A Series of Software-Related Sociotechnical System Failures

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Railway companies provide a service, namely transportation, in exchange usually for money. These transactions were formerly largely person-to-person, with transaction history largely encoded in low-tech (namely, a piece of printed paper called a ticket). The transactions have increasingly been supported by higher-tech systems, usually software-based. For a few decades, such systems were largely restricted to use by professional personnel of the service provider. Nowadays, automated ticket machines and WWW portals offer direct interactions with passengers and other service users as well as with the service provider (on the "back end").

With a change in nature of a sociotechnical system comes often a change in nature of its failure characteristics. I believe it is important to understand the nature of failure characteristics in order to improve system reliability (that is, render failures less frequent).

However, with sociotechnical systems which provide a service to the general public, it often seems that the reaction to a failure is not necessarily objectively to analyse it dispassionately in order to improve the system, but rather to assign human responsibility and with it the costs of compensation.

Why would one do that? One quick answer is that it's what people do and have done for thousands of years. In case of conflict, or damage, reconciliation, or compensation, is apportioned, according often to principles which go along with the evolved concept of responsibility. This is enshrined in a social system, namely the legal system. System science isn't yet even 100 years old. So looking first at responsibility and compensation rather than applying system analytics may well be habit.

There are also some general business mechanisms which may come into play. If you are partner to a transaction and you can assign costs of failure away from yourself, then you do not yourself suffer damage and, providing future such assignations are successful, failure characteristics are cost-neutral for you. You can accept whatever failure rate manifests and thereby avoid the costs, which may be substantial, of improving the reliability of the system. Let me be clear that I am expressly not ascribing this or similar motivation to any person or organisation mentioned in this paper.

There are some complex sociotechnical systems whose failures are nowadays mostly well-analysed using sophisticated system analytics: accidents with nuclear power plants, and in a couple of renowned studies with nuclear weapons systems in peacetime; air traffic control. Others are not so well analysed, at least in public. According to experts, bank ATM systems and their susceptibility to phantom withdrawals have a mixed failure-analytical record. Unauthorised intrusions into systems which store confidential records are increasingly in the news, but are hardly ever publicly analysed in a wholly satisfactory manner.

This paper concerns a sequence of failures in which the author participated. I believe it is worthwhile to analyse these from a system perspective for a number of reasons. One is that they are unlikely to be the only instance, thus offering opportunity for system improvement. Another is a cautionary observation, that the technically more sophisticated system turns out to be considerably less reliable than the system which it replaced (39%, against formerly almost 100%). A third is that other parts of the system did not appear to have adapted appropriately to this change in reliability. A fourth is that the existence of a sequence of failures was masked by other system characteristics,

possibly explained by “migration to the boundary” (MttB)-type behavior by system participants.

A final point is illustrated by a conversation I had with a stakeholder. I asked her if she had any objection to me writing it up this event. She asked, essentially, why I would be bothered to do that. She didn’t think it was that important. In some sense, that is right. One event is individually not that important. But lots of these kinds of events happen day in day out, and collectively the phenomena affect the world we live in significantly: when formerly-reliable transactions become unreliable, it does not take much imagination to see “daily life” becoming unnecessarily harder. There is value to promoting appropriate analytical techniques, rather than immediately indulging in a “he said, she said” responsibility-assignment exercise.

The Fundamental Transaction

The German railways, Deutsche Bahn as it used to be known and DB as it is now known, is actually a collection of cooperating companies, explained somewhat below.

But let us treat it initially as one entity, one agent, “the railway system” or DB. A fundamental service operated by a railway system is as follows. A civilian wishes to travel between A and B at a particular time and wants DB to render that service, under the usual constraints. The inquirer communicates that desire to DB. DB makes an offer to enable the travel for money. The inquirer accepts or rejects the offer. If rejected, the transaction ends. If accepted, the inquirer and DB exchange a promise-to-render-service, a certificate, called a ticket, for cash or a promise to pay. The inquirer avails himherself of the service, and validates the transaction if/when required by presenting the certificate during the service rendering. It is significant that the transaction usually consists of two time-separated stages: one is exchanging the certificate for cash; the later stage is providing and undertaking the journey. The certificate encodes the necessary transaction history from the first stage to enable the second stage.

This is to simplify the entire process. Various middlemen are involved. Those who initiate the transaction and complete this initial exchange, for example, are not those who provide the desired service, and neither are either of those necessarily the agents who validate the certificate.

However, to simplify is not to render false. That is, at its basis, the way things have always worked, no matter how simple or complex the details. People who design well-engineered systems often do so according to a hierarchical model, in which more detailed process descriptions are shown to be a *refinement* of simpler descriptions of the same process, that is, they may be interpreted as achieving exactly the steps in the simpler description through an interpretation. So we would expect the actual practice to be a refinement of this description. But in some sociotechnical systems the more complex process is no longer necessarily a refinement of a simpler one, and we shall see an important way in which that is the case here.

The Contribution of Train Travel to Work

The German railways, Deutsche Bahn, used to be a state-operated company but was “privatised” a number of years ago. This means that a number of private limited companies (“Gesellschaft mit beschränkter Haftung”, or GmbH) and publicly-traded companies (German “Aktiengesellschaft” or AG) were formed, for various different aspects of railway operations, and the state became a shareholder in these companies, in most or all cases the majority shareholder. Many of the companies receive state funding in addition to their business transactions with customers. All these companies have a name which starts with “DB”, which used to stand for “Deutsche Bahn” (“German railways”) but is now its own insignia.

The part of the railway which deals with ticket selling, information-dispensing and some other customer transactions is DB Vertrieb GmbH. Ticket costs are nominally based upon the distance travelled, the type of train used (regional; InterCity or IC, InterCityExpress or ICE) , and the class of travel (First or Second). In addition, there are various discount schemes for regular travellers. An interesting difference with other rail systems is that basing fares on the distance travelled rather than city-pairs leads to varying prices for travel between city pairs which are connected by more than one line.

Bielefeld and Frankfurt for one example of this. I often make the daily return journey for engineering-standardisation committee meetings, for the last few years between 20 and 25 times a year. There are two routes. One travels first from Bielefeld either east or west, to Hanover, resp. Cologne, and changes to a train to Frankfurt (some trains via Cologne go almost all the way there, to the airport in fact). Travel times are similar: via Hanover takes about 3 hours 20 minutes; via Cologne takes about ten minutes longer; there are one or two trains via Cologne that take just under 3 hours 10 minutes. Much of this variation is due to the timing of connections. The full price via Hanover is €99 2nd or €165 1st Class; via Cologne is respectively €110 and €184. I currently travel under a 50% discount scheme.

I usually travel to Frankfurt via Cologne and plan to return via Hanover, for scheduling and reliability reasons. I sometimes spontaneously choose to return via Cologne, and thereby theoretically have to pay a supplement on the train, since the journey via Cologne costs more.

I think it is important here to note what possibilities this train travel brings. The route to Frankfurt via Hanover travels, between Hanover and Fulda, on the first stretch of dedicated high-speed track in service in Germany. It has been in service since 1991. Trains attain speeds nominally of 255 kph, but they may go some 10% faster. The route via Cologne travels on a dedicated high-speed line opened in 2002, between Siegburg/Bonn and Frankfurt Airport at a nominal 300 kph, again plus 10%. I can travel to Frankfurt and back on the same day, leaving home at 05:50 and arriving back again at 20:10, or 21:10, using public transportation, and have 5 hours, respectively 6 hours, of meeting time at the DKE standards organisation in Frankfurt. The day is not unusually long, and I can work comfortably on the train (there is plenty of table and elbow room in First Class). This convenient work situation is enabled by the provision of high-speed rail lines. Were these speeds not to be available, I would have to arrive in Frankfurt the day before, stay overnight in a hotel, and leave the meeting earlier in order to return. That takes a far greater chunk out of my working week, and doubles cost. That would have made it infeasible for me to engage in standardisation activity as much as I have in the last five years.

This generalises, of course, to many standards-committee participants from all over the country. The service provided by the DB rail companies thereby contributes manifestly to engineering standardisation in Germany, and reliable high-speed connections are a part of this – more people can participate at lower costs to their companies and less disturbance to their work and to their lives outside work.

That said, one could get to Frankfurt from Bielefeld faster by car, because there are north-south Autobahns – motorways – that cut the corners off the rail journey. But in a car one cannot work effectively, so one ends up wasting more time. Fastest turns out to be private plane. Even in a slow aircraft (150 kph airspeed) one can save an hour door-to-door in each direction over train times, as my colleague Bernd Sieker has done, and enjoy the trip. It is possible to save another hour in a high-speed general aviation aircraft such as a Cirrus or a Mooney. But it is crucially dependent upon passable weather, and daylight travel. However, the marginal use of energy per person by train is effectively zero, whereas for personal car or personal aircraft it is considerable.

Pertinent Details of the Fundamental Transaction, the Service-for-Money Interaction

There are various discount schemes available to DB passengers. One can buy season tickets for particular journeys, as in many railway systems. By far the most popular discount scheme is the universal 25% or 50% discount. There is an annual fee for an annual card with credit-card format and technical functionality. There is a Second Class version and a First Class version of each. They are called BahnCard 25, BahnCard 50, BahnCard 25 First and BahnCard 50 First. Further, companies may make company-travel arrangements with the DB, with which they get a rebate of between 3% and 9%, depending on travel volume. The volume counted to determine the rebate level is dependent upon the use of different BahnCards, namely BahnCard Business (First or Second Class, with 25% or 50% discounts as above). The BahnCard Business is more expensive than the normal BahnCard, but travel with it counts towards the rebate whereas use of the normal BahnCard does not.

I travel with a BahnCard 50 First. My tech-transfer company Causalis pays for it rather than the University. I obtain it at half-price since I am over 60 years of age, whereas there is no age discount for BahnCard Business 50 First. If I were to have the University buy me a BahnCard Business 50 First, I think it would cost the University more than it would save on my trips to Frankfurt. But – here's the rub – I don't know for sure because I can't find out how much a BahnCard 50 Business First costs, without going through the entire process of ordering one through my company (University) account on the DB Vertrieb's WWW portal. I conclude that it belongs to the DB Vertrieb's business model not to make such information available to the general user.

The Former and Current Transaction Systems

Up until July 2013, I used to order my train tickets with the DB Vertrieb company travel department in the Bielefeld railway station, an office stocked with real, helpful people to whom I would e-mail a request on a standard form and the tickets would be waiting at the ticket counter for me to pick up when I went to the station for my trip. The bill was sent directly to the University, which paid and performed the associated internal accounting. The University thereby obtained the company discount, but there was a fee sometimes associated with the service, although not with my use of it.

In early 2013, this arrangement stopped because the University no longer wished to pay the service fee. University travellers were to order tickets through various University accounts on the DB WWW portal, which were paid via a University "credit card" registered with the on-line account. The transition to this system had caused some difficulty – it was supposed to happen already in 2011 but was postponed for a couple of years. I was very content with the original arrangement, because of its reliability and convenience. Even though there was no fee associated with my particular use of the service, I had to change along with the other University travellers.

One of my main concerns at transition time was that I travel regularly to London, and via London onwards in GB. Many, even most, of my colleagues would travel to GB by air. Door-to-door travel time to central London is overall not that different, and with the train I find it far more convenient to work. Tickets for foreign train travel are not generally available to book on-line through the DB WWW site, because pertinent price information is apparently not available. However, DB has arranged a series of special tickets to London, called London-Spezial. DB runs some trains to Brussels, whose price conforms with the DB price regime. Prices on the Eurostar are set via a series of first-come, first-served discount levels. These prices are now offered on the DB WWW portal and one may book and pay for London trips via the portal, as with Germany-internal trips. This is also so for the joint DB/SNCF service to Paris via Frankfurt. So booking a trip to London is as convenient as one to Frankfurt.

However, if I travel onwards in GB I have to ask the DB company-travel service in Bielefeld to issue me the onwards ticket (at a substantial discount over what the natives pay!) and I have to pay for it personally, although I claim the cost back from the University afterwards.

Use of the DB WWW portal was and is not trivial. There are details of the trip to be given, including any discounts available with BahnCards; then there are details of the identification method to be used (showing the BahnCard is one, and you have to show it to the conductor anyway when using a ticket associated with a BahnCard; but one may used a credit card or other ID) and the payment method and details. There are four or five screenfuls of detail to complete, plus another few if you want to check your reserved seats and alter them. However, if use is routine, as mine is, one quickly gets accustomed to the steps. Or thinks one does.

The discount claimed via the BahnCard type is at the first step, when giving trip details. There is a button to open a window to give details of passengers (how many? Adults or children? Discounts claimed?) These details are carried through the trip-detail windows, and then disappear for the ID and payment steps, reappearing at the last step, which is confirmation-and-purchase. The confirmation-and-purchase window is seen in a screen shot in Appendix 3. The "type" of ticket under "Ihr Ticket" is in the lower half. The details for the desired transaction "HIN- UND RÜCKFAHRT" (return ticket), "1 Erw. mit BahnCard 50 First" (one adult with BahnCard 50 First), "1. Klasse" (First Class travel), and origin and destination are here correct.

In 2013, I discovered that the WWW portal did not allow a booking for two people on one ticket when one (me) had a BahnCard 50 First, and another (my colleague Bernd Sieker) had a BahnCard Business 50 First. The first selection of discount class, as either non-Business, resp. Business, forced the choice for the second selection to be also non-Business, resp. Business, although the choices of discount level 25/50 and class First/Second were retained. A selection of (necessarily two) Bahncard Business would have meant that a company discount would have been calculated for one trip (namely, mine) for which there was not an entitlement. A selection of (necessarily two) BahnCard (non-business) would mean that a company discount was not calculated on a trip (namely, Bernd's) for which the University was so entitled.

There was indeed a workaround, had we thought long enough about it and bothered to use it. Namely, Bernd and I could have booked our tickets separately, without a seat reservation, and then separately booked a seat reservation for two people. That, however, would have involved three separate transactions through the portal, and thus roughly three times the effort. Resources have their price; I chose to book such trips using one transaction for two BahnCard non-business. The University travel office has declared itself content with that arrangement. When it came time to renew his BahnCard, Bernd changed to a BahnCard 50 (non-business).

An Anomaly

Trying to deal with that issue on-line sensitised me to the selection of the discount, via a pop-up menu, at the beginning of the on-line process. This pop-up menu is shown at the lower left of the screenshot in Appendix 4. But then something odd happened from early December 2013. All my transactions, thirteen of them up until 2013-12-04, had been correctly classified, that is, classified as I expressly intended, for discount. However, from 2013-12-13 until 2014-12-11 inclusive, fourteen return tickets for which I had intended to choose, and thought I had chosen, the BahnCard 50 (non-business) discount were issued as BahnCard Business tickets. During this period, for comparison, four transactions were issued according to my intent as BahnCard (non-business) tickets, two singles and two returns.

The information about the discount class is carried during the transaction. It is possible for me to

have checked it at the “confirmation” stage of the transaction. However, I can’t recall whether I did so. At this stage I am usually focussed on checking the train details and changing my seat reservations (the WWW portal allows you to pick individual available seats).

On the printed ticket, there is a code indication for DB personnel of the ticket class, but this code is not intended for reading by the ticket holder.

Until, of course, DB personnel point it out to you when there is an anomaly.

Discovery of the Anomaly: First Stage

On the way back from Frankfurt on 2014-12-11, the conductor noted that Bernd and I had a ticket with BahnCard Business 50 First discount, but we only had BahnCard 50 First cards. He pointed out that the ticket said that it was for two people with “BCB50FK”, which means BahnCard 50 Business with company rebate.

That is how I found out what “BCB50FK” means. A copy of the on-line ticket is shown in Appendix 2.

What then transpired was odd. He said we had “chosen” a rebate for which we were not entitled, and he would have to require supplementary payment. It is certainly appropriate to require supplementary payment, but I disputed his claim that I had “chosen” the discount category. I imagine he thought his claim proved by what was printed on the ticket, as people inexperienced with computer software often do.

Whereas, as computer professionals know, there are at least three possibilities. One is that I had chosen the category deliberately. A second is that I had mistakenly chosen the category, intending to choose another category. A third is that I had chosen correctly, but a different category had been printed from what I had chosen.

Concerning the supplementary price, he offered that either we (I) could pay it then, or it could be paid later. I chose the second option. He asked for identification. German citizens have ID cards with their legal address (one must have an address in Germany which is registered with the state) on it. GB citizens have a passport, on which there is no address. Did I have another piece of ID with my address on it? Nope, but I gave him a Causalis business card and that seemed to suffice. And he printed the supplementary documents, one for each person, called in German a “Fahrpreisnacherhebung”. This established a supplementary price of €116.50 per person, so €233 for us both. And this was just for the portion of the journey from Frankfurt main station to Cologne. Compare that with the original entire ticket price of €341.20! (€18 of the total price of €359.20 on the ticket in Appendix 2 is the seat-reservation charge.)

In fact, the difference in price between the ticket printed (for 2 adults with “BCB50FK”) and the ticket I thought I had bought, is €29.80.

Second and Final Stage

I scanned all the documents in, and wrote a letter offering to pay that difference to the DB Vertrieb GmbH “Fahrpreisnacherhebungsstelle” (don’t let anyone tell you that contemporary German avoids long words! But contemporary Germans laugh at them – and it’s fun to try to make them even longer). You can’t call them on the telephone (theoretically you can, but they have an automated system with a rigid hierarchy of transactions that doesn’t seem to allow you to say “I wish to discuss an anomaly”). You can’t email them (theoretically ..... etc). But you can fax or send

snailmail. I faxed.

DB Vertrieb responded by mail personally and politely, with a real name on the bottom of the letter, and accepted my offer.

However, the writer also said that the conductor had acted correctly, in that one (or more) passengers did not show a valid BahnCard. This is incorrect. We both had valid BahnCards. But we didn't have BahnCards corresponding to what it said on the ticket. So I wrote, and faxed, another letter pointing this out.

Analysis

There are a number of points worth making about this system, as embodied in this series of transactions (one human-machine, two others human-human).

First, the pervasive assumption, in this case made by DB personnel, that computers and WWW sites do what you told them to do. Those of us who have specialised in analysing software-based system failures know that that is far from being the case. Comparing the reliability of the computer-based transactions in comparison with the personnel-based transactions in this case is startling.

The numbers. Years of having real people issue tickets, including three and a half years of twice-monthly trips to Frankfurt, showed essentially exceptionless reliability. Whereas, in a year and a half since, 19 WWW-portal transactions out of 31 total resulted in a ticket being issued that was not what I wanted. 5 times this occurred deliberately, when I could not choose what I wanted (mixed BahnCard types) and had to compromise. 14 times this occurred either inadvertently or through inappropriate processing. That is a total transaction reliability of 39%. Most interesting is that there appears to be a date, somewhere in the second week of December 2013, when the on-line transactions went from intended outcomes to mostly unintended outcomes. More on this below.

Second, the reliability of operations conducted by DB in-train personnel. Most conductors are polite, helpful, friendly and accommodating, especially in First Class. Tickets are checked against BahnCards once per journey; conductors mostly do not re-check BahnCards on the second leg of a journey but accept the validation of their colleague on the first leg. So a single journey will be validated once, and a return once on outbound and once on return. Since 2013-12-04, tickets showing "BCB50FK" had been "validated" against a BahnCard 50 First 24 times, and it was only queried on the 25th time of presentation.

In five years of regular Frankfurt trips, I have only been asked once to pay a supplement when travelling via Cologne when my ticket specified the Hanover connection. I have no record of how often I have done that.

Irrespective of whether the mismatch between ticket and journey is deliberate or inadvertent (to use the phrase the DB letter-writer used), if the DB is using a price discrepancy which is only enforced in, say, under 5% of cases, the question arises what business purpose it serves. This apparently holds for company-rebate pricing and also for mileage-differential pricing between city pairs.

Third, the nature of the operations conducted by DB in-train personnel and their reliability. It took the conductor who remarked the discrepancy some ten minutes to validate our identification details and write out the "Fahrpreisnacherhebungsschein", the supplementary tickets. Furthermore, he got it wrong. He wrote out tickets for a second-class journey between Frankfurt and Cologne, but we were travelling in, and had reservations for, first-class seats. And he didn't ask us to move.

Jens Rasmussen pointed out a phenomenon in 1996 called “migration to the boundary” (which I often abbreviate as MttB. See Rasmussen, J., *Risk Management in a Dynamic Society: A Modelling Problem*, Safety Science 27(2/3), 1997). He observed that people working in a complex sociotechnical system will often “optimise” their tasks to make them “easier”, or even in some cases he observed to make them doable at all. That means the tasks are not performed according to the organisational intent. Rasmussen noted that this happens almost invariably; he was just the first to put a name to it (Snook also observed it and put a – different – name to it in a 2000 book). It appears to be a pervasive organisational phenomenon.

In cases in which the system has safety-critical operations, such “optimisation” can be dangerous, for steps in procedures may be there to avoid or mitigate a hazardous situation which rarely arises, and therefore the steps can mostly be omitted or effort reduced without any overt consequence – until of course the situation arises for which they were designed! Both Rasmussen and Snook gave examples; indeed some in which people died.

The transactions I am considering are not safety-critical. Nobody is going to die on a train if a conductor accepts a ticket for which heshe should write a “Fahrpreisnacherhebungsschein” if following company policy to the letter. But at ten minutes per ticket it might take an awful long time to get through a carriage of some 60 people or more, let alone get through three First Class carriages before the next station. Also, a conductor being rigorous in a situation lacking full reliability of the ticketing process might thereby encounter a number of somewhat annoyed people who wish to discuss the matter at length with himher. For most conductors, that is surely going to make the working day more difficult and unpleasant.

Besides, if it takes me five minutes to order and print out an original ticket, why on earth should it take a conductor ten minutes to correct it, and then only in part?

I would suspect on the basis of this experience that there is quite a lot of deliberate MttB going on. Indeed, it may well be that such complex and unreliable ticketing is only possible *because* of the MttB adaptions of in-train personnel. If the rules were really enforced then the job would certainly become more difficult.

Fourth, a transaction status with import and history, such as the type of BahnCard to accompany a ticket, should usually remain interpretable to all participating agents in a transaction. In this case, the fact that I possess a ticket to be accompanied by a Bahncard 50 Business First should be clearly apparent not only to the conductor but also to me as the ticket holder.

One can question the business efficacy, let alone moral legitimacy, of a transaction system whereby a passenger cannot tell what ticket heshe possesses and in-train personnel do not check it accurately. This is the situation in which I apparently found myself for a year.

This phenomenon demonstrates that the transaction-processing through the WWW portal is not a refinement either of the abstract transaction or indeed of the former human-human transaction processing, which enabled the passenger to know what certificate heshe held.

Fifth, what is there to be learnt about the history? There has been a situation in which I exceptionlessly correctly used a specific selection in a transaction system for six months until December 13th, 2013; then used it 4 times successfully and 14 times unsuccessfully (but inadvertently) until almost exactly a year later. (I have tried to duplicate the transaction failure in January 2015 without success, but only once went all the way to issuing a ticket.) Keep in mind that I am normally a careful user of WWW-based transaction systems in which payment is involved, or so judge myself, and cannot recall (otherwise) ever having made a mistake (better said, a mistake

which manifested itself) during a transaction.

So one possibility is that I had a brain flip in early December 2013 which led into some “finger trouble” which lasted almost exactly a year.

The other possibility is that there was something wrong with the transaction processing on the DB WWW-portal. Indeed, a major change to the transaction-processing system is made twice a year, on or round about 6 December and 6 June, which are the dates on which the DB introduces the semi-annual train timetable modifications. Indeed the problem with my inappropriate Bahncard selection began sometime between 3 December 2013 and 12 December 2013, the dates on which I enacted the transactions.

Sixth, whether or not there was a fault in the processing system, those expert in human-machine interaction will point out a design principle that seems to have been violated in this case. There is (was?) an interface in which it is (was?) easy to make a significant error of choice inadvertently. That phenomenon is easy to avoid.

So what is to be done?

First, if there is a fault in the transaction processing, fix it. This may well have been done already.

Second, if there is an interface which leads people into making selections that they do not intend to make, then redesign it so that the act of selection is more reliable.

Third, if there is a continuing transaction, make all relevant details of the transaction clearly apparent to all participants until the transaction has concluded. (For completeness, this doesn’t just mean between ordering a ticket and making the journey; it also means retaining details necessary for recompense if the journey is not made for some reason; and so on.)

Those are the easy things. There are some which might be a little harder.

Fourth, if a transaction processing system is unreliable (recall the 39% success rate), then replace it with an system which is reliable (for example, the people in the company travel bureau at the Bielefeld station).

Fifth, if there is a condition of use which is procedurally checked in all cases, but in which less than 5% of violations are noted, then drop the condition or modify the checks.

This may be harder than it looks. Many of the procedures of a formerly state agency in Germany are given in minute detail in administrative law – such a change proposal might require a change in applicable law. This is a hurdle which is not necessarily apparent to those not familiar with a Napoleonic-law system. And it is far more socially robust than an outsider may consider reasonable. Which, in other situations, may sometimes be advantageous.

Finally, adapt real procedures to reality. For example, possessing and smoking marijuana (which entailed possessing) was illegal in California, and still is for non-medical purposes; however, the police in Berkeley have been procedurally required by the Police Department not to enforce this law for some forty years. It is equally possible for DB in-train personnel to check city pairs, and BahnCard 25/50 First/Second and let other distinctions go unremarked, if management wishes. If laws are unreasonably hard to change, this might be the easiest way to keep well-meaning and honest customers happy as one waits for changes in the law to happen. And it looks to me very much as if most DB in-train personnel know this already.

Technical Conclusions

Sociotechnical transaction-processing systems such as the DB's current WWW-based ticketing abound nowadays. They are quite often less reliable than their forerunners, or increase reliability of certain functions while decreasing it in others. There are, to businesses and their customers, hidden as well as not-so-hidden costs associated with a change in reliability of a business function. Comparative reliability assessments are rarely performed. It may well be time to make them more commonplace.

Systems are often designed in part or "in the small". Someone thinks selling tickets through the WWW is a good idea, so a SW company is employed to design and implement a "ticket sales via the WWW" system. And a design company is employed to design the "WWW interface" which the SW company is told to implement along with the "back end". The overall system in which this part fits is often lost to view. In the example considered in this paper, how the system fits with user understanding and the in-train validation procedures appear not adequately to have been taken into account. Taking into account the overall system in which a part fits is often called "systems thinking". The basic technical part of systems thinking is to identify the system whose functions are being (re)implemented, and to specify those functions per se. And to check whether a redesign or reimplementation of a critical system part is indeed a refinement of the function's specification, and to fix it when not. Such techniques have been successfully, although unfortunately not universally, used for decades in safety- and reliability-critical systems development. They are regarded by many eminent software engineers as best practice. Systems thinking, specification, and refinement checking could and in my view should become expected practice in the engineering of such SW.

So-called "human factors" (HF) analysis techniques are not often employed, or not employed thoroughly, in the design and implementation of sociotechnical systems, unfortunately even in some safety-critical applications. Sometimes the consequences can be quite crude. Professionally-trained operators are given a set of rules which they are to follow, and at taken to be "at fault" (and disciplined or fired) if the rules are not followed. Checking that the rules are consistent and complete is rarely undertaken. Neither is any analysis of whether they are always feasible, or whether combinations are problematic. Issues of cognitive overload and underload are rife. This all means that MttB is also rife, and analysis of MttB behaviors and comparison with "intended" procedures is almost universally lacking. I propose that best-practice HF techniques be routinely used in sociotechnical systems analysis.

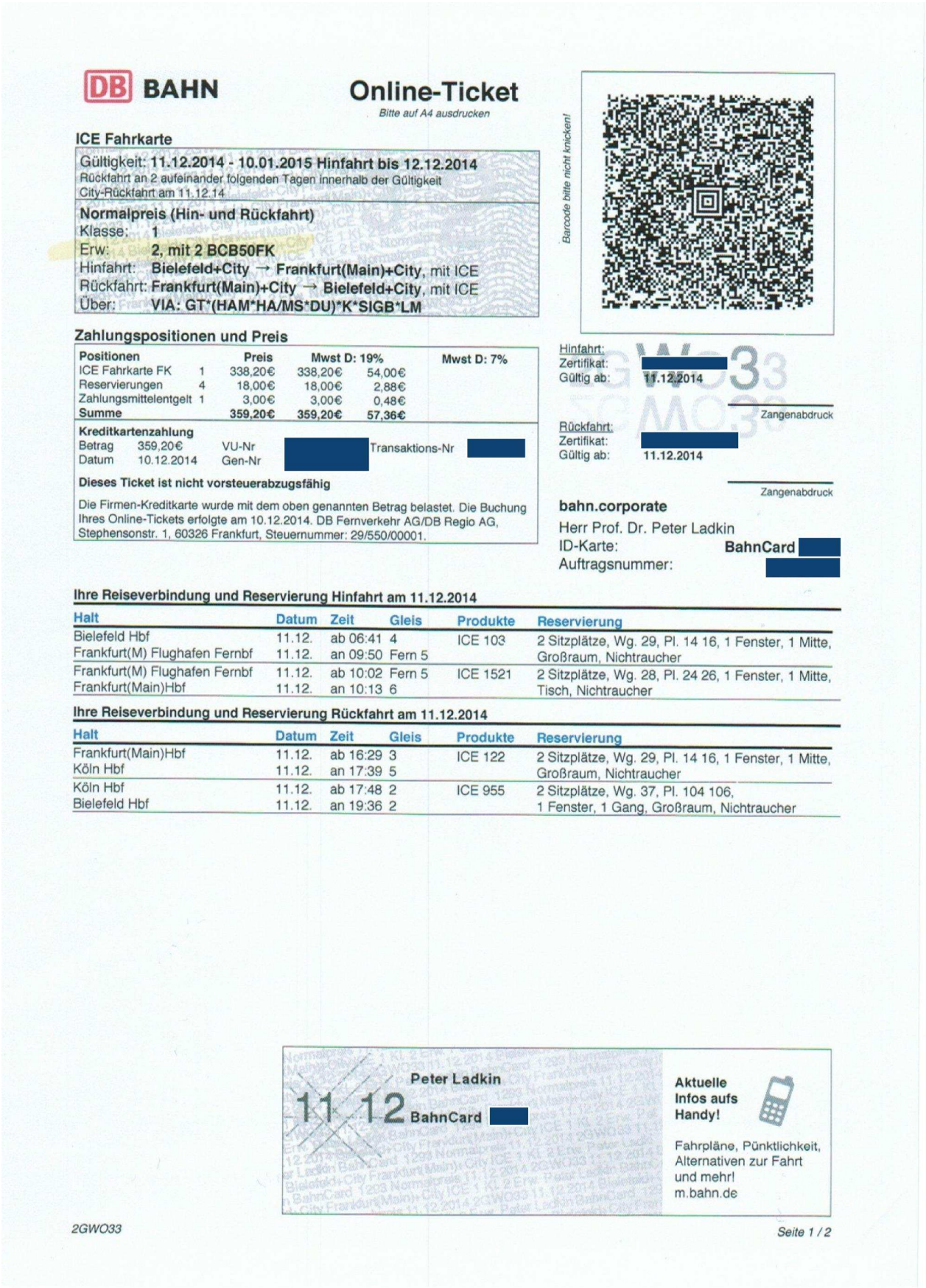
It should be evident that attention paid to these aspects of systems will lead to greater reliability of function. However, the costs of using them lie squarely with the (sub-)system procurer. Whereas the costs of greater unreliability are otherwise distributed: on customers, on personnel in other organisational departments, and so on. It is an issue of organisational economics to consider how those costs might be otherwise adduced or apportioned and it is well beyond the scope of this paper to consider how.

Appendix 1: On-Line Booking History

Date	Type	Correct Type	Desired Type	Price	Single or Return
2013-07-04	BC50			€172	R
2013-07-18	BC50 x 2		BC50+BCB50	€344	R
2013-26-08	BC50			€172	R
2013-09-10	BC50			€172	R
2013-09-17	BC50 x 2		BC50+BCB50	€210	R
2013-09-30	BC50 x 2		BC50+BCB50	€344	R
2013-10-08	BC50			€172	R
2013-10-24	BC50			€172	R
2013-11-04	BC50 x 2		BC50+BCB50	€328	R
2013-11-08	BC50			€172	R
2013-11-18	BC50			€164	R
2013-11-22	BC50 x 2		BC50+BCB50	€328	R
2013-12-04	BC50			€172	R
2013-12-13	1 + BCB50FK	1 + BC50	1 + BC50	€193.40	R
2014-01-20	BC50			€178	R
2014-03-06	BCB50FK	BC50	BC50	€169.10	R
2014-03-19	Special			€437	
2014-04-29	Special			€387	
2014-05-02	Special			€213.50	
2014-05-05	Special			€263.50	
2014-05-19	BC50			€119.50	S
2014-05-20	BC50			€115	S
2014-05-27	BCB50FK	BC50	BC50	€161	R
2014-05-28	BCB50FK	BC50	BC50	€169.55	R
2014-05-29	Special			€193.50	
2014-06-02	Special			€193.50	
2014-08-20	BCB50FK x 2	BC50 x 2	BC50 x 2	€169.10	S
2014-08-20	Reservation			€9	
2014-08-20	BCB50FK x 2	BC50 x 2	BC50 x 2	€187.10	S
2014-08-26	BCB50FK x 2	BC50 x 2	BC50 x 2	€276.40	R
2014-08-28	BCB50FK	BC50	BC50	€89.05	S
2014-08-28	Special			€213.50	

Date	Type	Correct Type	Desired Type	Price	Single or Return
2014-08-30	Special			€163.50	
2014-09-15	BCB50FK	BC50	BC50	€169.55	R
2014-09-17	Special			€387	
2014-10-21	BCB50FK	BC50	BC50	€169.55	R
2014-11-04	BCB50FK	BC50	BC50	€169.55	R
2014-11-12	BCB50FK	BC50	BC50	€186.50	R
2014-11-20	BCB50FK	BC50	BC50	€171.05	R
2014-11-25	BC50 x 2			€359	R
2014-12-11	BCB50FK x 2	BC50 x 2	BC50 x 2	€359.20	R

Appendix 2: On-Line Ticket 2014-12-11



DB BAHN

Online-Ticket

Bitte auf A4 ausdrucken

Barcode bitte nicht knicken!

ICE Fahrkarte

Gültigkeit: **11.12.2014 - 10.01.2015 Hinfahrt bis 12.12.2014**
Rückfahrt an 2 aufeinander folgenden Tagen innerhalb der Gültigkeit
City-Rückfahrt am 11.12.14

Normalpreis (Hin- und Rückfahrt)
Klasse: 1
Erw: 2, mit 2 BCB50FK
Hinfahrt: **Bielefeld+City → Frankfurt(Main)+City**, mit ICE
Rückfahrt: **Frankfurt(Main)+City → Bielefeld+City**, mit ICE
Über: **VIA: GT*(HAM*HA/MS*DU)*K*SIGB*LM**

Zahlungspositionen und Preis

Positionen		Preis	Mwst D: 19%		Mwst D: 7%
ICE Fahrkarte FK	1	338,20€	338,20€	54,00€	
Reservierungen	4	18,00€	18,00€	2,88€	
Zahlungsmittelentgelt	1	3,00€	3,00€	0,48€	
Summe		**359,20€**	**359,20€**	**57,36€**	

Kreditkartenzahlung
Betrag 359,20€ VU-Nr [redacted] Transaktions-Nr [redacted]
Datum 10.12.2014 Gen-Nr

Dieses Ticket ist nicht vorsteuerabzugsfähig

Die Firmen-Kreditkarte wurde mit dem oben genannten Betrag belastet. Die Buchung Ihres Online-Tickets erfolgte am 10.12.2014. DB Fernverkehr AG/DB Regio AG, Stephensonstr. 1, 60326 Frankfurt, Steuernummer: 29/550/00001.

Hinfahrt:
Zertifikat: [redacted]
Gültig ab: 11.12.2014

Zangenabdruck

Rückfahrt:
Zertifikat: [redacted]
Gültig ab: 11.12.2014

Zangenabdruck

bahn.corporate
Herr Prof. Dr. Peter Ladkin
ID-Karte: **BahnCard** [redacted]
Auftragsnummer: [redacted]

Ihre Reiseverbindung und Reservierung Hinfahrt am 11.12.2014

Halt	Datum	Zeit	Gleis	Produkte	Reservierung
Bielefeld Hbf	11.12.	ab 06:41	4	ICE 103	2 Sitzplätze, Wg. 29, Pl. 14 16, 1 Fenster, 1 Mitte, Großraum, Nichtraucher
Frankfurt(M) Flughafen Fernbf	11.12.	an 09:50	Fern 5		
Frankfurt(M) Flughafen Fernbf	11.12.	ab 10:02	Fern 5	ICE 1521	2 Sitzplätze, Wg. 28, Pl. 24 26, 1 Fenster, 1 Mitte, Tisch, Nichtraucher
Frankfurt(Main)Hbf	11.12.	an 10:13	6		

Ihre Reiseverbindung und Reservierung Rückfahrt am 11.12.2014

Halt	Datum	Zeit	Gleis	Produkte	Reservierung
Frankfurt(Main)Hbf	11.12.	ab 16:29	3	ICE 122	2 Sitzplätze, Wg. 29, Pl. 14 16, 1 Fenster, 1 Mitte, Großraum, Nichtraucher
Köln Hbf	11.12.	an 17:39	5		
Köln Hbf	11.12.	ab 17:48	2	ICE 955	2 Sitzplätze, Wg. 37, Pl. 104 106, 1 Fenster, 1 Gang, Großraum, Nichtraucher
Bielefeld Hbf	11.12.	an 19:36	2		

11 12 Peter Ladkin
BahnCard [redacted]

Aktuelle Infos aufs Handy!

Fahrpläne, Pünktlichkeit, Alternativen zur Fahrt und mehr!
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2GWO33

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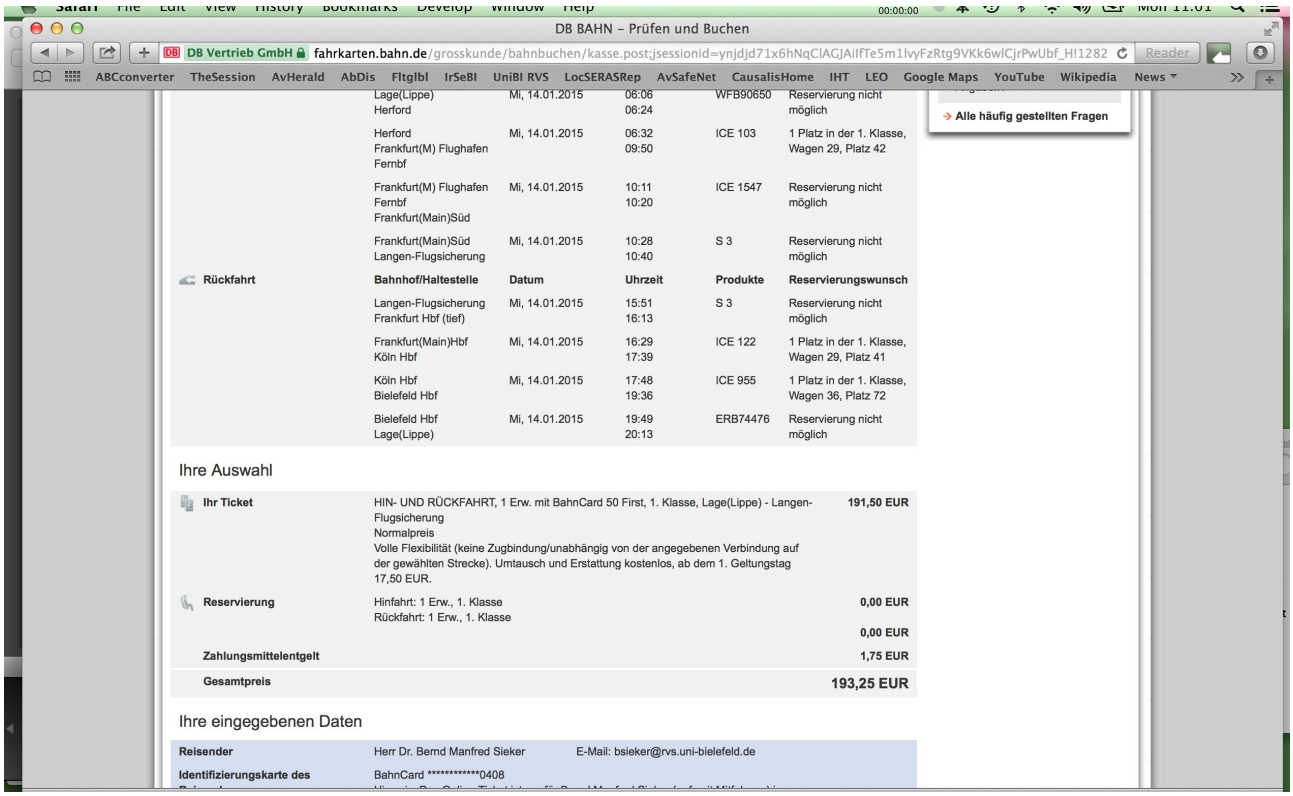
Appendix 3: Interaction with the WWW portal: Confirmation step



Appendix 4: The Pop-UP Menu for Selection of Discount Type (Lower Left)