Hertie School
of Governance

Large Infrastructure Projects in Germany
Between Ambition and Realities

Working Paper 1

Large Infrastructure Projects in Germany:
A Cross-sectoral Analysis

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This working paper is part of the research project by the **Hertie School of Governance** on **Large Infrastructure Projects in Germany – Between Ambition and Realities**.
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The study was made possible by the friendly support of the Karl Schlecht Foundation

Hertie School of Governance | May 2015

Table of Contents

Introduction

Germany´s infrastructure spending is at the heart of an international debate. German austerity policy, in the wake of the Eurocrisis, forbade excessive public spending at home. Critics assert that Germany is "saving itself to death" (Der Spiegel, 2013), by amassing an infrastructure investment bottleneck. Infrastructure is a key driver for sustained economic growth (OECD, 2012). According to the Cologne Institute for the German Economy (IW, 2014), Germany would need to invest €120 billion by 2024 in transportation, broadband and electricity infrastructure to remain a competitive economy. Germany´s cap on public spending in turn keeps the European Union´s (EU) overall investment balance down. Consequently, critics demand that the "German government should invest money in infrastructure, not worry about balancing its budget." (The Economist, 2014)

Necessary infrastructure projects are large in scale, which is in danger of what Flyvbjerg, Bruzelius and Rothengatter (2003) called the "curse of the megaproject." Large-scale projects, especially in infrastructure, are often finished late and over the initially planned cost. In Germany, this has been subject to heated controversy over the alleged waste of public money. The Elbphilharmonie in Hamburg, the Berlin BER airport and Stuttgart 21 are prominent examples. This study examines large-scale public infrastructure projects in different sectors, including buildings (construction, maintenance), energy (wind, gas, nuclear), information and communications technology (ICT), defense acquisition, and transportation (airport, bridge, port, road, rail, tunnel and waterway). By taking a look at Germany, as a case study, we aim to find out where cost overruns in public infrastructure are most problematic and why. A study investigating the reasons for time delays and cost overruns is a necessary start for developing solutions to the problem. The study's focus on Germany also allows for comparisons between sectors and between countries, a topic that has largely been ignored. An exemption is the study by Cantarelli, Flyvbjerg and Buhl (2012), who compare infrastructure projects in the Netherlands to transnational data.

Based on a database of 170 cases (119 finished, 51 unfinished projects) of projects between 1960 and 2014, this study shows that there are significant variations in infrastructure project outcomes across sectors in Germany. The energy and ICT sectors especially are facing significant cost overruns, with 136% and 394% on average for finished projects respectively. In building and transportation, average cost overruns are lower, at 44% and 33%.

By selecting specific examples, and by drawing attention to the most successful and most unsuccessful infrastructure projects, the study summarizes possible explanations for this variation and offers recommendations for better management of large-scale public infrastructure projects. In particular, with regulatory power, technical expertise, delivery capacity and financing ability dispersed among a multitude of state and non-state actors, the findings suggest that effective governance of large-scale infrastructure projects requires the institutionalization of learning from experience to ensure completion on time and on budget.

Main Explanations for Time and Cost Overruns

Germany is, of course, not the only country that is facing significant additional costs when completing large public infrastructure projects. Cost and time overruns are a transnational problem across sectors. Comparable studies exist for the sectors road, rail, tunnel and bridge (Flybjerg et al., 2003), ICT (Whitfield, 2007; Bloch et al., 2012; Flyvbjerg and Budzier, 2011), industrial megaprojects[1] (Merrow, 2011), hydropower and large dams (Ansar, Flyvbjerg, Budzier and Lunn, 2014), electricity infrastructure[2] (Sovacool, Gilbert and Nugent, 2014) and buildings (Rigsrevisionen, 2009). There are no comparable studies on the sectors airports, waterways and offshore wind energy, on which data has been collected.

Previous studies on large infrastructure projects point to various explanations, including technological, political-economic and psychological factors. Technological factors include, for example, interface complexity, unanticipated changes in project technology and unknown magnitudes of risk at the start of a project (Flyvbjerg, 2014). Secondly, neoclassical economics point to the problem of cost externalization if the project outcome is supplemented with guaranteed public finance (Sovacool and Cooper, 2013). Cost externalization means that a competitive firm in the market obtains an advantage over other firms, if it can externalize costs by third party actors. In the same vein, Flyvbjerg (2007) points to bad incentives. Public institutions are often mandated or have the incentive to choose the project with the lowest cost-to-benefit outcome. This results in “survival of the unfittest” (Flyvbjerg, 2009) because firms are incentivized to systematically underestimate costs. In Germany, too, the legal requirement of choosing the most “economic” project has, in practice often meant choosing the “cheapest” project (BMWi, 2013). Additional political factors

[1] Oil and gas production, petroleum processing and refining, minerals and metals, chemicals, LNG, power generation, pipelines and other.

[2] Hydrodams, nuclear power plants, thermal power plants, transmission lines, wind farms, solar facilities.

include the deliberate deception by proponents of the project (Flyvbjerg, Garbuio, Lovallo, 2009) as well as governance problems such as incomplete contracts. Psychological factors include delusion and over-optimism (Flyvbjerg et al., 2003). In the course of a project, the planners systematically underestimate the chance of failure and overestimate the chance of success.

This study contributes to this debate in numerous ways: First, the existing studies are transnational. This can be a problem because variations in cost overruns, due to differences in geographic factors and national policy, are underexplored. Additionally, the data between different countries are sometimes problematic to compare, especially under different policy scenarios and regulatory regimes. Second, a variety of sectors and subsectors were included in order to better understand variations in the scale of cost overruns across sectors. Third, the analysis includes projects of different size categories and tracks additional variables such as citizen protests and public-private partnerships (PPPs).

Methods and Data Selection

Description of Database

The results are based on a database of 170 large infrastructure projects planned between 1960 and 2014, of which 119 are finished and 51 are still under construction. Our unit of analysis is the project case. A project was included in the database if it was based in Germany, was in public interest (taxpayer-funded or otherwise regulated), and had a clear actual or intended project outcome. This includes projects by public procurement, public-private partnership (PPP) or "semi-private," i.e. subsidized and regulated industries such as electricity infrastructure (e.g. nuclear power plants, offshore wind parks, transmission lines). The majority of projects (135) are by public procurement, 22 were PPPs and 13 were semi-private.

Projects differ in size. According to the US Federal Highway Administration, a "megaproject" is a project that costs more than $1 billion or has a high public or political impact. According to Flyvbjerg et al. (2003), "mega" is relative because a project considered small for a large city can be large for a small community. Hence, all projects were collected on which data was available. Project size is defined by its planned cost at the start of construction or execution.[3] The smallest project is the visitor and information center, Grube Messel, which was planned to cost €4.4 million. The largest

[3] Projects are identified as "small" if they were planned to cost less than €50 million, "medium" if they were planned to cost more than €50 million and less than €500 million and "large" if they were planned to cost more than €500 million.

project is the acquisition and integration of the Eurofighter jets into the German military, which was planned to cost €14 billion in 1987 (adjusted for inflation 1987-2014, it is now worth more than €23 billion).

This study grouped projects into sectors and subsectors. In total, 87 projects in the building sector (construction, maintenance), 51 projects in the transportation sector (airport, bridge, port, road, rail, tunnel, waterway), 10 projects in the energy sector (wind, gas, nuclear), 10 in ICT (services, transportation), 8 in defense, and 4 in other sectors (events, science), were examined.

Table 1: Number of cases across sectors

Sectors and Subsectors	**Number of Projects (n)**		
	Not finished	*Finished*	**Total**
Building	**28**	**59**	**87**
Construction	18	50	68
Maintenance	10	9	19
Defense Acquisition	**5**	**3**	**8**
Energy	**1**	**9**	**10**
Gas		1	1
Nuclear	1	6	7
Wind		2	2
ICT	**2**	**8**	**10**
Service	2	5	7
Transportation		3	3
Other		**4**	**4**
Events		3	3
Science		1	1
Transportation	**15**	**36**	**51**
Airport	2	4	6
Bridge		2	2
Port	1		1
Rail	6	6	12
Road	4	20	24
Tunnel	1	2	3
Waterway	1	2	3
Total	**51**	**119**	**170**

Data Sources

The cases were selected from publicly available sources, predominantly from state institutions (Bundesrechnungshof, state and federal ministries, parliamentary reports etc.), the Bund der Steuerzahler e.V., a special interest group (including the "Schwarzbuch," an annual publication that

lists cases of alleged waste of taxpayers' money), documents by the construction company or architecture firm in charge, a financial auditor, project planner or newspaper reports.

Collected Variables

Our key variable is the cost overrun. By focusing on it, the study follows the methodology by Flyvbjerg et al. (2003) and developed in more detail by Cantarelli et al. (2012).[4] A cost overrun is the difference between initially planned or estimated cost and actual cost at the end of the project, measured as a percentage of estimated costs. Actual cost can entail unplanned follow-up costs, such as lawsuits, damage control costs, time delay costs and others. The initially planned or estimated cost is the number given by the responsible authority at the start of construction or execution of the project.[5] Consequently, cost increases during the planning period of the project were excluded. An adjustment of estimates is rarely a cost problem—quite the opposite, it could be necessary for an accurate cost assessment. The study further collected data on the start of planning time, start of construction, planned end of construction, actual end of construction, the federal state where the project was built, a variable for governance (public procurement, PPP, semi-private), project size (small, medium, large) and if protests took place.

Data Limitations

The case selection was limited by data availability. In Germany, there is no comprehensive database on a project-by-project basis and this database is, to the knowledge of the authors, the first attempt to create one. Consequently, the availability of cost numbers is limited by factors such as public awareness and scrutiny, regulation, institutional capacity and oversight that influence the cost reporting. In the process of data collection, projects were dropped when information was not available, and in some sectors (e.g. energy) there were no primary sources that provided information on a project-by-project basis. The selection is hence skewed towards the building (87 cases) and

[4] Cantarelli et al. (2012), however, compare all projects if they were finished or „90% finished." This was not possible to do for this study, because the data on schedule times was too imprecise across projects. Additionally, it is also possible to learn a lot from unfinished projects. This study hence strictly separates between finished projects and unfinished projects.

[5] To compare cost numbers at different points in time, we include inflation. We adjust the number-value of the initially planned cost of a project for historical inflation for CPI2010 baseline for the period of planned construction. Inflation during unintended additional time of the project is considered part of the cost overrun percentage.

transportation sectors (51). In other sectors such as energy, ICT and defense, more data would be necessary to gain better insights. Nevertheless, this study is able to infer from a sample of 170 cases to the wider population of large-scale infrastructure projects in Germany.

Findings

The 170 large infrastructure projects in our database cover a total planned cost of €141 billion. When adding all the additional costs under real prices, the actual costs were almost €200 billion. In other words, projects were an additional €59 billion more expensive than anticipated at the start of the project (see Table 2).

Table 2: Total Costs, in million €

Sectors	Sum of additional cost under real prices	Sum of planned cost (=real prices)
Building	**3,601**	**11,730**
Construction	3,168	10,172
Maintenance	433	1,558
Defense Acquisition	**10,976**	**54,220**
Energy	**11,382**	**14,188**
Gas	361	639
Nuclear	10,482	11,508
Wind	539	2,041
ICT	**14,774**	**11,821**
Service	7,752	10,628
Transportation	7,023	1,193
Other	**2,177**	**4,740**
Events	1,717	4,200
Science	460	540
Transportation	**15,705**	**43,878**
Airport	5,260	7,311
Bridge	1	198
Port	222	278
Rail	5,491	12,516
Road	2,602	17,289
Tunnel	1,645	5,735
Waterway	484	550
Total	**58,615**	**140,576**

Table 3 summarizes the average cost overruns for all the projects and across sectors. The table differentiates between finished and unfinished infrastructure projects. For finished projects the

actual cost figures are available, while for unfinished costs the estimated actual costs are used. Finished projects have a higher average cost overrun of 73%, while unfinished projects are at 41%. It is to be expected that unfinished projects will face additional cost increases before completion.

Table 3: Average Cost Overruns Across Sectors

Sector	Unfinished Projects		Finished Projects		Total	
	Average Cost Overruns (in %)	*n*	*Average Cost Overruns (in %)*	*n*	*Average Cost Overruns (in %)*	*n*
Building	**29**	**28**	**44**	**59**	**39**	**87**
Construction	35	18	41	50	39	68
Maintenance	18	10	63	9	39	19
Defense Acquisition	**26**	**5**	**87**	**3**	**49**	**8**
Energy	**28**	**1**	**136**	**9**	**126**	**10**
Gas			57	1	57	1
Nuclear	28	1	187	6	164	7
Wind	-	-	24	2	24	2
ICT	**101**	**2**	**394**	**8**	**336**	**10**
Service	101	2	388	5	306	7
Transportation			405	3	405	3
Transportation	**61**	**15**	**33**	**36**	**41**	**51**
Airport	73	2	48	4	56	6
Bridge	-	-	11	2	11	2
Port	80	1			80	1
Rail	27	6	34	6	30	12
Road	17	4	30	20	27	24
Tunnel	364	1	42	2	149	3
Waterway	91	1	57	2	68	3
Other	**-**	**-**	**68**	**4**	**68**	**4**
Total	**41**	**51**	**73**	**119**	**63**	**170**

The lowest cost overruns are in the building and transportation sector (44% and 33%). Cost overruns in the defense sector were in the range of 87%, while energy and ICT had cost overruns of 136% and 394%. This variation across sectors in cost overruns invites a more sector specific analysis.

Sectors with Lower Cost Overruns: Transportation and Building

Transportation

In the transportation sector, cost overruns average 33%, but hide variation among its different subcategories. Among the sectors, roads have cost overruns of 30%, followed by rail with 34% and airports with 48%. Generally, transportation infrastructure is a key sector because projects are large (average project size: €1.2 billion) and are a demanding planning challenge.

- Road (30% cost overrun for finished projects)

Roads have cost overruns varying between -23%, i.e. below budget, and 125%. An example is the Bundesautobahn 20 ('Ostseeautobahn'), a highway crossing four federal states and connecting the northwest with the northeast after the fall of the Berlin Wall. Planned to cost €1.6 billion in 1992, it finished on time, in 2005, and had a cost overrun of 16%. Given that projects over €500 million in size cost twice as much as planned, on average, the Ostseeautobahn was comparatively well-planned. On the other hand, German road planners perform badly compared to the rest of the world (20%).

- Rail (34% cost overrun for finished projects)

Rails have cost overruns varying between -9.9% and 59%. A prominent case is Stuttgart 21, a rail-restructuring project (involving also a building project), which led to large public protests that received nation-wide media coverage. Originally intended to cost about €4 billion, Stuttgart 21 already has an estimated cost overrun of 54% and is planned to finish in 2021. A similar case to Stuttgart 21 was the Cologne/Rhine-Main fast-rail track, which was also planned to cost about €4 billion in 1995. Because of economic complexity, legal issues and problematic stakeholder relations, the project was delayed from a scheduled finish in 1999 to 2002 and increased by almost 52% in cost.

- Airports (48% cost overrun for finished projects)

Airports have higher cost overruns compared with other transportation sectors, varying between -3% and 148%. A few airports, such as the Frankfurt Airport Landebahn Nordwest, a landing platform, were completed within budget and within time, while the majority of airports, such as the Kassel-Calden airport or the Munich Airport 1 and 2 faced cost overruns. The Berlin-Brandenburg (BER) Airport is an exception in the transportation sector with estimates by the end of 2014 stating a cost overrun of 148%.

- Bridges, Waterways, Tunnels and Ports

In the sectors bridges, waterways, tunnels, and ports, average cost overruns for finished and unfinished projects are 11%, 68%, 80%, and 149% respectively. Of two bridges, one had a cost overrun of 25% and one was 2% below the planned budget. Two finished waterways have an average cost overrun of 57%, while the currently constructed Jade-Weser-Port is already at almost double the initially planned €480 million costs, and the end of construction, originally scheduled for 2011, is postponed to 2016. Ironically, the smallest transportation project, the maintenance of the Elbtunnel St. Pauli-Steinwerder, planned to cost €15 million, is a stunning 364% over budget, while the largest one, the Tiergartentunnel in Berlin, planned to cost more than €5 billion, was finished with 24% cost overrun.

Buildings

In the building sector, the cost overruns for finished projects were 44%, including the construction of new buildings and investments in maintenance of buildings. Projects included are the construction of ministries, public libraries, embassies, theatres, and museums. Rigsrevisionen, an independent Danish public auditor, looked at 49 public building projects in Denmark and found that 39 of 49 projects were within budget or not more than 10% cost overrun, and ten projects were more than 10% over budget (Rigsrevisionen, 2009). By comparison, projects in Germany have performed worse. Of 59 finished building projects, only 22 were below 10% cost overrun, and the other 37 were between 10% and 425%.

Some public building projects received plenty of media attention, such as the Elbphilharmonie Hamburg, which became associated with cost mismanagement. Another example is the new headquarter of the European Central Bank (ECB) in Frankfurt. The ECB was planned to cost €850 million in 2008 and end construction in 2011. In 2014, the building was finished with an estimated cost of €1.3 billion (Frankfurter Allgemeine Zeitung, 2014), a cost overrun of 48%. The project was blamed on complacent European politicians, as “oddly inappropriate” in the wake of European austerity policy (Der Spiegel, 2013). But there are also numerous successful examples in the building sector. In 2014, for instance, the new Ministry of Interior in Berlin was finished on time and almost 8% below the €208 million budget.

Sectors with Medium Cost Overruns: Defense

Acquisition of defense equipment is generally in the medium range of cost overruns with 87% for finished projects and 26% for unfinished ones. However, only three out of eight projects in the

sample can be considered finished, with four projects scheduled to be in military use between 2016 and 2018. Cost overruns in this sector have become a controversial topic in Germany, because the increased total cost is massive. The average defense acquisition project in the database is €8.1 billion, with 19% of total additional costs across all sectors for only 8 out of 170 projects.

Germany's defense minister Ursula von der Leyen, who took office in 2013, has the key task to reform the German military (Bundeswehr) to deal with sunk costs and lack of equipment for the troops. A recent study by KPMG (2014) examining nine defense acquisition projects in Germany with a €50 billion investment volume found the key issue to be the complexity of international defense contracts with major defense firms, for which the German bureaucracy is insufficiently equipped. The most costly of all the cases in this study is the acquisition and integration of the Eurofighter, a fifth generation multi-role jet, into the German military. It was estimated to cost €14 billion in 1987. Originally intended to acquire 250 fighter jets until 2014, the project was downsized to 143 fighter jets, and scheduled to be fully delivered in 2018, with a cost overrun of 11%.

Sectors with High Cost Overruns: Energy and ICT

The sectors with highest average cost overruns are energy and ICT, with cost overruns for finished projects of 136% and 394% respectively. In the energy sector, the study contains six nuclear reactors built between the 1960s and 1980s, a nuclear reactor de-construction project, two wind farms and one gas power plant. In electricity infrastructure projects, Sovacool et al. (2014) found a 117% average cost overrun for nuclear power plants, 13% for thermal plants (13%), wind farms (8%), transmission lines (8%) and solar facilities (1%).

Germany has ambitious energy policies. Nuclear reactors built with support of heavy subsidies from the 1960s onwards were technologically challenging projects, intended to substantially transform Germany's electricity infrastructure. Six nuclear reactors had an average cost overrun of 187%, significantly the Schnelle Brüter Kalkar (494%). An additional problem has been the de-construction of existing nuclear power reactors after the decision was made in the 2000s to phase out nuclear out of electricity production, accelerated in 2011 by the Fukushima accident in Japan. The de-construction of the Lubmin nuclear reactor, originally scheduled to be deconstructed between 2007 and 2008, faces eight years of delay and 28% cost overrun.

Germany has more recently planned another ambitious re-engineering project of its energy infrastructure – the 'Energiewende' (energy turnaround). Germany intends to shut down all nuclear

power plants by 2022, reduce greenhouse gas (GHG) emissions by 80% in 2050, increase the renewables share of power production to 35% in 2020 and 80% in 2050 and its share of total energy consumption to 18% in 2020 and 60% in 2050 (BMUB, 2014). Electricity from renewable sources of energy is key of this re-engineering, and offshore wind was intended to become a crucial pillar with 15% of total electricity production by 2030. Germany rapidly expanded its offshore wind capacity with eight operational wind farms, four under construction and 30 more planned or proposed. Offshore wind parks had particular problems of cost overrun and time delays because of technological challenges in grid construction and expansion.[6] Certainly, this study suggests that offshore wind parks have much lower cost overruns and have hence more accurate cost estimates than, for example, nuclear reactors.

In the IT sector, the study found the highest cost overruns of all sectors – 394% in total. This is mainly due to several spectacular cases such as Toll Collect (+1150%) and FISCUS (+1150%), a failed taxation IT system. Studies have highlighted the particular vulnerability of the ICT sector. Whitfield (2007) looked at 105 public ICT projects in the UK and found an average 31% cost overrun. Flyvbjerg et al. (2011) looked at 1471 ICT projects and found a 27% cost overrun. Bloch et al. (2012) looked at 3400 large ICT projects (above €15 million cost) and found an average cost overrun of 45%. Flyvbjerg et al. (2011) have especially highlighted the 'black swan' risk, i.e. a cost overrun of over 200% that hits one out of six ICT projects. The sample in this study found 4 out of 10 'black swan' projects as well. Mertens (2012) examines a number of cases in Germany and finds that Germany seems to perform worse than its neighbors because of regulative barriers and the inefficient allocation of expertise due to the federal structure and underpaid public ICT experts compared to the private sector.

An example for a 'black swan' is the Gesundheitskarte, a nation-wide electronic health service card. The card was intended by the federal government to make health care provision more efficient. In 2005, it was scheduled to become effective in 2006, and cost €1.6 billion. After it became repeatedly delayed, its roll out was started in 2011 and already cost €5 billion. It is yet not fully rolled out and accepted by the German population, partly due to concerns about privacy. The key challenge was the step from development to implementation. Many doctors criticized the lack of a business model and

[6] See separate case study by Anzinger and Kostka (2015), downloadable at: www.hertie-school.org/infrastructure

unclear responsibilities.[7] Another black swan case is "Toll Collect", a system that collects toll for truck use on highways. Toll Collect had an overwhelming cost overrun of 1150% because, according to Flyvbjerg et al. (2011), "developers struggled to combine the different software systems," which led to lost revenue by the government of about €7.5 billion.[8] But despite time delays and cost overruns, the Gesundheitskarte and Toll Collect were pioneering, high-risk venture that could turn out attractive. In the ICT sector, as well as in the energy sector, the German state took on transformative projects that entail first-use of technology in a large scale.

Project Size

The conventional view is that time and cost overruns are a particular characteristic of very large projects, as the planning and management of large projects is difficult due to the complexity. The findings in Table 4 however show that while "large" projects have on average a cost overrun of 100%, "medium" projects had 59% and "small" projects had 78%. In other words, the scale of a project is influential, but not the only explanation for cost overruns, since smaller projects also have significant cost overruns.

Table 4: Cost Overruns and Project Size*

Project Size	**Not Finished**		**Finished**		**Total**	
	Average Cost Overruns (in %)	*No. of Projects (n)*	*Average Cost Overruns (in %)*	*No. of Projects (n)*	*Average Cost Overruns (in %)*	*No. of Projects (n)*
Large	37	21	100	23	71	44
Medium	40	19	59	60	55	79
Small	48	11	78	36	71	47
Total	**41**	**51**	**73**	**119**	**63**	**170**

** Projects are "small" if they were planned to cost less than €50 million, "medium" if they were planned for more than €50 million and less than €500 million and "large" if they were planned for more than €500 million.*

[7] In addition, there are a few factors about the Gesundheitskarte that this study did not examine in-depth. The key challenge was that the implementation clashed with many special interests that have to do with the particularities of the German national health care system.

[8] The cost overrun estimate for Toll Collect represents the point of view of the German federal government. There are the following caveats to this estimate: the responsibilities for its outcome and the final damage are unclear. Toll Collect is currently in an ongoing legal mediation process. The number also includes "benefit shortfalls" due to unrealistic expectations at the beginning. Therefore, this estimate may fall short of the final damage or not accurately represent the complex web of responsibilities and risk.

Public-private partnerships (PPPs)

Public-Private-Partnerships (PPPs) had mixed performance outcomes. An OECD report (2012) defines PPPs as "long term agreements between the government and a private partner whereby the private partner delivers and funds public services using a capital asset, sharing the associated risks." A PPP is difficult to compare with conventional public sector projects. This study, if possible, applied the same standards to PPPs as to conventional projects. PPPs often face problems similar to non-PPPs. PPPs in both the building and the road sector perform significantly better than non-PPPs, with cost overruns of 3% compared to 45% and 9% compared to 34% respectively (Table 5).

Table 5: Cost Overruns and PPPs

Sector	Average Cost Overruns (in %)	Number of projects (n)
Building		
Non-PPP	45	73
PPP	3	14
ICT		
Non-PPP	277	8
PPP	572	2
Roads		
Non-PPP	34	18
PPP	9	6

In the road sector, PPPs were planned better than conventional projects. Half of PPPs in road construction were finished for less money than originally planned. In total, the six collected road-PPPs only had an average 9% cost overrun, compared with 34% in the 18 conventional road projects. However, on a closer look, costs were saved in smaller projects while high cost overruns occurred in larger projects. In total, €562 million more were spent than originally planned, which is 13% additional costs of total planned costs in the PPP-roads (€4.2 billion). By contrast, conventional road projects account for 16% additional costs of total planned cost for public roads (€12.2 billion).

In the ICT sector, PPPs have been less successful than conventional projects with cost overruns of 572% compared to 277%. Partly, this is because there is little experience with PPPs in the ICT sector. An influential case was Toll Collect (+1150%), mentioned earlier. A different case is Herkules, an IT system for the German military (Bundeswehr), the largest PPP-project in Europe with a planned costs of about €7 billion from 2006 until 2016. Herkules was criticized as a 'debacle' (Handelsblatt, 2010) after additional costs of €700 million were announced in 2010. However, if adjusted for inflation, Herkules cost 6.7% less than originally planned. Despite this seeming success, defense minister

Ursula van der Leyen announced to cancel the contract with IBM and Siemens in 2017 because an internal solution would make “more sense economically” (Handelsblatt, 2014).

A key risk for PPPs is cost externalization. For example, the Warnowtunnel, a private toll road including a tunnel, was the first PPP in Germany. According to the plan, a consortium of banks was supposed to invest €219 million, including a 12% subsidy by the European Union, for a duration of 30 years. During the construction phase, significant cost overruns occurred, because the contractor took advantage of unclear regulation and the contract allowed to externalize the cost to the public or by increasing the toll rate. In the end, traffic was 65% below forecast and the consortium declared the project unable to repay the investment. To avoid insolvency, the consortium wrote off equity and extended the contract for 20 years before it will be transferred to the City of Rostock.

Citizen Protests and Impact on Time and Cost Overruns

Citizen protests are associated with a higher cost overrun of 91% compared to 51% in projects without protests, but to a lesser degree with a time overrun, 68% compared to 65% (Table 6). The causal relation is unclear, however. Protests predominantly took place in sectors such as energy (nuclear) and defense, which were particularly politicized. In the wake of Stuttgart 21, the journalist Dirk Kurbjuweit coined the term ‘Wutbürger’ (angry citizen) for protest against government projects disregarding citizens’ interests (Spiegel, 2010). Apart from political issues, citizens usually protest if they see the project affecting their life (e.g. road projects close to local communities) or if the projects are present in the media as waste of taxpayer’s money. Protests were predominantly against large and medium projects – only 3 out of 53 projects with protests are small while 47 out of 170 are small in total.

Table 6: Citizen Protests and Cost and Time Overruns

	Average Cost Overruns (as % of additional costs)	**Average of Time Overrun (in %)**
No Protests	51	65
Protests	91	68
Total	**63**	**66**

Regional Variation in Germany

Between the Bundesländer, the cost overrun performance varies widely. For eight Bundesländer, the database had five or more cases of finished projects, excluding projects abroad (e.g. the German Embassy in Washington, DC) and projects where the regional jurisdiction is unclear (e.g. the defense acquisitions). Because the jurisdiction over project planning was not a variable included in this study,

this paragraph does not depict *performance* of the federal states, but only the mere fact of *location*. The causal factors were not tested, but differences are likely either explained by geographical differences or differences in planning capacity.

The federal state North Rhine-Westphalia had the highest average cost overrun of 108% among 19 finished projects. Expensive nuclear reactors, which were planned on the national level, not the state-level, drive North Rhine-Westphalia's performance down. However, two examples for poor planning of building projects are the Kreuzbauten (251%) and the Schürmannbau (245%). By contrast Berlin has only 26% average cost overrun despite its reputation as a city of bad financial planning because of massive mismanaged projects such as the infamous Berlin-Brandenburg BER Airport. As an unfinished project, BER is not included in this calculation, but also Berlin's unfinished projects have a cost overrun of only 27%. As the capital city of Germany, cost increases such as the recent €93 million additional cost for the maintenance of the Staatsoper Unter den Linden, an opera house, receive plenty of media attention.[9]

The German South has lower average cost overruns, with Bavaria at 31% and Baden-Württemberg at 22% from 27 and 14 finished projects respectively. Baden-Württemberg has only 5 out of 18 total (including unfinished) projects with cost overruns of over 30%, despite Stuttgart 21. Bavaria seems to plan its transportation projects well, 18 out of 32 totals (including roads, rail, airport and bridge) are at only 21% compared to 41% national average. In Thuringia, cost overruns were only 15%, but 6 out of 7 cases are from the road sector which has a low average cost overrun of 30% across all Germany compared to other projects. An example is the fast-track highway Nürnberg - Ebensfeld – Erfurt shared with Bavaria (which is scheduled to finish in 2018), which cost €5.3 billion and had cost overruns of 13%.

Top Outperformers and Underperformers

The top ten performing and underperforming projects offer additional insights. Table 7 lists the ten projects with the largest cost overrun. These flop ten projects alone account for 36% of total additional costs of €59 billion. They include four ICT projects, Toll Collect and FISCUS (both 1150%), Inpol (491%),[10] an IT system for the Bundeskriminalamt (BKA), the federal anti-crime agency, and the Gesundheitskarte (208%). The list also includes two nuclear reactors, the Schnelle Brüter

[9] The Staatsoper, scheduled to finish in 2015, increased in cost at the time of the data collection. Like with other projects, it may have increased even further since this study finished data collection by the end of 2014.

[10] FISCUS and Inpol had high cost overruns not only due to technological factors, but specific political factors this study could not accurately reflect. Such factors were, for example, the implementation challenge in the often-complex federal system in Germany.

(494%) and the Thorium-Hochtemperaturreaktor (336%) and three buildings, e.g. the Bischofsresidenz Limburg (425%). For example, the bishop's residence was initially supposed to amount to 147m² in size, but ended up as a 2000m²-complex with additional features such as private rooms for the bishop, an atrium and a chapel—which was blamed on the bishop's decadence and demands for luxury (Der Spiegel, 2013).

Table 7: Worst Cost-Performing Infrastructure Projects

Flop 10 Projects	Cost Overrun (in %)	Additional Costs (in million €)
Lkw-Maut Toll Collect (ICT)	1,150	6,900
FISCUS - Steuersystem (ICT)	1,150	4,600
Schnelle-Brüter Kraftwerk Kalkar (Energy)	494	2,326
Inpol Neu (BKA) (ICT)	491	119
Bischofsresidenz Limburg (Building)	425	25
Alter Elbtunnel St. Pauli - Steinwerder (Tunnel)	364	71
Thorium-Hochtemperaturreaktor Hamm-Uentrop (Energy)	336	3,082
Bonner Kreuzbauten (Building)	251	99
Bonner Schürmannbau (Building)	245	497
Gesundheitskarte (ICT)	208	3376

Some projects also perform exceptionally well. All of the top ten performing projects are in the building and transportation sector. Five out of ten were PPPs. The best performer is the A8 Augsburg-München. This project was one of four first PPPs established by the German government in road construction in Germany, and as such, this project received high attention by the relevant stakeholders.

Table 8: Best Cost-Performing Infrastructure Projects[11]

Top 10 Projects	Cost Overrun (in %)	Additional Cost (in million Euros)
A8 Augsburg – München (Road)	-23	-70
A3 Autobahndreieck Würzburg-West (Road)	-15	-13
Justizzentrum Heidelberg (Building)	-9	-5
A5 Malsch - Offenburg (Road)	-8	-84
Bundesinnenministerium Berlin (Building)	-8	-17
Klinikneubau Hochtaunuskliniken (Building)	-6	-12
Umweltbundesamt Dessau (Building)	-6	-4
A8 Augsburg West - München Allach (Road)	-6	-43
Bundespolizeifliegerstaffel Oberschleißheim und Polizeihubschrauberstaffel Freistaat Bayern (Building)	-5	-2
Nationalpark-Haus Berchtesgaden	-4	-1

Comparison to transnational studies

Compared with transnational studies of projects in the transportation sector, Germany performs a bit worse (see table 9). Overall, Germany is six percentage points below the world average of 24%. In the rail sector, Germany is on the world average with 34%, but worse than the rest of North West Europe[12] (22%) and the Netherlands (11%). In road, Germany is 10 percentage points worse than the world average of 20% (NW Europe: 21%, Netherlands: 19%). In tunnels and bridges, Germany is six and five percentage points better than the rest of the world (33%) and NW Europe (32%), but five percentage points below the Netherlands (22%). In the public IT sector, Germany has a very high 394% average cost overrun compared with Britain´s 31% (Whitfield, 2007). In nuclear energy, Germany is with 187% average per power plant worse than the transnational average of 117%. There are no comparable studies for the sectors building, airport, port and waterway.

[11] In the initially published version of this ranking the Chemikum Universität Erlangen-Nürnberg held the top position. Based on additional information we have received in the interim, the project has been removed from the list as it was not completed in the study's stipulated timeframe.

[12] Great Britain, Belgium, Ireland, the Netherlands, Luxembourg, northern Germany, northern France, Denmark, Norway, Sweden and Iceland.

Table 9: Comparison of findings with relevant transnational studies

	Germany		Netherlands		North Europe	West	World	
	Average cost overrun (%)	Sample size (n)	%	n	%	n	%	n
Road	30	20	19	37	21	315	20	537
Rail	34	6	11	26	22	90	34	195
Tunnel/Bridges	27	4	22	15	32	54	33	74
Total	30	30	17	78	22	459	24	806

Source: Hertie School Infrastructure Database, Cantarelli et al. (2012)

Explanations

In the literature, technological, political-economic and psychological factors explain the phenomenon of time delays and cost overruns in large-scale projects in general. Many of these factors also help to explain poor planning and infrastructure management in Germany. For specifically the German case, three factors particularly explain the outcome: governance factors, geographical differences and a pioneering risk attitude.

The analysis shows that governance factors lead to differences in the allocation of risk and competition for lower cost. PPPs vary from non-PPPs; however, they still often have the same problems as conventional projects. This study suggests that more successful examples had a better allocation of risk of additional costs and incentives for good cost performance. For example, the West Rail in Hong Kong was a completely public project, planned to cost €8 billion. It finished on time and 27% below budget. Throughout the project stages between 1998 until its completion, the budget was continuously downgraded, because it had effective cost control, continued value engineering and lower prices resulting from a competitive market (OMEGA Centre, 2007).

Furthermore, the results of this study confirm the finding of Cantarelli et al. (2012) that cost overruns vary across geographies. First, within Germany, the observed cost overruns in eight Bundesländer varied greatly between 15% and 108%. In addition, when comparing our Germany-based sector

analysis with other countries, large differences between Germany and the transnational data emerge. These findings suggest that infrastructure planning and management is influenced by the specific political-economic context in which the decisions are made and implemented. More research is needed to understand what the exact reasons are.

Finally, costs and time overruns increase drastically in sectors with a high share of pioneering projects. As there is no benchmark for pioneer projects, the pioneer takes a higher risk of cost overruns than then second and third-mover. In the energy sector, for example, Germany built a lot of nuclear power reactors the 1960s and 1980s, with massive subsidies, while nuclear was an infant industry. While risky and costly, Germany pioneered nuclear technology and significantly re-engineered its energy infrastructure. Currently, too, Germany has another transformative re-structuring project of its energy infrastructure (Energiewende) with more large-scale, new technology-projects to follow. More examples are in the ICT sector. Toll Collect and the Gesundheitskarte were pioneering ventures without previous experience that would substantially transform Germany´s transportation and health infrastructure.

Bent Flyvbjerg et al. (2003, p. 16) said that “no learning seems to take place” in planning of large-scale projects looking at the last seventy years. This study finds that the problem of public planning is that experience is not sufficiently institutionalized; therefore, each new large project planned is a new “pioneer” that does not build on previous experience. This study claims that pioneer risks are the key problem and learning is possible if sufficiently institutionalized and incentives for public planners are right.

Recommendations

The key recommendation of this study for the governance of large-scale projects is “sector-based benchmarking.” In the private sector, benchmarking means the comparison of industrial processes based on performance criteria to develop “best practices.” The German government should do the same. The idea of benchmarking in public infrastructure planning entails three steps: a public megaprojects database, a references class forecasting (RCF) model for different sectors, a contract model based on micro-level risk allocation and cost control.

- Introduce a public megaprojects database

Transparency is essential. Germany should introduce a publicly available database about large-scale projects to provide transparency, intended to increase the incentive for the project planners to stay

on budget, because of the higher chance of public scrutiny if they do not. The database should include all projects publicly financed and projects that receive direct or indirect subsidies and collect annual data on cost, status of completion and other relevant metrics. Such a database should make benchmarking possible for private investors to properly plan project finance and enable learning curves in specific sectors. The UK has pioneered this approach by introducing the "Major Project Authority" (MPA). The MPA maintains a database of almost 200 infrastructure projects with a total volume of about €677 billion, regularly publishing reports and key data (UK Government, 2015). It has the mandate to request information, evaluate planning and intervene if deemed necessary.

- Introduce sector-specific planning models

Public project planners should introduce reference class forecasting (RCF). RCF is a method intended to reduce optimism bias, developed by Kahnemann and Tversky (1979a, 1979b) and applied to transport infrastructure planning by Flyvbjerg and COWI (2004) and Flyvbjerg (2008). On the basis of the aforementioned database, the MPA identifies relevant reference classes, categorized in sectors (e.g. road and rail) and sub-sectors (e.g. highways, trunk road, local roads). It then establishes a probability distribution based on past cost overruns and other metrics for the selected reference classes. New projects are then compared to those reference classes, and the MPA calculates "uplifts" based on the average cost overrun for the project class.

- Micro-level risk allocation contracts

A potential problem with RCF is that planners view the "uplift" as the real budget instead of the contingency, which they are not supposed to use. This could lead to bad incentives. Therefore, detailed risks assessments for each step in the project phase prior to project start are necessary. Such risks assessments involve comprehensive planning of each project phase and require the allocation of a risk for each micro-level project step, based on experiences of previous projects. The planning for additional, yet unforeseen complications in large and complex projects, need to be continuously updated to identify cost risks in advance. This helps to avoid that project managers simply convert additional risk allowances into their budget calculations. The key challenge for project planners is to be continuously on alert to mitigate cost escalations.

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