from beyond the Iron Curtain and the Mediterranean, but this possibility was silenced in the debate and had to give way to the view that the risks involved were worth taking. The new vulnerabilities linked to gas imports from far away were thus accepted for the sake of economic gain.[18] All in all it is obvious, judging from the studies in this book, that minimizing vulnerability is not necessarily in every stakeholder's interest.

Coping with vulnerability

Our book has revealed a variety of strategies to cope with transnational infrastructure vulnerabilities. Some of these have aimed at reducing the risk of failures or interruptions, while others have aimed at limiting the consequences of such events. Obviously, the nature of vulnerabilities differs between, say, energy infrastructure and transport infrastructure, and some of the strategies discussed below, are not relevant to all infrastructure.

In the case of energy infrastructure, the very *creation of physical transnational links* itself has often been perceived as an effective way of reducing vulnerability. We have seen, for example, how the European electricity grid emerged out of power companies' desire to reduce the risk of blackouts and electricity shortages. Power lines across borders made it possible to share reserve power plants and storage capacity, and to help each other if needed.[19] The forging of transnational gas connections was in many cases also understood as a way to escape structural energy shortages, which was widely interpreted as the most pressing vulnerability in the field of energy in postwar Europe.[20]

Trying to *establish reliable social relations* with partners on "the other end" of the connecting lines has also been an important strategy. Early electricity cooperation among power companies in neighboring countries was often based on existing relations of trust, and in many cases the cooperation was surprisingly informal, based on gentlemen's agreements. In the case of gas imports, both parties often had to make huge investments before an exchange could commence, and here long-term contracts became an important instrument for creating reliable relations. More generally, reliable relations can be established by developing *transnational governance* of infrastructures, and this will be discussed in the next section.

However, power or gas links to neighboring countries inevitably created (inter)dependencies, and to cope with these one common strategy has been to *diversify* by building links to several countries. Greece, for example, built power lines to its three neighbors in the north: Albania, Yugoslavia, and Bulgaria. All three were ideological adversaries of Greece, but as they were also adversaries among themselves, the Greek power company felt safe that they would not simultaneously stop cooperating with it.[21] In the case of natural gas, the Western European countries that started importing gas from the Soviet Union tried to balance these imports by signing contracts for gas from other regions as well.[22]

Other chapters, however, show how *refusing connections* could also function as a strategy for reducing vulnerability. In 2006, for example, the Finnish authorities refused Russia's offer for a submarine cable from Russia to the coast of Finland. The Finnish authorities reckoned that this connection would make the national Finnish grid vulnerable to capacity overloads. It would also make the country overly dependent on the Russian energy system. This fear of dependence on Russia was deeply rooted in the history of Finnish-Russian relations. The two countries had had a very strained collaboration in the past and although the Soviet Union had been dissolved long before the new discussions about a submarine cable began, the memory of this traumatic past refused to go away.[23] In the case of natural gas, in the 1980s the US administration tried to convince Western European governments not to expand their imports of Soviet natural gas, albeit in vain.[24]

An additional strategy for coping with foreign energy dependencies has been to *create back-up capacities* of different kinds in case a major disruption should occur. In electricity systems, such capacities took the form of reserve power plants or sometimes pumped storage facilities.[25] In gas supply, underground gas-storage facilities or idle domestic gas fields played similar roles. Moreover, in the case of natural gas, importing countries could also create "virtual" backup capacity by agreeing to help each other if interruptions occurred.[26] A related kind of strategy has been to *increase substitutability* by making it easy to switch from imported to domestic fuels in power plants, for instance. In the early 1970s, for example, Bulgaria built big power plants that could use both anthracite from Ukraine and domestic lignite as fuel, thereby reducing its dependency on Soviet coal imports.[27]

The above strategies were primarily applicable to energy infrastructures, but we have also discovered strategies of a more general relevance. One such strategy was to *standardize technology or procedures* across national boundaries so as to facilitate connections and exchanges. Standardization in emergency communication served as a way to improve cooperation among policemen and fire brigades in Europe, which was seen as crucial for coping with major critical events. However, several standards competed and an all-encompassing, pan-European standard was not achieved.[28] In aviation there was a long tradition of standardization of both technology and procedures going back to the emergence of civil aviation after the First World War. But the establishment of EUROCONTROL called for a more far-reaching standardization. There was a parallel in the case of electricity, where there was also a very long tradition of technical standardization, and where the increasing importance of information and communication technologies in recent decades has called for new kinds of standardization.[29]

When standardization has not been possible to achieve, historical agents often used *gateway technologies* to counter vulnerability. Such technologies make it possible to connect systems that would otherwise not be compatible. In the case of electricity, for example, high-voltage direct current (HVDC) links emerged as a transnational gateway technology of some importance, and made it possible to connect networks that did not operate synchronously. The main motive for constructing HVDC links was rarely to reduce vulnerability, but it was an important side-effect. Hence the Nordic countries, which were connected to the Union for Co-ordination of Production and Transmission of Electricity (UCPTE) only by way of HVDC cables, proved less vulnerable to disturbances on the Continent than other regions.[30] In the case of natural gas, a problem was that Dutch and north German natural gas had a lower calorific value than Soviet and Algerian gas, which meant that they were not interchangeable. Initially it was considered necessary to build gas-merging plants as a gateway technology to transform Soviet gas to the Dutch calorific level by adding nitrogen. This would have made it possible for Dutch gas to come to the rescue in case of supply disruptions from the East. However, building such plants would have been expensive, and when high calorific gas was discovered in the North Sea, this was seen as sufficient backup so that the plans for gas-merging plants were abandoned.[31]

An important strategy for coping with the risk of a breakdown of computers or communication links has been to prepare for *fallback to manual operation*. For example, EUROCONTROL made careful preparations so that it could continue to guide airplanes if its computers failed.[32] In electricity systems, similar preparations have been made, not least to ensure that nuclear power plants can be controlled if computers fail. However, the fast development towards "smart grids" is likely to make it increasingly difficult to cope with major failures of ICT technologies supporting critical infrastructure.

Transnational governance

An important contribution of our book lies in its analysis of European integration from a critical infrastructure perspective. Many of the chapters demonstrate that the creation of transnational infrastructure has been a complicated process, involving much more than just building physical links connecting national systems. There has also been a need to develop new forms of transnational governance to coordinate flows across borders, and to cope with vulnerabilities. The organizations and actors involved in these processes were often not very well known to the general public and have not been dealt with in traditional scholarship on the political and economic integration of Europe. Our book thus contributes to the understanding of the "hidden integration" of Europe, to use a concept introduced by Schot and Misa.[33]

The forms of transnational governance have varied over time, between different kinds of infrastructure and between different parts of Europe. Chapters 2 and 3 made it possible to compare the emergence of transnational governance for electricity and natural gas in Europe. Although both systems became transcontinental in extent and came to play key roles in Europe's energy supply, there were striking differences between the two in terms of transnational governance. In the case of electricity, major power companies in neighboring and "friendly" countries established organizations like the UCPTE (1951) and Nordel (1964). These rather informal bodies became important arenas for developing guidelines, standards, and plans for building grids across borders, and for establishing conditions for electricity exchange. In Eastern Europe a somewhat more hierarchical form of organization was established in the early 1960s, in which the Moscow control center was responsible for frequency regulation and power exchanges. The rather informal character of governance, particularly in the West, is partly explained by the fact that the interdependencies were not as strong as in the case of gas. Each country had its own power plants and could be self-sufficient if needed. Electricity exchange across borders was intended to increase the efficiency and reliability of supply.

In the case of gas, by contrast, transnational governance was mainly bilateral and strongly decentralized, with hardly any international organizations of any significance, apart from a few branch organizations that functioned as arenas for community formation and knowledge exchange. On the other hand, the state was often more strongly involved in shaping the European natural gas regime than in shaping transnational electricity. Long-term contracts between exporting and importing companies, with strong direct or indirect state involvement, enabled the establishment of transnational connections. These agreements were difficult to reach and often took a long time to negotiate because of the huge diversity of interests of the actors involved. At the outset it almost appeared impossible that a highly integrated system of pipelines would actually be built across so many countries, as the countries involved often had strong ideological divergences or had been at war not long ago. The importance of long-term contracts in the transnational gas governance can largely be explained by the huge investments that were needed in both exporting and importing countries, and the huge unidirectional flows of gas. This created strong interdependencies that were strictly regulated in the contracts.

In the case of aviation, a transnational governance regime was established after the First World War based on the Paris Convention of 1919. The collision of two airplanes over the Grand Canyon in 1956 led to an ambition to expand transnational cooperation to encompass coordinated flight control for the ever denser air traffic above Western Europe. The combination of supranational governance and improved air-traffic monitoring technology – with the aspiring name EUROCONTROL – was seen as the best way to reduce this growing vulnerability in air transportation. However, EUROCONTROL's role as a European integration project soon lost momentum as a consequence of its inability to extend its operations of air traffic control beyond Belgium, Luxembourg, and the Federal Republic of Germany by 1976. Its member countries were not willing to give up control of their national airspace. This prompted the reconceptualization of EUROCONTROL's objective from being supranational to becoming international, codified in the second EUROCONTROL convention of 1981.[34]

A similar failure to achieve functioning transnational governance was seen in the case of emergency communication. Again, some of the core members of the EU failed to agree on the development of a single common European standard for emergency communication, and instead two competing standards (Tetra and Tetrapol) were allowed on the European market. Each was backed by strong industrial interests, and in the 1990s, neoliberal policies of stimulating market competition took priority over EU policies to improve public safety with a single standard for all. As a result, a very scattered and heterogeneous pattern of communication networks emerged.[35]

In the current policy debate, the EU and its predecessors are often intuitively viewed as the most important organizations contributing to the emergence and governance of Europe's transnational infrastructure.[36] The omnipresence of the EU and its institutions in media and the public debate tends to obscure the key roles played by more specialized organizations working behind the scenes in various transnational contexts, such as the UCPTE and EUROCONTROL. The role of these organizations tends to attract attention only in the case of major critical events, such as the 2006 European blackout or the collapse of air traffic in Europe following the volcanic eruption in Iceland in 2010. Historically it can be seen that this is the type of organization that has been crucial for the shaping of transnational critical infrastructure in Europe. However, they often tried to avoid media attention to their endeavors as this might induce political debates that could cause obstacles. This media aversion contributed even further to the "hidden" character of the infrastructural integration of Europe.

A porous Iron Curtain

Our book provides additional insight into the hidden integration of Europe by focusing on the "Iron Curtain". Many of the chapters in this book demonstrate that this was often neither very solid nor effective when seen through the lens of transnational critical infrastructure. From the late 1960s the Iron Curtain became increasingly "porous" for energy flows, particularly for natural gas. It was less porous in the case of electricity. NATO actively sought to and managed to prevent any far-reaching integration in electricity between East and West. There was thus hardly any perceived vulnerability in Western Europe to communist "political manipulation" of East–West electricity links; the lines were too insignificant for that, and in case of disagreement the connections could easily be disconnected without any far-reaching consequences. This was definitely not the case for natural gas supplies from the East, where NATO tried but never succeeded in exerting any notable influence on transnational system-building. Put differently, military policy objections in the case of natural gas had a much smaller impact on the transnational network geography than geological and economic aspects.

The chapters in Part II of the book analyze various ways in which small countries on both sides of the Iron Curtain maneuvered their energy connections during the Cold War. Greece belonged to the Western camp after a civil war in the late 1940s. In the 1960s and 1970s it created power links with its Cold War enemies Albania, Bulgaria, and non-aligned Yugoslavia, but not with its NATO allies, Italy and Greece. The power cooperation with the three socialist neighbors worked very smoothly, even during the years of a reactionary military dictatorship in Greece. This pragmatic and non-ideological cooperation in the field of electricity continued after the Cold War and became particularly salient after the earthquake in 1995, when a number of Greek power plants ceased functioning. In this critical situation the power company in Macedonia (or the Former Yugoslavian Republic of Macedonia, as it is called in Greece) came to the assistance of its Greek colleagues with substantial power supplies, despite the tense political relations between the two countries.[37]

Bulgaria, located on the other side of the Iron Curtain, developed very close connections with the Soviet Union, and to a lesser degree with other Council for Mutual Economic Assistance (COMECON) countries, during the 1950s and 1960s, in terms of both material flows of electricity and coal and a massive transfer of competence in the fields of nuclear-power and coal-power technologies. However, from the 1970s onwards, Bulgaria was able to become gradually more independent from the Soviet Union in terms of technological skills, and it developed suitable technologies to produce power from its domestic lignite sources. This not only decreased its dependence on energy imports from the Soviet Union but also made it possible to export electricity from the lignite-fired power plants in the southern part of the country. Therefore Bulgaria built power lines to its Cold War enemies Turkey and Greece as well as to non-aligned Yugoslavia in the mid-1970s. This power cooperation has gradually developed and made Bulgaria into the power hub of the Balkans.[38]

Finland did not belong to the socialist camp but had an "uneasy alliance" with the Soviet Union during the Cold War, not least in the field of energy. The Kremlin often exerted strong political pressure to make Finland build cross-border infrastructure or accept Soviet technologies, while Finnish actors did their utmost to increase energy self-sufficiency. This tug-of-war became particularly apparent when the Finnish state-owned power company decided to build two nuclear power plants and invited international tenders. For political reasons the company was forced to accept a bid from the Soviet Union, but after hard negotiations it managed to achieve a deal entailing that the two reactors would be fundamentally redesigned and provided with a protective shield. The forced collaboration between energy actors in the two countries prevented the development of relations of trust, and this became manifest after the fall of the Soviet Union, when Finland was no longer politically dependent. In 1995, for example, the Finnish government rejected a Russian power company's offer to build a submarine cable across the Gulf of Finland.[39]

The geography of Europe's vulnerability

In Chapter 1 we coined the term "vulnerability geography" to emphasize that different spatial configurations of vulnerability can be discerned in relation to Europe's transnational infrastructure. Indeed, our case studies have brought to attention the strikingly unequal spatial distribution of vulnerability. This can be seen in relation to Ulrich Beck's theory of the "risk society." Beck argued that politics in the developed world has now reached a stage where the main issue is not so much the distribution of wealth but rather the distribution of risk.[40] Echoing this argument, much of the infrastructure studied in this book has become so omnipresent that there is nowadays hardly any place in Europe that does not have access to electricity, natural gas, air traffic, emergency services, and the like. There is thus a reasonable equality in terms of *access* to networks. The same cannot be said when it comes to distribution of *vulnerabilities*.

In general, our research results hint at a much larger number of critical events in Eastern Europe than in Western Europe. In the West the impressive performance of large-scale infrastructure, such as electricity networks and air-traffic systems, which are so complex that they "should have failed" to a much greater extent than they actually do, prompted scholars of risk to define the responsible organizations as "high-reliability organizations."[41] The geographic reach of such organizations and systems is limited, however, as demonstrated by our book. It is not true, as suggested by Fritzon et al., that "actual experience in Europe shows that modern systems are extremely reliable, especially if historical performance is used as a measure."[42] This claim possibly holds for Western Europe. To the east of the Iron Curtain, high-reliability organizations hardly existed. Economies and societies were troubled by a more or less constant stream of blackouts, gas disruptions, air-traffic accidents, and computer failures. As in the West, some of these events may be said to have been planned, as in the case of electricity consumers being shut off in accordance with a predefined plan. But many events were not planned, and the responsible organizations completely lost control over the systems that they were set to manage. Due to the high frequency of failures, no one was surprised if an international phone call was suddenly interrupted, if the lights went out, or if there was suddenly no gas for cooking at home. Users had become accustomed to breakdowns. In short, Eastern Europe lived in a completely different vulnerability world.

Western European actors were rarely aware of the radical differences between East and West in terms of vulnerability. Had they known, for example, that the Soviet natural gas system and the attempts to expand it were in such a mess, they would hardly have been as willing to engage in far-reaching cooperation as they actually were. Lack of knowledge thus stimulated the expansion of transnational infrastructure across the Iron Curtain. When Western actors did get a detailed insight into the true functioning of the Soviet infrastructure they were shocked.

In the case of natural gas there was a direct connection between the vulnerabilities in the East and the West. While the Soviet Union did its utmost to live up to its contractual obligations vis-à-vis importers in Western Europe, the main victims of Soviet failures to produce sufficient quantities of gas were households and industries in the Soviet Union itself. Thus, while gas customers in Western Europe enjoyed steady supplies, millions of households in the Soviet Union experienced painful gas shortages, not least in wintertime.[43] On a much smaller scale there was a similar dependency across the Iron Curtain between Bulgaria and Turkey. In the early 1980s a Turkish region bordering with Bulgaria was supplied by the Bulgarian lignite power plants, which had excess capacity. However, the Bulgarian authorities adopted a very different approach to their foreign customers; when a domestic crisis of electricity supply occurred in Bulgaria in 1985, the exports across the border were cut, putting the Turkish customers in a precarious situation. As a result, Turkey decided to build new power stations to reduce its dependence on Bulgarian electricity deliveries.[44]

Vulnerability geographies, as analyzed in several chapters, were typically found to be the result of historical patterns of transnational system-building. In the 2006 "European blackout", for example, the origin of the failure in northern Germany caused lights to go out as far away as in Italy, Spain, and Portugal – and even in Morocco, Algeria, and Tunisia – but not in neighboring Denmark and Sweden. The division line between areas that were affected and those that were not coincided with the historical division between UCPTE and Nordel established in the late 1950s. Central and Eastern Europe, despite operating in parallel with the Western European grid, were also less affected by the blackout than regions located to the west of the former Iron Curtain. The political divide in Cold War Europe thus became visible again in connection with the blackout, despite the demise of the Iron Curtain nearly two decades earlier. In the case of the 2006 and 2009 European gas crises, the former Iron Curtain also seemed to reappear, as the former communist countries to the east of it were most severely affected by the disruption of gas deliveries from Russia.

It is important to note, though, that vulnerability geographies of Europe often did not correspond to the political borders of nation-states, nor to established political or military "blocs." An important result of our empirical studies is that some Western European countries have seen the reliability of their infrastructure increase thanks to well-developed physical connections with regions beyond the Iron Curtain. Moreover, actors on opposite sides of the Iron Curtain were often prepared to share vulnerabilities with one another. This is an intriguing result, especially when seen in relation to the overall Cold War tensions. It contradicts the view taken by Linnerooth-Bayer, who argues that

> if the countries involved have a history of conflict, cultural differences, or ongoing tensions, even minor potential "exports" of risk may generate widespread media coverage, societal attention, public concern and protests. The public may be especially averse to even minor risks emanating from a country they regard as hostile or untrustworthy, especially if the public views the risk producers as receiving large benefits.[45]

The closest we come to such a situation in our book is in the case of Finnish-Soviet energy relations. But in most cases we have seen the opposite. A particularly striking case was in connection with the 1995 earthquake in northern Greece, when neighboring Macedonia did not hesitate to help the Greeks.

Ironies of vulnerability

In Chapter 1 we discussed a number of ironies and paradoxes in relation to Europe's transnational infrastructure vulnerabilities. Let us conclude this book by emphasizing three ironies that have been demonstrated in several of our case studies.

One conclusion arrived at in several of our case studies is that transnational infrastructure, as it evolves over time, tends to become increasingly reliable but at the same time increasingly vulnerable. In the early career of a transnational network, failures, and breakdowns of various kinds may be frequent but (user) vulnerability may still be perceived as low, since the system is not yet firmly integrated with other user activities. Moreover, users often keep older technologies as a backup in case of breakdowns – for example, a wood stove that can replace an electric stove if needed. Once everyday activities become more deeply integrated with and dependent on the infrastructure in question, however, user tolerance is reduced and the perceived vulnerability increases – despite technical advancements and improvements. Thus in the twenty-first century users are often deeply disturbed by any blackout, gas disruption, airplane delay, or the like, no matter how brief the event. The general expectation is that infrastructure should always be available and functional, and any deviation from this availability and functionality tends to give rise to dismay.

The second irony that emerged in many of our chapters is that efforts to reduce infrastructure vulnerabilities, whether or not successful, often generate new vulnerabilities. For example, the introduction of emergency communication standards in the 1990s was intended to facilitate cross-border emergency collaboration and thereby make Europe safer in case of major accidents. However, it also generated new vulnerabilities by increasing our dependence on the suppliers of these technologies and their willingness to improve and carefully maintain the system. There are also many examples of this irony in relation to efforts to reduce vulnerabilities in electricity supply. Establishing power connections to neighboring countries for assistance in case of electricity shortage created a new risk of major blackouts cascading across borders. And the introduction of information and communication technologies for better surveillance of power grids led to greater complexity and the new risk that the information technologies themselves will break down.

A final irony is that infrastructure managers and regulators base their strategies for coping with infrastructure vulnerabilities on experiences of past critical events, but they are often totally perplexed when new, unforeseen events occur. This was illustrated in many of our historical cases, and it has also been demonstrated in a number of more recent events. For example, in April 2010 a cloud of volcanic ash originating in Iceland spread over Europe, paralyzing transnational air traffic for a period of several weeks, with disastrous consequences for many airlines as well as for travelers. Similarly, in March 2011 a devastating tsunami hit Japan and totally destroyed the huge Fukushima nuclear power plant. The most challenging task for those in charge of transnational European infrastructure might thus be to *cope with unknown and unforeseen vulnerabilities*. It remains to be seen how Europeans will respond to this challenge. International organizations such as the EU and the various sector organizations featuring in this book are sure to advance intensified cooperation between actors in different countries as one way to go ahead. But as we have seen, international cooperation does not provide any simple solution. Judging from our findings, it may even bring about new vulnerabilities. If history is to be taken as a guide, we will have to learn to live with such a constantly evolving vulnerability landscape, and, although we may wish to, we are unlikely to ever arrive at any final destination on this historical journey. What we can say with some certainty, though, is that the future calls for humility and an open mind.

Notes

1. For instance, Jasanoff 1998; Summerton and Berner 2003; Lagendijk and Van der Vleuten 2010b.
2. Summerton and Berner 2003, p. 6.
3. Chapter 3.
4. Chapter 9.
5. Van der Vleuten and Lagendijk 2010b, p. 2057.
6. Chapter 6.
7. Chapter 5.
8. Chapter 5.
9. Summerton and Berner 2003, p. 6.
10. Chapter 6.
11. Chapter 4.
12. Chapter 4.

13. Chapter 7.
14. Chapter 9.
15. Boin and McConnell 2007, p. 1.
16. Gheorghe et al. 2007, p. 8.
17. De Bruijne and van Eeten 2007, p. 20.
18. Chapter 2.
19. Chapters 3 and 4.
20. Chapter 2.
21. Chapter 5.
22. Chapter 2.
23. Chapter 6.
24. Chapter 2.
25. Chapters 4 and 9.
26. Chapter 2.
27. Chapter 4.
28. Chapter 8.
29. Chapter 9.
30. Chapter 3.
31. Chapter 2.
32. Chapter 7.
33. Misa and Schot 2005.
34. Chapter 7.
35. Chapter 8.
36. For example, Fritzon et al. 2007, p. 38.
37. Chapter 5.
38. Chapter 4.
39. Chapter 6.
40. Beck 1992.
41. Roberts 1990; La Porte and Consolini 1991; La Porte 1996; Rochlin 1996.
42. Fritzon et al. 2007, p. 37.
43. Chapter 2.
44. Chapter 4.
45. Linnerooth-Bayer 2001 p. 23f.