SI 741 – Systems, Networks, and Webs

The German Toll Collect System as Context for Infrastructure Studies

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1 Introduction

The appearance of the electronic toll collection system for commercial trucking on Germany's Autobahn in 2005 signaled a substantive shift in multiple aspects of German society. This large-scale project has the potential to induce significant change in social, economic, political, industrial, and other spheres of the German infrastructural landscape. The aim of this paper is to explore some of these infrastructure issues related to the Toll Collect (MautSystem) project. Before proceeding, however, a few notes are in order.

First, since the release of the system in January 2005, the data collected by Toll Collect GmbH, the company responsible for the construction, implementation, and management of the system, has been unavailable for research purposes. As a result, little to no academic literature currently exists on such a recent project. Meetings in March 2006 with the Toll Collect data management team have provided a reasonable sense of the system construction and nature of the data collected, which will be available this summer; however, comments made in this paper on aspects of the system will be drawn from personal notes taken during discussions with the Toll Collect team.

Second, following from the recent implementation of the system, the infrastructural effects described in this paper are to a large extent anecdotal or speculative. It is my sense that when studying infrastructure, the effects of a system change on the sprawling infrastructure may take time to be seen, understood, measured, and adequately described. It is my intention to formulate these types of questions during my dissertation work, and I see this paper as a "work in progress" fleshing out early ideas and perspectives toward that goal, rather than a neatly encapsulated commentary on an existing infrastructure.

Finally, and related to the above, the ideas I put forth in the paper will attempt to ground my ideas in literature, but are intended to be explorations of finding workable perspectives or angles that may be fruitful for further study.

It is also important to note, I believe, the process by which I have come to this point in thinking about infrastructure. The project began with several (mostly failed) attempts to cast the MautSystem as infrastructure, or at the very least, as a component of infrastructure. While I think the argument can be made the the technological system itself exists as a complementary component to a larger, heterogeneous network of other systems, the collection of which can rightfully be called infrastructure, the justification of the project itself is problematic. Instead, I was forced to attempt a Gestalt switch with respect to how I could situate the Toll Collect system, suspecting that there is a rich infrastructure story to be told. This shift in perspective hinged on the differentiation

between considering the Toll Collect project as *text*, and subsequently reframing it as *context*. The latter framing, I believe, has far greater potential for studying infrastructure. That is to say, the appearance of the MautSystem in Germany has the potential to make other aspects of German culture less transparent. Using Bowker and Star's rhetoric, the MautSystem can be considered a lens for infrastructural inversion[1]. It is under this premise – that the MautSystem is not infrastructure, but exposes facets of infrastructure in other aspects of the German environment – that I will proceed.

The paper will be organized in the following way: First, an abbreviated history of the German Autobahn and the Toll Collect project. Following this, I will describe four areas in which infrastructural issues relating to the Toll Collect system might be seen. Finally, I will propose a research design to advance one of those topics.

2 Autobahn and Toll Collect History

The network of major highways in Germany, the Autobahn, was planned and constructed during the period of 1933-1945, beginning with plans to develop a major north-south thoroughfare running through Hamburg, Frankfurt, and Basel[2]. The planning commission, HAFRABA, envisioned an internetworked system of high-speed roads to stimulate German economy, handle the increasing numbers of privately owned vehicles, and compete with similar initiatives emerging in neighboring Italy[3]. During the rise and tenure of Hitler's empire building agenda, special attention was paid to the Autobahn. The common interpretation of this attention is that the Autobahn was developed for the purposes of military mobilization; however, other scholarship provides a convincing counterargument that the primary purpose of the Autobahn project under Hitler was to provide widespread employment opportunities making good on the propaganda of an employed nation[4]. Additionally, the construction of the roadway system was intended to be a balance of powerful symbology - that the German empire would last - as well as aesthetics, weaving into the beautiful landscape, showing respect for the glory of the Fatherland. As such, the Autobahn is a symbol of German security, productivity, and pride that was woven into the national psyche[5].

Along with the creation of the Autobahn, a licensing fee structure and tax system for commercial trucks was put in place. While this set of fees does represent a long-standing source of payment centering on commercial logistics and transport systems, the fee structure has historically been transparent to truckers, and more importantly to the public, This lack of visibility is primarily because it is not instantiated in physical form that may be seen on the Autobahn, but has been absorbed into the routine governmental infrastructure[6].

[1] Bowker, G., and Star, S. L. (2000) Sorting Things Out: Classification and Its Consequences. MIT Press; Cambridge, MA.

[2] Vahrenkamp, R. (2005) "Roads without Cars: The HAFRABA Association and the Autobahn Project 1933-1943 in Germany." *Working Papers in History of Mobility.* No. 1/2002 (update 2005), University of Kassel, Faculty of Economics and Management.

[3] *Ibid.*

[4] Vahrenkamp, R. (2006) "Planning and Constructing the Autobahn Network in Germany during the Nazi Period: Styles and Strategies." *Working Papers in History of Mobility.* No. 6/20026, University of Kassel, Faculty of Economics and Management.

[5] Zeller, T. (1999) "The Landscape's Crown': Landscape, Perceptions, and Modernizing Effects of the German Autobahn System, 1934-1941." in Technologies of Landscape: Reaping to Recycling. David Nye (ed.), Amherst, MA: University of Massachusetts Press, 218-238.

[6] Vahrenkamp, R. (2003) "Rivalry and Regulation: The German Cargo Transport Policy 1920-2000." *Working Papers in History of Mobility.* No. 2/2003, University of Kassel, Faculty of Economics and Management.

Jumping forward several years[7], the idea of a specific toll for heavy trucks was reintroduced by the Red-Green party in 1990. There was a short experiment in charging tolls; however the collection was stopped after a few weeks after the European Court of Justice determined that the joint charging of tolls and taxation was not permitted.

In 1994, the issue of toll collection was revisited when Germany, the Netherlands, Belgium, Luxembourg, and Denmark entered into a convention agreeing to collect fees for heavy commercial trucks. Later that year, the Motorway Use Fee Law (ABBG) was passed by the German government, officially paving the way for a legal installation of tolling for trucks.

In June 1998, a call was made for prototypes and demonstrations of potential models for collecting commercial tolls. Earlier in the year, Deutsche Telecom had begun experimenting with a hybrid GPS/GSM system and had decided to pursue this technology, which would ultimately become the form the Toll Collect system would take. The first successful prototype was constructed by Dornier SystemConsult (now Dornier Consulting) along with T-Systems (one of the suite of companies along with T-Com, T-Mobile, etc.) This successful early endeavor spurred the Red-Green political party to place the initiative to shift the cost of roadway costs onto the users, rather than distribute the costs among all taxpayers. By the end of 1999, the early stage development had concluded with an advisory group firmly in place, having invited a French company with experience in developing tollway systems, Cofiroute, to join the table.

In January 2000, an official request for proposals for the design and construction of the toll collection system was issued. The main competitor was a consortium formed among Deutsche Telecom (45%), DaimlerChrylser (45%), and Cofiroute (10%), organizing under the name of ETC.de (later to be reincorporated as Toll Collect GmbH.) The other primary competitor, AGES, was rejected from the competition due to the inability to provide proof of adequate financial resources to undertake the project. In August of the same year, the Federal Cabinet announced that the winner of the contract will be expected to launch the final product in January 2003. That month, the Federal Ministry of Transportation officially awarded the contract to Toll Collect. Immediately, AGES registered a complaint that the bidding procedures and evaluation of proposals was illegitimate. A year-long negotiation to settle the matter ensued.

Concurrently, in December 2001, the Red-Green party launched a pre-emptive program to charge tolls depending on the number of truck axles and emissions ratings, ranging from 10 to 17 eurocents per kilometer. Within three months, the Upper House of Parliament quashed the toll, claiming that the Red-Green party did not adequately consider infrastructural costs of the launch, nor the wider-ranging effects on the economy. After reworking the initiative, combining the contract negotiations with a request that Toll Collect and AGES resubmit project offers, the establishment of a heavy truck toll duty was signed into law on April 5, 2002.

AGES, meanwhile, had been actively appealing the case of contract disenfranchisement to progressively higher courts. In August 2002, an informal request was made to the Toll Collect consortium that AGES be included, and the thorn in the project's side be eliminated. After a month of negotiation, an arrangement is agreed upon and accepted; however, due to contractual arrangements dating from 2001, the inclusion of AGES shortened the period for construction from 18 to 11 months, and placed the consortium in a poor position. Further, the contract also required agree-

[7]Unless otherwise specified, the remainder of this section on the history of Toll Collect has been culled from interviews and documentation provided by Toll Collect GmbH, and has not been published elsewhere. A caveat to this approach is that the historical perspective is inherently biased by potential exclusion of competing accounts. While the reconciliation of these accounts is outside the scope of this paper, the details of the Toll Collect story are the subject of in-progress dissertation work by Svezdana Seeger and Andreas Möbs, both of the Institute for Information Systems, Johann Wolfgang Goethe University, Frankfurt, Germany.

ments with the Federal Republic of Land Use to agree on the physical structure and placement of the system. An agreement was settled upon quickly to allow the smooth transition to the new consortium structure, and a revised release date of August 31, 2003, was set. With this new contract in place, the MautSystem initiative officially became the largest public-private partnership in German History. Unfortunately, with scale comes complexity, and the road to a successful launch would prove to be a more difficult path than any of the players could have anticipated.

The following months saw a number of obstacles for the Toll Collect project. First, in November, the European Union declared the incompatibility of concurrent toll collection systems during a period of transition. In the short term before the installation of the distance-based toll (being developed by the Toll Collect consortium), a stopgap system named Vignette had been installed, which charged tolls based on time spent on the Autobahn. The ruling, as before in the tolling story, was that the concurrent charge for two systems was not permissible, and that Vignette must be discontinued for a period of nine months before Toll Collect could be installed. The reason given was to prevent any possible overlap of the systems double billing clients. Second, an inquiry was launched with regard to DaimlerChrylser's involvement in the consortium. Since Daimler was responsible for the greatest market share of heavy trucks, and would be in a position to integrate the Toll Collect in-truck technology, this raised concerns about possible anticompetitive action and unfair market domination[8,9]. Fortunately, the exploratory commission concluded that the availability of the on-board technologies to other truck manufacturers was adequate to avoid further anticompetitive scrutiny[10].

Further difficulties were encountered in the spring of 2003, when the AGES group was unable to secure broad contracts for the installation of electronic kiosks (Mautstellen) for truckers to register with the MautSystem. As a result, they approached securing individual contracts for each location, which would take much more time and effort. Additionally, the Federal Land Regulation Offices in each of the surrounding countries required expensive and difficult-to-implement changes with respect to physical structure (guard rails, slope protection, concrete reflecting walls, etc.) and negotiations had to be pursued with each country separately. The responsibility of the AGES group (which was primarily securing the Mautstellen locations and installation) prompted an unforeseen and significant stress on the overall project schedule and budget. Only in April did AGES begin to see the first successful contracts in France; however, the entire process ran sluggishly, and the Toll Collect project fell far behind schedule.

For the remainder of 2003, AGES found it difficult to secure Mautstellen location contracts, and blame for the lagging deadlines fell primarily on the ersatz entrant to the Toll Collect consortium; however, other members of the group were experiencing demands that threatened the project's success. The European Union was highly critical of the relatively small number of on-board units (to be placed on trucks) that had been produced, and felt that 150,000 units would be insufficient, claiming that it was prohibitively inconvenient for truckers to schedule routes through a web interface or at the Mautstellen. It was clear by May, but solidified by October, that the deadline for launch would not be met. In response, the project was expanded with additional personnel,

[8]EUROPA (2002) "Commission deepens probe into German Toll Collect venture between Daimler Chrysler and Deutsche Telecom." EUROPA Online. Article archived at http://www.scholar-warrior.info/wiki/docloc/TollCollectGmbHHist/EUROPA2002.pdf

[9]National Economic Research Associates, Inc. (2003) "Conditional Clearance for Toll Collect Joint Venture between Daimler Chrysler and Deutsche Telecom." *Global Antitrust Weekly.* No.232.

[10]Brussels Monitor (2003) "Commission clears joint venture between DaimlerChrylser and Deutsche Telecom." *Competition, Regulation and Trade.* Article archived at http://www.scholar-warrior.info/wiki/docloc/TollCollectGmbHHist/BrusselsMonitor2005.pdf

and the promise of delivering 400,000 units was made. In October, after the numerous failures and missed deadlines, the manager of the Toll Collect project, Dr. Michael Rummel, resigned, and an entirely new management staff is put in place to get the project back on track. In addition, the new board contracted with a highly regarded European consulting company, Roland Berger, to manage the project rollout. In consort with Roland Berger, the new team released a three-phase project schedule, but failed to provide estimated dates of completion for the various phases. The Ministry of Transportation responded with an ultimatum: Set up a feasible schedule for project completion before the year's end, or the contract would be withdrawn.

After an admonishment from the Federal Chancellor, Toll Collect announced an new launch date, December 31, 2004, but only promised a stripped-down version of the system. It had already been projected that the missed deadlines and late start date represented approximately 2.8 billion euros, and this was unacceptable to those in power who had funded the project. It was decided that in the interim, the Vignette system would go back online in order to mitigate some of the loss. Negotiation of an acceptable transition to the new system took place for two months, and was agreed upon in March, 2004. As a part of the agreement, the board of Toll Collect is disbanded in favor of yet another regime change. This time, a strong representation from the upper management of T-Systems, DaimlerChrysler, and Deutsche Telecom took the reins, and promised to make the last promised deadline.

The new board showed great success in delivering. By May, a complete end-to-end test of the system had been successfully run, and the construction of 500.000 on-board units underway. In addition, the new board devised an incentive program to facilitate the rapid installation of units into existing truck fleets. A final pilot test of the system took place in September, and the remaining months before final release were spent fixing bugs in the software and creating patches for errors detected during the testing. The final system was approved in December, 2004, and launched with the start of the new year. Since January 1, 2005, and experiencing one major software update, the MautSystem seems to have been working with minimal problem, and is considered by those in power to be a technological success.

Unfortunately, the problematic history of the contracts carries on. Despite the functioning system, the missed deadlines and accompanying default of payment on the Ministry of Transportation's investment (5 billion euros to be repaid within the first year of scheduled operation) have prompted legal action. Currently, the Ministry of Transportation and Toll Collect GmbH are in pre- federal court negotiations to settle the financial matter. If the parties cannot agree to mutually acceptable terms, the case with progress to a litigation phase where the Federal Court will rule on the fate of Toll Collect.

This rough sketch of the history of the Autobahn and Toll collect project serves to illustrate that the contemporary transformation of a nationally embedded and valued infrastructure - the Autobahn - has been a consistent display of publicly viewed failure. As with anything public, many eyes on a topic serve to render aspects of the system's functional components visible, and further, commented upon (or more to the point, criticized.) In the following sections, I will explore some of the aspects made visible in German culture by the Toll Collect system. Some of these aspects flow from the flawed history of the project management, while others will discuss observed early indicators of change seen as a result of the functioning system.

3 Infrastructural Inversion in Four Dimensions

Considering the colorful and troubled history of Toll Collect, growing out of the glorious monument of the Autobahn, we can look at the tensions that have arisen from various aspects of the project. Daniel Dennett, in his description of systems construction, points out that all systems must have a designer, and the MautSystem is certainly no exception. Whether this design process is one of intention (i.e., man-made constructions, in this case) or one of evolution largely determines the eventual fit of the technology designed[11]. One of the difficulties in designing a large technical system is the limitation in scope of the designer to predict *all* effects of the implemented system. Owing to this bounded rationality[12], the inability to predict far-reaching consequences and second-order effects, or in the cases useful to infrastructure - revenge effects which cause the infrastructure to become visible upon breakdown[13,14]. As mentioned in the introduction, the early effects of the MautSystem are only beginning to be seen, and many were not predicted. As pointed out by James Scott in describing the attempts of various societies to construct large-scale control systems, "Any large social process or event will inevitably be far more complex than the schemata we can devise, prospectively or retrospectively, to map it[15]." In the following four sections, I will attempt to describe some of these early effects.

3.1 Political

The construction of a large-scale project such as the MautSystem involves significant capital. It is not atypical for projects of this magnitude to be funded through public-private partnerships, in which governments provide the capital to a private company that oversees design, construction, and maintenance. As seen in the history of Toll Collect, the MautSystem is one of these cases, where the Ministry of Transportation and Federal government used public monies to fund the new toll collection system. To be more precise in categorizing the Toll Collect endeavor, this project falls into the category of *megaprojects*, defined by both Altshuler and Flyvbjerg as a project, typically involving the construction of some aspect of publicly-utilized infrastructure at a cost of over $1 billion[16,17]. The MautSystem clearly meets these criteria. The need for public funding in megaprojects is not unique, as pointed out by Thomas Hughes.

> Stressing that large construction projects require the use of a systems approach to coordinate and control the activities of numerous semiautonomous contractors, [Bugos] points out that firms responsible for such a multifaceted task have often resorted to joint ventures in order to pool the needed organizational and technical resources. Joint

[11] Dennett, D. (1996) Darwin's Dangerous Idea: Evolution and The Meaning of Life. Simon & Schuster. New York, NY.

[12] Simon, H. (1996) The Sciences of the Artificial. MIT Press. Cambridge, MA.

[13] Tenner, E. (1997) Why Things Bite Back: Technology and the Revenge of Unintended Consequences. Vintage Books. New York, NY.

[14] Bowker, G., and Star, S. L. (2006) "How to Infrastructure." Pre-press manuscript. Obtained from Steven Jackson, University of Michigan School of Information.

[15] Scott, J. C. (1998) Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed. Yale University Press. New Haven, CT. p 309.

[16] Altshuler, A., Luberoff, D. (2003) Mega-Projects: The Changing Politics of Urban Public Investment. Brookings Institution Press. Washington, DC.

[17] Flyvbjerg, B., Bruzelius, N., Rothengatter, W. (2003) Megaprojects and Risk: An Anatomy of Ambition. Cambridge University Press. New York, NY.

> ventures also spread the risks of the heavy financial liabilities for nonperformance that companies must carry in guaranteeing and fulfilling performance specifications[18].

According to Hughes, both the funding and the risks involved in such projects are of a highly political nature.

Further, Flyvbjerg points out that when the funding comes fully from the public section, as in the case of Toll Collect, rent-seeking behaviors are encouraged on the part of the private contractors. While it is unclear that this was the source of time lags in the case of AGES not securing Mautstellen locations, or similarly in producing mass numbers of on-board units, it can be speculated that these behaviors were free of this rent-seeking tendency. Only with the installment of the new management board in 2004 did the commitment to schedules strengthen. Given the current state of the financial arrangement in this public-private partnership – probable litigation over lack of repayment of Federal investment – we can see how the MautSystem, in terms of project management and systems development, exposes the riskiness in the infrastructure of public spending. Whether the outcome of litigation is in favor of Toll Collect or the Ministry of Transportation, it stands to reason that this debacle may have further-reaching effects on the nature of future public-private endeavors in German megaprojects[19]. Flyvbjerg, et al, have modeled the transition points of risk assessment for megaprojects, and give the recommendation that public funds comprise no more than one third of the total project cost, in order to mitigate the tendency for rent-seeking behaviors, and tip the accountability of such projects back toward the contractors, in line with the description given by Hughes[20].

Another aspect of political infrastructure exposed by the Toll Collect project is possibly one of path dependence in developing the larger array of national infrastructure components. The current debacle with Toll Collect may have further-reaching results for the future of the way large-scale development projects are conducted in Germany, making a number of potentially beneficial future infrastructure projects inviable through cost-estimation phases of planning. One possible case of this situation may have already been seen. After the planning for the Toll Collect project had begun, proposals to apply German MAGLEV (magnetic levitation) technology to construct friction-free, high speed trains between Berlin and Hamburg was rejected in 1998, due to the inability to invest an extra $1.5 billion[21] One interpretation of this decision is that enough money had been invested in other public transportation infrastructure development, namely Toll Collect, that a path dependence had been created. As economist Scott Page explains,

> Any large public decision, be it a prison or university takes up space and requires money. Both create negative externalities with future public projects. Obviously, the more money and space a project demands, the greater its impact on the path. Small projects are less likely to influence the path of history than are large projects. That is not to say that smaller decisions cannot accumulate over time and restrict history to certain paths, but that any big project crowds out other projects[22].

[18] Hughes, A., Hughes, T. (2000) Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After. MIT Press. Cambridge, MA.

[19] Hagen, A. (2004) "Toll Collect: A Public-Private Partnership (PPP) Disaster." Telepolis Online. Last accessed 04/22/2006 at http://www.heise.de/tp/r4/artikel/16/16684/1.html

[20] Flyvbjerg, B., Bruzelius, N., Rothengatter, W. (2003) Megaprojects and Risk: An Anatomy of Ambition. Cambridge University Press. New York, NY.

[21] Apel, R. (2003) "Shanghai's MAGLEV Launched: Revolutionary Step for Eurasia.' *Executive Intelligence Review.* January 10, 2003 issue.

[22] Page, S. (2005) "An Essay on the Causes of Path Dependence." Santa Fe Institute Working Paper Series.

It is, then, possible that the investments made in Toll Collect drove out the possibility of a grand MAGLEV megaproject, and altered the path of national German transportation infrastructure.

3.2 Economic

Graham and Marvin cover two complementary concepts of particular relevance to the introduction of tolling on the Autobahn[23]. *Unbundling*, as an economic construct and *splintering* as a social phenomenon, can both be seen as infrastructure shifts since the introduction of the Maut. The MautSystem initiative, in effect, is the unbundling of traffic on the Autobahn. Previously. although there were commercial trucking license fees "behind the scene," to the driver, traffic was undifferentiated traffic. The appearance of control bridges, gantries, and on-board units in trucks is a physical manifestation of this unbundling of commercial and non-commercial traffic. It makes visible the density of trucks on the road, and since behaviors to go off the Autobahn to (mistakenly) avoid tolling (see section 3.3 for a further discussion), makes the commercial traffic more visible to communities along the Autobahn.

An as yet unmeasured, but predicted outcome of the toll is related to splintering effects. As companies adjust for the costs of tolls, it is possible that the new price structure could adjust the demand curve for the roadway to a place where it is no longer cost effective to deliver certain goods to particular locations. If these goods or services become unavailable to some communities, and remain available to others, we can see the effects Graham and Marvin describe. Toll Collect GmbH, to attempt a measure of this effect, are considering ways in which the MautSystem data may be used as an early economic indicator for industries. If, in fact, the toll is causing a splintering effect, one course of action is to adjust the tolling rates to mitigate the shifts in product availability across regions. In terms of the MautSystem, then, as a lens of infrastructural inversion, the awareness of differentiated traffic – the unbundling – exposes the economic infrastructure of resource allocation within industry, both in terms of goods and access. A further exploration of defining and measuring this newly visible price structuring is explored in Section 4.

3.3 Industrial/Organizational

In Aramis, or the Love of Technology, one of Latour's main arguments for the failure of the Aramis public transportation system was that "the people simply didn't love Aramis enough[24]." In the Aramis case, the users of the system, the mobile public, had choices of transportation, and because of the reaction to the technological system, did not provide enough support for Aramis to be a success. Users not loving the technology enough may be a parallel story in the case of the MautSystem as well; however, unlike the shunned Aramis project, users (e.g. truckers) largely have no choice but to engage the system. Two transformations in industrial or organizational infrastructure can be seen here.

First, the switch from a broad licensing fee (discussed earlier, and transparent due to the inclusion in tax structures) to a distance-based toll imposes a different set of costs on trucking and logistics companies. That is to say, rather than a fixed cost which may be anticipated, the new variable cost can only be controlled by the routing strategies employed by each trucker or dispatcher.

[23]Graham, S., Marvin, S. (2001) Splintering Urbanism: Networked Infrastructures, Technological Mobilities, and the Urban Condition. Routledge. New York, NY.

[24]Latour, B. (1996) Aramis, or the Love of Technology. Harvard University Press. Cambridge, MA.

To this end, there has been a renewed interest in organizational engineering efforts among companies that drive through Germany to better estimate solutions to the *traveling salesman problem*, a so-called NP-complete problem involving optimal route determination for multiple locations. For example, network theorists have begun turning to the issue of tolls in Germany as an applied area of research[25]. With better solutions to the problem of cost minimization along routes may come a shift in organizational practices, including a change in where trucks may travel and when goods may be delivered along a route. Consider the idea that multiple actors concurrently evolving optimized strategies to travel along the Autobahn. Since actors located in, for example, Berlin, all need to deliver to Frankfurt, the chance that they will evolve suitably similar logistics strategies is high. Given enough actors, this may cause increased congestion along the tollway, and the cost minimization strategy for distance may be confounded by the cost increase in time and fuel. As a complex system, the equilibrium point of multi-actor strategy finding is unclear, and the has the potential to force consistent organizational and industrial change.

Second, the appearance of the MautSystem, and its associated costs to trucking companies, is prompting another strategic shift in industrial behavior. Returning to Latour and the Aramis project, truckers do, in fact, have an alternative to use of the MautSystem (just as the French citizenry found alternatives to Aramis-based transit), albeit a criminalized one. Unaware in the early implementation that the GPS-outfitted on-board units were capable of continuous tracking, truckers evolved a "cheating" strategy that involved exiting the Autobahn at exits before a control bridge (where information is transmitted via GSM for billing purposes) and re-entering the Autobahn at the exit past the control bridge. Clearly, this behavior was considered unacceptable by Toll Collect and the Ministry of Transportation, and the continuous tracking capabilities were enforced to determine which trucks were attempting to avoid tolls. As a matter of infrastructure studies, this example exposes the linkage between industrial patterns (at the micro-level) and the law enforcement infrastructure with the MautSystem as a technology that bridges between the two. The interim solution to this criminalized behavior, thus far, has been to impose heavy fines on trucks that are found to engage in toll avoiding behavior[26]. A fine-based strategy such as this is not unlike the recent attempts in the United States to curb the use of mobile phones while driving. This measure has been met with dismal success, largely because the ability to control individual level behavior through regulation does not properly address the incentive structure for individuals[27].

Through these two examples, we can see that aspects of industrial and organizational infrastructure in Germany are made visible through the appearance of the MautSystem - the complex networks by which logistics companies determine distribution, and the relationship between individual driver behaviors and legal regulation of traffic flows.

[25]Corberán, A., Mota, E., Salazar, J. J. (2003) "Some recent contributions to routing and location problems." *Networks.* Vol 42, Issue 2. Pp 109-113.

[26]Bloomberg.com (2005) "Germany to Raise Fines 33% on Truckers Who Dodge Highway Toll." Article last accessed on 04/22/2006 at http://www.tjg.co.uk/our_services/ec_competition/brussels_april4.html

[27]For an example of this type of ineffectiveness, one might observe the number of drivers using cell phones on Chicago's Skyway roads. Chicago has made cell phone use while driving illegal and subject to fines; however, casual observation easily shows that high rates of drivers can be seen using phones while driving, despite the threat of fine. Part of this willful infraction is from the realization that the fine is, to the greatest extent, and empty threat, since there are not enough law enforcement mechanisms on the individual level to enforce the regulation. This, arguably, would also be the case for Autobahn-based truckers to dodge toll bridges; however, the technology itself - the on-board unit - serves as a proxy for law enforcement personnel.

3.4 Social

The social aspect of infrastructure transformation is, perhaps, the most difficult to capture and describe; however, it may also be the most interesting. Latour, his "follow-the-actor" style, assigns equal weight to both human and non-human actors within a system, constructing mixed chains of interaction[28] In the construction of social infrastructure within German driving culture, we can see the appearance of the MautSystem, and the halo of technologies surrounding it, as a new actor within this chain of social patterns.

The details of this observation are merely anecdotal, but I intend for them to be the subject of interviewing on further research trips to Germany. With this in mind, and since social transformation may only be in quite early stages, I offer the following idea: the changes in traffic patterns due to the toll collection system are (1) the focus of extreme negative perception on the part of the German public, and (2) are encroaching on the habits of the public with respect to leisure activities.

Previous research on the social situatedness of technical systems have taken place on a smaller scale. For example, Kling and Scacchi advance that no technical system may be evaluated without considering the social reaction to it[29]. Further, Zuboff chronicles the myriad social shifts when new technology is introduced into an organization, often with negative social reaction[30]. Although both lines of research focus on smaller-scale phenomena, the basic tenets - that technology is set in a social context, and the social fabric cannot help but react to the introduction of new technology - is likely a scalable concept.

Beginning with the negative perception of the toll collect project by the public, general interviews with randomly selected German citizens (to be later formalized in research interview format when IRB approval is obtained) resulted in an overwhelming consistency in criticism of the project. Several examples of negative reports on the project have been circulated in the media, citing the consistent failure of the project to be delivered on time and on budget. Aside from the general jaded attitude of the typical German, there are also serious worries about how the system will evolve to impact the lives of private citizens further. For example, there is a general worry about expansion of the Toll Collect system to include not only commercial trucks, but everyone. The idea that the government spent public money to construct a system designed to extract even more money from the public is, as it would seem, rather unpalatable. Beyond this worry about monetary extraction, there is further negative reaction to the data that is collected and stored by the system - data which is apparently available for secondary use. One of the functions of the Toll Collect control bridges is to take a digital scan of every passing vehicle, and these images are processed using optical recognition algorithms for analysis - including vehicle type, license plate, as well as digital images of the driver's face. If this type of data were not enough to draw criticisms regarding information privacy and security[31], new agreements between Toll Collect and the Federal police to use Mautdata to aid in the war against terrorism, using the digital information to track suspect vehicles, is reminiscent of a type of surveillance that makes citizens more than nervous at prospects[32]. Given the reaction to

[28]Latour, B. (1991) "Technology is Society Made Durable." in A Sociology of Monsters: Essays on Power, Technology, and Domination. J. Law, ed. Routledge. New York, NY.

[29]Kling, R., Scacchi, W. (1982) "The Web of Computing: Computer Technology as Social Organization." *Advances in Computers.* Vol. 21. Pp 1-90.

[30]Zuboff, S. (1989) In the Age of the Smart Machine: The Future of Work and Power. Basic Books. New York, NY.

[31]Golem (2003) "Truck motorway toll: Computer scientists call data security in." Golem.de article. Last accessed 04/22/2006 at http://www.golem.de/0307/26642.html

[32]Heise Online. "Datenschützer: Bürgerrechte werden für Terrorabwehr ausgehöhlt." Last accessed on 04/22/2006 at http://www.heise.de/newsticker/result.xhtml?url=/newsticker/meldung/70986&words=LKW%20Maut

this potential encroachment on personal privacy, shifts in the relationship between the public and the government may be forthcoming.

The hint at a second shift in social structure is gleaned from the same type of incidental conversations, and was noted as an unusually consistent theme. At this point, I am not sure how it fits into the larger infrastructure story, but is is interesting nonetheless, given its repetition in conversations. As an example, the sentiment was best captured by an 18-year-old male from Hanover.

> We Germans, we love to drive. We love our cars and we love to drive for pleasure. On the weekend, we ask ourselves, "What shall I do today?" and the best thing to do is take a drive on the Autobahn to drive fast and enjoy the countryside. This is what we do. Since the Maut, there are more trucks on the road, and we cannot enjoy the same way. We go for a drive for pleasure, and because of the trucks, cannot go more than 70 kilometers per hour, and there is no countryside to see. Instead of the countryside, we end up spending the afternoon looking at the [backside] of a truck. How fun is that?

While the quote is somewhat cavalier, it suggests that driving as a leisure activity may wane. Related to the economic transformations, there may be cottage industries located in communities along the Autobahn that are sustained by this leisure traffic that find themselves unsustainable as the weekend citizens opt to stay closer to home. At the same time, other industries located in the cities may experience an economic surge as more people choose to spend their leisure time (and money) on more centralized activities. If this shift in consumer behavior happens, it may have consequence for the economic and social infrastructure causing an urban splintering effect[33].

4 A Suggested Research Topic

Following on the idea that the unbundling of traffic on the Autobahn exposes variable utility, and thus, demand for use of the roadway, the possibility that further differentiation among the value that truckers have for different routes becomes visible in a way that was not previously realized. In short, even within the unbundled population of truckers, there may be a variability of demand for specific routes along the Autobahn. Joint work with Charles Taragin of the University of Michigan department of economics has yielded an early co-developed model for further study of this variable demand.

4.1 The Demand for Routes

Suppose a cost-minimizing truck driver i must travel between locations A and B. Let J_{ABt} denote the set of possible routes between A and B at time $t \in \{Morning, Afternoon, Evening\}$. The cost to driver i of travelling on route $j \in J_{ABt}$ is

$$c_{ijt} = \beta_{i1} Toll_j + \beta_{i2} Time_{ijt} + \beta_{i3} Fuel_j + \gamma_j + \epsilon_{ijt} \quad (1)$$

$$Time_{ijt} = g(N_{jt}, Weather_{jt}, Speed_{ijt}) + \eta_{ijt} \quad (2)$$

where $Toll_j$ is the total amount driver i must pay in tolls and $Time_{ijt}$ is the amount of time driver needs to traverse route j at time period t. Equation (2) asserts that the amount of time

[33] Graham, S., Marvin, S. (2001) Splintering Urbanism: Networked Infrastructures, Technological Mobilities, and the Urban Condition. Routledge. New York, NY.

required to traverse route j at time-of-day t is a function of the number of other vehicles on route j at time-of-day t (N_{jt}), the road conditions on route j at time-of-day t ($Weather_{jt}$), and the driver's average speed along route j at time-of-day t ($Speed_{jt}$). ξ_i and γ_j are the unobserved (to the econometrician) costs unique to individual i and route j. The regression coefficients in above model are indexed by i to allow for heterogeneous costs across truckers.

Driver i chooses the route-time pair that minimizes the driver's costs; in other words, i chooses

$$\begin{aligned} c^*_{ijt} &= \min\{c_{i1(Morning)}, c_{i1(Afternoon)}, c_{i1(Evening)}, \dots \\ &\quad , c_{iJ(Morning)}, c_{iJ(Afternoon)}, c_{iJ(Evening)}\} \end{aligned}$$

with

$$\begin{aligned} j^*_{it} &= arg\min\{c_{i1(Morning)}, c_{i1(Afternoon)}, c_{i1(Evening)}, \dots \\ &\quad , c_{iJ(Morning)}, c_{iJ(Afternoon)}, c_{iJ(Evening)}\} \end{aligned}$$

4.2 Identical Costs

Suppose that all truck drivers face identical costs, $\beta_{ik} = \beta_k \forall k$. If in addition ϵ_{ijt} follows a type I extreme value distribution then

$$Pr(j^*_{it} = j) = \frac{\exp\left(\beta_1 Toll_j + \beta_2 Time_{ijt} + \beta_3 Fuel_j + \gamma_j\right)}{\sum_{h=0}^{|J_{ABt}|} \exp\left(\beta_1 Toll_h + \beta_2 Time_{iht} + \beta_3 Fuel_h + \gamma_h\right)} \tag{3}$$

which can be estimated using maximum likelihood. Alternatively, taking the log of equation (3), normalizing the cost of travelling on route k to 1 [34] , and subtracting the probability that a driver chooses route $k \neq j$ yields

$$\log Pr(j^*_{it} = j) - \log Pr(j^*_{it} = k) = \beta_1 Toll_j + \beta_2 Time_{ijt} + \beta_3 Fuel_j + \gamma_j + \mu_{ijt} \tag{4}$$

which can be estimated using the random effects model.

Once we have uncovered the parameters in equation (4), the demand for route j can be constructed using the summation rule

$$D_j = \sum_i Pr(j^*_{it} = j) \tag{5}$$

The first issue is: the ξ_is fall out of the above equation. In other words, a linear, individual-specific fixed effect cannot be included in the above equation as it stands. We need to take a second look at how to specify this regression. Also, γ_j is included nonlinearly in the regression, but is unobserved. How to account for it? Answer: γ_j is the xi_j of the typical model. There is not an additively separable effect. There can, however, be random effects.

The next question: How to aggregate up the individual probabilities to form the the market probabilities? One way is to use the summation rule for probabilities to calculate the market probability. The other way might be to use a variation that is present in other models; find the set of values for which option j is chosen and integrate over that set.

The ultimate outcome of this line of inquiry is that we will be able to build models for both variable and dynamic pricing of tolls on the Autobahn that will be sensitive to driver demand, as

[34] This normalization is necessary since the $\sum_{j \neq k} Pr(j^* = j) = 1 - Pr(j^* = k)$

well as varying environmental changes. We anticipate being able to optimize the model in different ways, such as maximum profit for the Ministry of Transportation, minimization of costs for truckers and transport companies, optimal traffic control and distribution patterns, incentive alignment for adhering to traffic laws, or a combination of the these factors.

In terms of the infrastructural transformations discussed earlier, it is the exposure of value, the reduced transparency of utility of the Autobahn that has allowed us to consider such variable pricing models. Without the appearance of the Toll Collect system, and the accompanying unbundling of Autobahn traffic, it is unclear that this type of research could be effectively undertaken.

5 Conclusion

Through inspection of the history of the Autobahn and the Toll Collect system, we can see that many aspects of German infrastructure, lying slightly below the surface of the larger culture, become exposed. The Toll Collect system, while being a highly complex technological system in its own right that serves as a gateway for other systems and technologies, is not infrastructure itself; rather, it is a lens through which other infrastructure may be interpreted, or it is a "shock to the system" against which changes in complementary systems may be studied and measured.

It is my hope that through this type of examination, moving forward, that the Toll Collect example can be used to further extend and refine the concept of infrastructural inversion. Laying bare the changes within a large cultural structure through the lens of a large technical system may have potential for applying established theories in a new way (such as structuration theory, taking into account Latour's concept of human/non-human chains), or evolving a new theory to propel our understanding of social change and large technical systems.