2010

DISCUSSION PAPERS

5

Joint Transport Research Centre

ROUND TABLE
4-5 February 2010, Paris

International Transport Forum

REVISITING THE COST OF THE STOCKHOLM CONGESTION CHARGING SYSTEM

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

International Transport Forum

JOINT TRANSPORT RESEARCH CENTRE

Discussion Paper No. 2010-5

Prepared for the ITF/OECD Round Table of 4-5 February 2010 on

Implementing Congestion Charging

Revisiting the Cost of the Stockholm Congestion Charging System

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January 2010

Abstract

In January 2006, a system for congestion charging was introduced in the city of Stockholm, Sweden. The charging scheme was run in the form of a full scale trial for seven months, after which it was deactivated, awaiting its evaluation and an advisory public referendum. Several parties, including representatives of the scientific community as well as media and special interest groups, have analysed and evaluated the system. A recurring theme in several of these analyses is that the cost to build and operate the system was excessive, compared to costs for other road charging installations.

This study revisits some of the key project participants and archive data, to provide a deeper understanding of what were the major cost drivers and whether it can be lower in future installations. The approach taken is to emphasise understanding of the particular circumstances rather than comparing aggregates with other seemingly similar systems. A main conclusion is that the political context, with a tight time plan and very high political risks for all involved, were key factors for the eventual costs of establishing the system.

INTRODUCTION

It is well known that optimal road pricing on a congested road will yield a social surplus. From this surplus, however, costs for investment and operation of the road pricing system must be subtracted. Since these costs can be large, it is necessary to carefully investigate the cost side of road pricing.

The Stockholm charging system was introduced as a trial for the first seven months of 2006. After a subsequent referendum, the system was reintroduced permanently in August 2007. The system has been portrayed as an expensive installation in the media and public debate. Establishing cost including the seven months trial was indeed 1 800 MSEK (approx 180 M€) for the technical system alone – an inherently large number. But does that make for an expensive endeavour? If so, compared to what? The aim of the paper is to provide for a deeper understanding for what were the major cost drivers, why the cost ended up the way it did and whether it can be lower in future installations. Thereby the question what is expensive can be better answered, and more importantly still, the lessons learned can be better harvested by those who consider investing in congestion charging in the future.

The question of costs can be seen from two different perspectives. One is the actual situation when the system was constructed and implemented, given the then-current context and knowledge. Another is the “ex post” perspective – whether costs are high given the knowledge and context available afterwards. The first question is interesting from a historical perspective, while the second one is the relevant question for other cities considering road pricing. By analysing how the specific Stockholm context affected the system costs and the implementation process, the intention is to shed light on both of these questions.

Methodology and sources are described in section 1.1. Section 2 briefly outlines the story of the Stockholm congestion charging system and its design, with a particular focus on some claims of cost and costliness in the public debate at the time. In section 3, various cost items are examined, beginning with those most often highlighted in the media and public debate, and then those identified by the stakeholders involved in the project. Each cost item or cost driver is discussed, both put in the then-current context and viewed in an ex-post perspective, and a lesson is formulated. In section 4, observations are synthesised and conclusions drawn.

Sources and methodology

The initial investment and the operation during the seven-month trial was managed as one unified project, with one prime contractor, managing the technical design, implementation, and operation of the system during the entire trial. Therefore it is dubious to make any clear distinction between investment and operational cost.

Discussing costs in general, and what is expensive in particular, requires quantitative measures. Wherever possible, costs are presented in monetary terms, or in some comparable resource quantification. Focus is however not on determining quantities exactly, but rather on understanding the significance of each cost driver and what can be learned from it for future cases.

The two main types of sources used are archive documents from the Swedish National Road Administration (Swe: Vägverket) and the Swedish Transport Agency[1] (Swe: Transportstyrelsen) and interviews with key stakeholders. The archive data includes tendering documents, contracts and official communication between the contract parties. In accordance with Swedish public law, any document incoming to a government agency must be recorded and made available for the public to view, unless it has been classified as secret. This way, I have been able to obtain and examine a large number of documents from the early tendering throughout the entire project delivery.

Interviews are made with key stakeholders representing Stockholm city, who initiated the procurement and wrote the requirements specifications for the system, the ultimate buyer and owner of the system, the Road Administration, and the prime contractor, IBM. Each interview took between one and two hours. The representative from IBM was interviewed via telephone without sound recording, while the other interviews were made face-to-face, sound recorded.

By going through the documented material and interview comments in chronological order, it is possible to recreate much of the situation as it was when each decision was made, including what information was available at the time. This has been key in offering any judgement as to whether a taking on a particular cost item was called for or not. The summary of each area presented here is based on a synthesis of all interviewees and the supporting documentation. Each interviewee have been presented with the full text, and been asked to comment not only on direct citations, but also on the interpretations made.

During the implementation phase of the Stockholm congestion charges I was employed by prime contractor IBM and involved in the system design of the system. Therefore I have a basic understanding of how the system works, and may also have some interest in portraying the project as more successful than I would had I a different background. It has been my ambition to counter any such tendencies, firstly by requesting frequent and critical

1. Parts of what was the Road Administration have been transferred to the newly formed Swedish Transport Agency. During the congestion charging trial, all of those activities were carried out by the Road Administration.

examination of the work in progress, and secondly by ensuring that any information I present, even if it was known to me on beforehand, is either stated officially by an interviewee, or confirmed by publicly available project documentation.

BACKGROUND

The Stockholm Congestion charges

Between the 3rd of January and the 31st of August 2006 congestion charges were being tried out in Stockholm, Sweden. After the 2002 general elections, the Green Party ended up with the balance of power both in Stockholm's municipal parliament as well as in the national assembly. The Green Party wanted to introduce congestion charging permanently, and the Social Democrats had made an explicit promise not to introduce them. (Instead they wanted have a referendum based on a detailed suggestion prior to any implementation.) Implementing the charges in the form of a trial was the result of a compromise, determining whom the Greens were to support to form the next Government. After the trial was ended, it was agreed, after some pressure from the opposition, that there would be an advisory referendum where the people of Stockholm would have their say in making the charges permanent or not. The referendum was scheduled on the same day as the next general election, September 17th, 2006. Before that day, a scheme was to be designed, a system procured and installed, and then run in full-scale operation for "several years", according to the original agreement. (See Gullberg and Isaksson, 2009, for a detailed record of the political proceedings.)

After a series of legal delays, the "several years" were reduced to seven months, but in most other key aspects, the trial was executed as planned. After the Yes-side had won the referendum held in the city of Stockholm, the system was made permanent, and has been in operation since August 2007.

Practically, the congestion charges were implemented as a cordon around the city, with gantries across all entries and exits. Cars passing in and out were identified using a combination of cameras and transponders. The price for a passage varied between 10 and 20 SEK depending on the time of day (approximately 1 and 2 €), with the highest charge during peak hours. Nights and weekends were free of charge.

Users had to pay the charge within five days after the passage, and they could choose from direct debit from their bank account (this required that they used a transponder), manual bank payment, and cash over counter at convenience stores from two widely spread chains.

Project environment

Information technology projects in general have a bad reputation for delivering late and above budget, and IT used for road tolling is no exception. The German truck tolling system TollCollect was initially planned to be launched in 2003, but after a series of technical, managerial, and political problems, it faced delays of more than two years. During that time, the German federal government lost toll revenues corresponding to € 3.5 billion, in addition to receiving a flood of bad press, hurting badly both the German government and the contractors responsible for building the system (Economist, 2004; Wieland, 2005; Deutsche Telecom, 2008).

The TollCollect story was an ongoing drama in parallel with the political process leading up to the Stockholm congestion charges, underlining the magnitude of the risk for anyone involved. Politically, a failure of any sort had the potential of tipping the next general election, locally as well nationally. According to Gunnar Söderholm (2009), who at the time was one of the leading civil servants on the municipal level involved, the centre-right political opposition in Stockholm was so certain that the congestion charges would be a failure, that the decision to introduce them was considered the “biggest political suicide in history”, (a view they shared with several people on the left as well) and all they had to do, they thought, was to “stand back and watch the Left-Green coalition commit it”.

Risk was however not limited to the political sphere. The prime contractor selected, IBM, was under pressure as well. The procurement contract included stiff penalties, in order to align the buyer’s incentives with those of the supplier (Road Administration, 2004, pp. 19, 23, 30). However, according to Mr. Gunnar Johansson (2009) of IBM, the large penalties for project delay and performance losses detailed in the contract, were still considered a smaller risk to the firm than the negative effects on the corporate brand following a possible failure. Weekly engineering newspaper Ny Teknik (2005) saw the risk, and gave their verdict even before the system was launched. They dubbed it “Sweden’s least profitable IT investment in history”, with three weeks to go before go-live. Not delivering on time, or launching a system that produced incorrect tax claims, would hurt the company nationally among customers of all industries, and globally as a supplier of road tolling solutions, according to Johansson (2009).

> [IBM’s] *future as a player in the international road user charging arena was at stake. If we had failed in Stockholm, we would not have been able to compete for any road charging bids in the future.*
>
> Johansson (2009)

Adding fuel to the fire, the political and media debate was intense and aggressive. Birger Höök (2009) of the Road Administration and Gunnar Söderholm both stress that this was far beyond what is normal in the Swedish debate on transportation infrastructure. The Automobile Association (Motormännen) and the Stockholm Chamber of Commerce (Handelskammaren) took the lead among the non-party-tied associations and issued pamphlets, a campaign website (tullvalet.se), and debate articles in the newspapers. The campaigns routinely resorted to hyperbole and scare mongering in their argumentation. For example, the Chamber of Commerce claimed that the design of the system was to lure people to vote yes, after which the charge levels would “soon be both doubled and tripled”, and that new charging stations would appear all over the city. (Stockholm City, 2006).

> *I don’t know where [Chamber of Commerce] got their numbers […] there is nothing that is correct about them. I think this is more a question of feelings than of facts.*
>
> Höök (2009)

During the early phases of the project, failure seemed almost inevitable, among authorities as well as in the media. The Tax Authorities actively went to the press, warning that congestion taxes would lead to children being indebted by an assumed widespread tactic where parents were expected to register their children as owner of their vehicle, and then refuse to pay the tax (DN 2005a). The National Collection Agency (Swe: Kronofogden) estimated that some 6 000 cases would be passed to legal collection every day (DN, 2006; SvD, 2005). And daily Aftonbladet (2005) ran on their first page their own estimates that 85% of people would attempt to cheat the system to avoid paying.

Next to those who hoped and believed that the project would be a dismal failure, were some who were in favour of congestion charging in general, but who feared that this particular implementation would do more harm than good. The reasoning was that if the system failed here, then no politician would dare touch the idea again for decades to come. So pressure on the project mounted not only from those who opposed it in general, but also from those who supported it in principle (Söderholm, 2009; Johansson 2009; DN 2005b).

In reality, none of these fears materialized. The system started as planned on January 3, 2006. The cost per passage is still unchanged as of 2010. Fewer than 600 cases were sent to collection during the entire seven-month trial combined (Söderholm, 2009), and the level of cheating was barely measurable (Höök 2009; Johansson 2009). But it is not under the soothing influence of hindsight that the project was carried out, but under the pressure of the fear and defeatism present at the time.

In summary, the stakes were high for almost all actors involved. Individual careers as well as the prosperity of private firms and political coalitions was at risk, or at least perceived as being so. This is an important aspect to bear in mind, as it dominated the context in which the project was carried out, and it was under the influence of this risk environment that decisions were made.

Costs and cost estimates in research and media

Morning daily Dagens Nyheter (DN) ran a series of articles in 2008, with the common theme of the high costs of the congestion charging system. DN (2008a) compares early estimates of 800-900 MSEK for investment and 100 MSEK for annual operation, with their own estimates of final costs totalling at 1 800 MSEK in investment and 380-400 MSEK per year in operation. These “early estimates” are found in a report from Transek (2003), outlining a possible system design and its consequences. Doubled investment cost and a quadrupled increase in operating costs sure seems a noteworthy cost overrun.

To understand this discrepancy, let us start with the consultancy report where the first estimates are made in April 2003. The main focus of this report is to suggest a high-level scheme design. Cost estimates make up only one paragraph of the report, and they are labelled as “very uncertain” (Transek, 2003 p. 15). Transek used two sources for preparing those early estimates, both of which are likely to underestimate real costs: First there was data from Norwegian road charging systems, which are developed and operating in a stable political and legal context with cost minimization as their main focus, and many of which had had more than a decade to trim their operation. Second there was data from equipment manufacturers, who have an incentive to underestimate such costs as part of their pre-sales process.

Furthermore, in the time between the publication of the first consultancy report (April 2003) and the eventual parliament budget decision (June 16th, 2004), the scope of the system changed in important ways, from being a municipal environmental fee similar in function to the Oslo toll ring, to a national congestion tax with a partially different view of how the technology (especially the transponders, see below) was to be used. Hence, the early cost estimates were not only uncertain, they were also estimating a different system than the one later decided upon.

In the same DN article, the budgeted 380 million SEK for operational cost for the fiscal year of 2008 are put in relation to an estimated revenue of 750 MSEK. It is then concluded that about 50% of the revenue is spent on collection of the congestion tax. This kind of *cost ratio* is a commonly used way of indicating the efficiency of a road charging system, i.e. its total operating cost divided by the revenues. If a system is spending a large portion of its revenue on the actual collection process, it is argued, then the system is inefficient.

A similar line of arguing is found repeatedly in the debate about the congestion charging trial as well. In a report financed by the Royal Automobile Association, professor Ilja Cordi (2006) reaches a similar estimate of the cost ratio of 50% for the Stockholm system. The same way of reasoning is used by Stockholm Chamber of Commerce (2005), who relates the 3 800 MSEK in total cost for the entire trial (including improved transit and park-and-ride), to the 500 MSEK estimated revenues during the seven month trial, thereby implying a 760% cost ratio for the trial. In a later report, they put an estimated 800 MSEK of projected income in relation to 1 200 MSEK in projected annual cost, implying a cost ratio of 150% (Chamber, 2006). For comparison, a corresponding cost ratio for the Norwegian toll rings is in the range of 9-10%. (Amdal et al., 2007)

By these cost ratio measures, the Stockholm system seems very expensive. Using cost ratio as a measurement of efficiency of a congestion charging system is however not completely relevant. Firstly, the charge amount collected bears no relation to the cost of collecting them. If a charging scheme has a complex tariff structure with many exemptions and price levels, the cost of collecting the charge will be higher without any related changes in the charge income level, and the cost rate will go up. Likewise, if the charge level is doubled, there is no additional cost of collecting it, and the cost ratio will go down. In neither of these cases, the cost rate is a fair reflection of the expensiveness of the charging system.

Secondly, the Norwegian toll rings are primarily revenue-generating schemes, where the value sought after is the money collected. To measure efficiency is to relate quantity of *outcome* to its required quantity of *input*. Amdal et al (2007) therefore rightly chooses cost ratio as their primary illustration of toll operators' efficiency. But the desired outcome of the Stockholm system was not primarily to collect funds, but to improve the traffic situation. Thus, the relevant ratio when measuring efficiency of a congestion charging system is to put the social benefits of congestion reduction in relation to the costs.

Outside of the debate in media, a more serious attempt to measure efficiency has taken place. Eliasson (2009) presents a social cost-benefit analysis, where the tax paid shows up first as a cost (as taxes paid by car drivers), and second as a benefit (as tax revenue to the government). Instead of seeing the tax itself as part of the outcome, positive effects are balanced against negative, where the costs to establish and operate the system is the single largest line item among costs, which is then to be compared to the value generated by reduced congestion etc. In addition, Eliasson (2009) uses the expected long-term operational cost, assuming that economies of learning will further reduce costs. Using Eliasson's figures to generate a metric similar to the cost rate, yields 220/654 (34%) as a measure of operational cost per social benefit (in monetary terms). Reversely, each SEK spent on technical system operation yields a return of 3 SEK in social benefit, although these are not ratios explicitly used by Eliasson. The assumed 220 MSEK of long term costs have since been beaten by reality, and the system is likely to operate in the 180 MSEK range from 2010, reducing the societal cost ratio to 27% and financial cost rate of 21% (Lissel, 2009).

Another evaluation of the Stockholm system carried out by Prud'homme and Kopp (2007) shows, unlike Eliasson (2009) a negative social surplus, primarily from using a different way to calculate time benefits (see Eliasson, 2008). The principal view of costs and benefits is however similar to Eliasson's, and the authors also agree by emphasizing three factors necessary for a successful congestion charging implementation; (1) High degree of congestion, (2) Low system installation and operation cost, and (3) Low marginal cost in public transit.

Even when ignoring the most politically biased interpretation of costs, it is clear that the cost to build and run the system is an important factor for how it is to be evaluated. System cost is among the most important line items regardless of whether one is measuring social or financial cost ratio. To understand why the cost ended up the way it did, it is necessary to know more than system size in terms of charging stations or number of vehicle passages. For the full picture, we need to factor in the project environment, and the information available when the decisions were made.

The cost for the seven month trial period included items not related to the congestion charging system per se, such as increased transit capacity, purchases of new buses and new park-and-ride facilities. The total of all these costs sum to 3 800 MSEK. This sum is sometimes quoted as the "cost of the system", although it apparently includes many other measures. The congestion charging system and its supporting functions alone, which is what is included in this study, was about half of that. The Road Administration's budget, set soon after the legislation was finished in July 2004, for the trial was 1 926 MSEK (Höök, 2009). For this amount, they got a system designed, built, and operated for seven months. This budget was, unlike the impression given in media, never completely used up (Höök, 2009). According to Eliasson's (2006) estimates, 1 050 of this was used prior to go-live, which could serve as an indication of investment cost excluding operation. After the congestion charges were made permanent, operational costs have gradually dropped, to 200 MSEK in 2009 and an estimated 180 MSEK in 2010 (Lissel, 2009). Eliasson (2006) uses an older estimate of 220 MSEK/year in his analysis. It should also be noted that included in the operational cost for the Stockholm system during 2007-2010 lies the cost of transferring the operation from the contractor to an in-house solution at the agency's own data centre.

For comparison, these investment (including the operations during the trial) and long run operational costs, rough as they may be, can be put side to side with those of Oslo and London. Oslo's toll ring has been in place for much longer time, and may not be fully comparable. It is however estimated by Ieromonacho et al (2006) to have cost only 208 MSEK to establish (using 1.23 SEK to the NOK), and 148 MSEK per year to run (see also Fjellinjen, 2004, and Eliasson, 2009). It is difficult to compare with the costs of the London system, since costs for operations and implementation were combined in a different way than in Stockholm. Oehry (2006) estimates London's investment cost to 1 495 MSEK and its operational cost for the year 2005 to 1 530 MSEK (at 11.50 SEK to the pound).

Worth noting is the asymmetry between Stockholm and London. The Stockholm system is larger in scope, and was slightly more costly to put in place (taking the operation as included in investment cost), but costs only a tenth to operate. This can partly be explained by the higher degree of automated identification and payment processes in Stockholm, and partly by the fact that the London system was procured differently than the Stockholm one, having the supplier carrying more of the capital investment.

COST ITEMS

This section lists a number of cost items and cost drivers, with a particular focus on circumstances or cost items that may have caused investment and/or operations costs to be unnecessarily high. Some of the claims of “excessive” or “unnecessary” costs have been put forward by external examiners, such as media or interest group, while others have been put forward by project stakeholders in interviews.

For each suggested cost driver, the claims made are presented, followed by my own conclusions based on comparison of the arguments presented, comparison cases, and documentation available. Where relevant, an order of magnitude of the impact of each cost driver is indicated. Finally, “lessons learned” for future road user charging systems are formulated.

Oversized back office

A new call centre was set up to support the public with information about the charges, when the system was active, who was liable for the charge, how to pay, as well as user specific payment information and account status. Even though the Road Administration already had a call centre in place for other purposes, a new separate centre was built up and staffed for the congestion charging trial. Based partly on comparisons with the call centre used for the London congestion charges, it was decided that the centre should be dimensioned to manage 30 000 calls per day, reaching a total of 400 seats. Managers of the London congestion charging system then advised the Road Administration that this might be too small (Söderholm, 2009). As it turned out, the numbers were vastly overestimated. The number of telephone calls during the first few days of the trial reached about 10 000, and then dropped to a steady state of less than 2 000 calls per day. In hindsight, the cost for the call centre could have been between 50% and 75% lower.

Similarly, the Tax Authority had staffed up a new department for dealing with appeals and complaints. Two managers, one legal advisor, four administrators, and 27 clerks were assigned to deal with an expected inflow of 1 000-1 500 cases per day. In reality, appeals and complaints barely made up a tenth of estimates, and the department was quickly downsized again. (DN, 2005a; DI, 2006) Yet another call centre was established at the city of Stockholm, staffed with 15 people, to deal with political questions. Virtually nobody called, and that too was dismantled (Söderholm, 2009).

The oversized back office is one of the cost items singled out for mentioning in the cost-benefit analysis by Eliasson (2009). Dagens Nyheter (2008b) claims that this could have been foreseen, and that it should have been obvious that the London comparison was not relevant, since the London system used the call centre as a payment channel, unlike the Stockholm system, where payments were managed by other means.

Mr Höök at the Road Administration agrees that they were probably pushed by the prime contractor to employ somewhat more call centre staff than they would otherwise had. This, he reasons, had to do with the way the contract was designed: If the call centre would not meet its quality of service targets, then the prime contractor would be financially penalized, while it was buyer that carried the cost of call centre staff. In this area, the design of the contract meant that risk and cost were borne by different parties, and the contractor had no incentive to increase its own risk by cutting down on resources (Höök, 2009).

It should however be noted that this separation of risk ownership and cost carrying in the case of the call centre is atypical for the contract, which in all other major areas manages to assign the prime contractor both the burden of the risk and the responsibility (and cost) for risk mitigation (Road Administration, 2004).

DN (2008c, 2008d) even claimed that the prime contractor had deliberately inflated their invoices to exploit the temporary monopoly they enjoyed. This is however not something that the Road Administration believes to have had any significant influence on the final cost level, referring here not just to back office, but to all disputable cost items:

> *If we had put pressure on the supplier we could have saved a hundred or a couple of hundred millions. [...] but it takes time and […] our platform was not so good to negotiate from. We wanted to have a functional system in operation for the trial. A 'money-fight' would most probably only have ended up with delays and no system in operation for the trial. One can consider whether it is worth entering such a fight.*
>
> Höök (2009)

Supplier incentives is however only one part of the answer to why the call centre was oversized. At the time nobody knew how many people would call, and with what kind of inquiries. One of the risk scenarios considered was that large numbers of disgruntled citizens would call and appeal every tax decision made, and thereby flood the citizen service channels. This would then lead to long waiting times, which would be portrayed as a project failure in the media. Given the heated tone in the public debate at the time, this scenario was generally believed to be plausible, and such attempts might actually have taken place. But if they were, with a high capacity call centre in place, they were unfruitful and discontinued.

Both Höök (2009) and Söderholm (2009) are of the opinion that poor service levels in the call centre, and the bad publicity expected in response, would have been more than the project could bear. In such an event, key people would quickly have pulled their support for the project. Thus, a potentially *undersized* call centre had on its own the potential to kill the entire project, they argue, and therefore, it was preferable to err on the high side.

Yet another way of interpreting the overcapacity of the call centre is to see it as a sign of a successful information campaign, scheme design, and system functionality. The users of the system knew more and had to ask less than expected about how the charge worked, and there were fewer disputes and appeals than expected.

Cost consequence: It is likely that the back office would have been equally good at keeping service levels up and mischievous calling at bay, even if the resources spent would have been cut down to half during the trial period.

Lessons learned: If procuring a system as a function, make sure that the party carrying the risk is also the one taking the cost for risk mitigation, in all areas of the operation.

Transponders were not really necessary

As part of the tendering documents, where suppliers were invited to bid for the design and construction of the system, it was not explicitly stated that the offer had to be based on transponder technology. It is, however, clear that this was the expectation of all key stakeholders (Höök, 2009; Johansson, 2009; Söderholm, 2009) and that any bid not featuring transponders would not have been favourably evaluated. So transponders were part of the winning bid, and a total of 700 000 units were bought and 450 000 distributed to the users, and radio beacons were mounted on gantries at the 18 charging stations.

During the project's implementation phase a principally important change order was issued (a *change order* is an instruction to the prime contractor to adjust the specifications). The Ministry of Finance together with those of Justice, Enterprise, Energy and Communications came to the conclusion that under Swedish law, a transponder signal was not a sufficient basis for making a tax decision. Instead it was found that a photo of the license plate must exist. Transponders were still kept in the system, as the first tests with the automatic license plate recognition (ANPR) were only able to interpret around 60-70% of the photos taken without manual assistance (Höök, 2009; Söderholm, 2009).

Transponders, which have a ratio of automatic identification (ID ratio) close to 100%, could not be made mandatory for legal reasons. Hence, the contractor initiated a focused development effort to increase the identification ratio for ANPR, and after a few months of experimenting they were able to push the ID ratio of ANPR well above 90%, which was the effective level of identification when the system went live in January 2006. After the end of the trial, when the system was re-launched in July 2007, the transponders were only promoted for users who wanted to be absolutely sure to get the benefit of the Lidingö exemption (see below). Meanwhile the ID ratio of ANPR had been pushed another few percentage points, so that with a small amount of manual support the total ID ratio was steadily between 95 and 99 percent. Finally, in late 2008 support for the last remaining transponders was discontinued (Höök, 2009; Johansson, 2009; Söderholm, 2009).

The system had evolved from being transponder based at the time of the contract into gradually being more and more reliant on photo-based identification. Since the charge is legally defined as a tax, making the vehicle owner liable, there is no need for a separate payment account, which a transponder might be used to represent. The Road Administration already had in their possession a complete registry with the names and addresses of all vehicle owners liable to pay, so identification of the vehicle was all that was required.

Even though the transponders were already bought and paid for, and the radio beacons over the road installed, there were still costs associated with managing transponders. New cars needed new transponders, cars changed owners, and transponders were lost, stolen, and broken. To save the cost of managing transponders, the Road Administration decided to discontinue its support of them and rely solely on photographic identification (Höök, 2009; Söderholm, 2009).

In hindsight, the entire transponder investment can be seen as an excessive cost item. But then it must also be understood that relying solely on cameras, and reaching such high ID ratio via ANPR in a real implementation, was unheard of in the industry at the time. Nobody could have foreseen that this would be possible, and even if some supplier had proposed such a system, it would have low chance of being selected (Johansson, 2009). (See also "Lidingö exemption" below.)

Perhaps one should not have been so surprised at the discovery of the high relative cost of using transponders. In Norway, where over 40 different road toll schemes are in operation, transponders are used in some, while others are managed by manned tollbooths. And even there, where the comparison technology is highly manual, there is a slight productivity advantage for those *not* using transponders (Odeck, 2008).

Cost consequences: The cost for radio beacons part of the installation is not separated out in the contract and invoices examined, so their cost can only be estimated by an order of magnitude as a share of the cost for roadside equipment. Cost for transponders is easier to single out in the archival material studied. All in all, 150-200 MSEK were spent on transponders and transponder related equipment and services.

Lessons learned: For anyone considering a congestion charging system in the future, it should be clear that cameras and ANPR can potentially reach a high ID ratio, and offer ample competition for any transponder-based solution. One remaining advantage of transponders is that they offer other possibilities, such as the ability to use one payment account, represented by the transponder, between different cars.

Excessive transaction costs

In the same series of DN articles as cited above, two were spent on the issue of the costs for payment transactions, paid via the prime contractor to the suppliers of financial services. In extreme cases, DN (2008e, 2008f) showed that the transaction fee could even exceed the charge itself, making a negative net for the government.

To understand the arrangement of payment transaction, one must first go to a remarkable aspect of the congestion charge. The charge itself was defined as a tax decision, summarising one whole day of driving. Such tax decisions were made overnight, and were available to the drivers the following morning, after which they had to be paid for within five days. Factoring in a little bit of delay for making bank transactions, this meant that a frequent commuter had to make payments several times per week, to be absolutely sure that the money was available at the Road Administration's account on the morning of the sixth day, or a sizeable penalty would be applied.

The reason for this cumbersome requirement was, at least in part, that the legislator had made an overly ambitious interpretation of the concept of marginal pricing. The drivers should experience the cost of using the road in direct relation to their decision to do so. And experiencing the cost was interpreted as making the actual payment (Johansson, 2009; Söderholm 2009).

This rule, unique in the context of tax payments, had two negative consequences in terms of costs. The first was simple: Making one payment per day instead of for example one per month multiplies the number of bank transactions with a factor of about 5[2]. Even if the Road Administration got a bulk discount in the per-transaction fee from the bank, the total cost of dealing with such a large number of transactions is deemed to be significant.

The second consequence was more elaborate: In order to make most of the five days available until the payment was due, and at the same time offering a convenient way to pay for occasional travellers, the Road Administration exercised an option in the contract to supply the option to pay cash over counter in retail stores. Two store chains totalling over 400 outlets were tied to the scheme, some of which were open 24/7. A new point of sale

2. If all drivers were regular drivers, paying the charge each day, the multiplier would be around 22. But a majority of the car drivers are in fact "occasional" car drivers who only pay the charge a few times each month. Hence, the multiplier drops to around 5.

application was developed, to make it possible for the driver to look up the current tax claims just by stating a license plate number, and to complete the payment in less than a minute. The store chains gathered the total amount paid during a day and transferred it with an absolute minimum of delay to the Road Administration.

The retail chains thereby gave the congestion charging system two important positive qualities: It was possible to use almost the full five days to make the payment, and doing so was generally a swift and convenient experience. But for the Road Administration, this speed and convenience did not come for free. Taking up time at the cashier’s desk in a busy convenience store means taking time away when something else could have been sold, and the retail chains charged a considerable transaction fee for it. The lowest tax decision was for a day with only one low-traffic passage, equivalent of about 1 €, and the fee charged by the retail chain was slightly above that, rendering the bizarre situation that the government made a negative net on any such payment.

Later, after the trial, the five days period was increased to fourteen, but still with one payment per day’s use of the roads, and then again in August 2008 the payment routines were changed to monthly invoices. Thereby, the number of transactions dropped by 80% and are no longer a major cost component (Transportstyrelsen, 2009).

Cost consequences: Bank payment transactions cost 10-20 times more by being charged by the day instead of by the month. DN estimates the transaction costs for the retail chain cost the Road Administration an excessive 50-60 MSEK per year.

Lessons learned: Marginal cost pricing is not the same thing as marginal cost payment. Each payment transaction comes at a cost, both in terms of convenience for the user and as a fee from the financial service provider. Cash over counter might be necessary for user acceptance, but it is probably the most expensive form of payment.

The Lidingö exemption

East of Stockholm lies the island of Lidingö, connected to the mainland with a bridge. The only way between Lidingö and the rest of Sweden passes twice across the toll cordon. Hence, Lidingö inhabitants would face significantly increased driving costs – especially those commuting by car to destinations outside the cordon, who would have to pay the charge twice per single trip. Many considered this to be unfair. Several possible solutions were aired in the debate, ranging from letting them pay anyway, as they are in fact using congested roads, to make residents of Lidingö exempt from congestion tax entirely. Finally, the compromise settled upon was to make journeys through the congestion charging area to or from Lidingö free of charge. For this exemption to be valid, the journey must be registered at one of the charging point facing Lidingö and any other charging point within an interval of 30 minutes (Söderholm, 2009; Gullberg and Isaksson 2009).

In principal, this is an elegant solution, requiring no preregistration of users legible for the exemption. All motorists will have equal access to the exemption, not matter whether they are making a visit to Lidingö from the mainland, or vice versa. Also, the rule decided upon makes sure that Lidingö residents are still charged when Stockholm is the destination of their journey – two passages both registered at the charging stations by the Lidingö bridge does not trigger the exemption. Elegant as it is, this rule turned out to be a significant cost driver in the implementation of the technical system, because it made the effective service level requirements higher than formally stated.

In the contract between the Road Administration and the prime contractor, it is established that the minimum ID ratio is 95% (99.9 for transponder passages) and the maximum error ratio is 0.0001 (i.e. maximum one incorrect charge per 100 000 passages) (Road Administration, 2004 pp.53-54). The design of the Lidingö exemption shortcuts these measurements, as it makes failed identifications turn into overcharging: If a vehicle is driving from Lidingö through the city and out on the other side, it generates two passage records. If both are correctly detected and identified, they should cancel each other out, according to the Lidingö exemption. But if one of them is not identified, the other passage will turn into a liable charge. Thus, too reach the low error ration target, the ID ratio must also be very high. This may be a major cost driver, since identifying the remaining few percent often requires considerable manual labour efforts.

The scale of the problem rapidly becomes large. If 5 in 100 passages are not identified, as allowed by the ID ratio requirement, only 90.25% of trips exempted Lidingö trips are correctly identified at both charging stations, 0.25% are captured by neither of the charging stations and that in 9.5% of the cases one of the two passages is identified and a charge is incorrectly generated. There are more than half a million exempted Lidingö trips each month, which would mean more than 50 000 erroneous tax decisions every month. Clearly, the ID ratio could not be allowed to be nearly as low as 95%.

Cost consequences: It is not possible to separate out how much of the system redundancy was caused by this particular rule, but it is generally agreed that this aspect of the Lidingö exemption is one of key reasons to add a camera capturing the rear of the passing vehicles (in addition to the already decided cameras taking pictures from the front), and it requires the system to run for longer hours each day. Höök (2009) estimates the increased project cost to “a couple of hundred million SEK”.

Lessons learned: When designing the price mechanism part of a charging scheme, make sure that each passage is priced based on information from that passage alone and other information available at the time, such as time of day and vehicle characteristics. Any pricing scheme using combinations of passages for pricing will immediately be more sensitive to errors and drive up the performance requirements of the system.

Additionally, service level metrics used in a contract benefit from being orthogonal, so that a failure to meet one of them does not automatically spill over to another one.

Appeal of procurement and project stand-still

Public procurement of large scale projects is strictly regulated by a directive in the Europe Union. Chapter 7 of the Swedish Public Procurement Act (the version of it relevant at the time) details how a procurement decision can be appealed, if one of the bidding parties experience losses due to a biased or unprofessional decision (SFS, 1992). When the Road Administration awarded the contract to construct and operate the congestion charging system to IBM, their decision was appealed by the runner-up consortium dominated by Austrian Kapsch, long time system provider in the road tolling business (Gullberg and Isaksson, 2009).

This led to a period of legal processing, where the decision went all the way through each level of the three-tiered public court system. During a period of almost two months, February 8th to March 30th, 2005, the contract award decision was inhibited, putting the project in legal limbo – the award was not reversed, but nor was it affirmed. Awaiting a final decision, the project had to be put on hold, although the development work was already well under way.

(for a more detailed description of the legal wrangling, see Gullberg and Isaksson pp. 65-148)

This put the Road Administration in a dilemma: The supplier's team of people working on the project had grown large and got up to speed, people involved had got to know each other and what to do. If the team was to be dissolved, its members would be reassigned to other projects, and it would take a long time to start the project up again. So the Road Administration decided to keep hiring the full team, awaiting the final court decision, so that development could recommence exactly where it halted, once there was a legal go-ahead.

During this period of standstill, there were to be no contacts made between the buyer and the supplier. No project work was to be carried out during this period, at least not on instructions from the Road Administration. But it is likely that a project with a tight time plan highly suddenly given a ten-week "holiday" gains some benefits beyond merely some rest. Even without contacts with the Road Administration, the prime contractor had an opportunity to catch up any delays already accumulated, and to prepare for expected continued efforts.

In addition to the standstill period, the time needed for court proceedings also led to a delay of the planned start date. From its already delayed date of August 15 2005, the launch date for the system was pushed all the way to January 3, 2006. From a project risk point of view, getting a paid catch-up period of ten weeks, and then getting the final deadline postponed more than four months, is a gift. Ironically, the appeal filed by the submitter of the runner-up bid came to serve the prime contractor and increase the chances of project success. (See also "Project owner and scope changed" below.)

Cost consequences: Including the work going on at subcontractors, more than 100 people were allocated in the project managed by the prime contractor. Keeping them at standby mode for 10 weeks, at a direct cost paid to the prime contractor of 140 million SEK. In addition to that, costs increased in the public administration, and the total congestion charge revenue was lowered, as the time of operation was shortened. All in all, the losses due to delays have been estimated to 600 MSEK. (Gullberg and Isaksson, p. 121)

Lessons learned: The sequence of political and legal events that lead to Congestion Charging first being decided, then looking highly unlikely, and then finally happening against all odds, is so specific to the local circumstances and random events, that few things make up any transferrable experiences. One key aspect however, which seems to have influenced many of the events, is the significance of the election cycle. The entire process from decision through planning, implementation and trial period to referendum had to fit inside such four year election cycle. As the decision to go for congestion charging came as an outcome from the government negotiations immediately following the election 2002, there was no opportunity to plan ahead and start the new election cycle with a complete plan.

Excessive service level requirements

In 2002, immediately after the announcement of a congestion charging trial, the city of Stockholm defined their procurement strategy. Dennis Bring was assigned as responsible of the procurement planning. The core principle of the contract was defined as a functional procurement. That meant that the bidders were not asked to build a system according to a detailed design specification, but rather a functional one, where processes were described at high level, and their outcomes defined and quantified. It was up to each bidder to suggest what technologies to use, and even where to put the charging stations. An important component in this setup was the list of key performance indicators, originally nine of them, and their target levels. In principle, the bidders had to accept all of them as they were stated, in order to be considered compliant in the evaluation. Each indicator was also, albeit somewhat ambiguously, tied to penalty clauses, which could have a severe impact on the eventual revenue to the supplier if targets were not met (Road Administration, 2004 pp. 53-54).

Over time the functional design changed from a municipal “environmental charge” to a national “congestion tax”, as a consequence of legal deliberations. This lead to a vast range of changes to the specifications, which rendered some of the key performance indicators no longer applicable. Eventually, four remaining indicators prevailed as governing the ongoing evaluation of the system performance; Identification ratio (number of vehicles identified divided by number of vehicles passing per month), error ratio (number of incorrect charges divided by number of passages per month), availability (lane minutes of uptime divided by total required up time times number of lanes) and call taken ratio (number of calls answered within some time limit divided by total number of incoming calls) (Johansson, 2009).

Each of these performance indicators were assigned numeric targets, and especially the error ratio and system uptime stood out as extraordinarily high (Johansson, 2009). In the case of error ratio it was stated that no more than one passage in 100 000 may lead to an incorrect charge, which means that either the automatic number plate recognition system had to perform far better than any other system existing at the time, or that a large share of the passage photos had to be verified manually, or that transponders (which generally do not generate incorrect identifications) had to be used by almost all vehicles passing the gantries.

Transponder usage eventually reached about 50% of all passages at the time of launch, which was not enough to guarantee that the error ratio target was met, and there was a both practical and economical limit to how many clerks could be assigned to reading license plates from photos. Recognizing this dilemma, IBM initiated an internal research and development effort to improve the system’s performance in terms of automatic license plate recognition, as mentioned above, eventually leading to meeting and exceeding the requirements both in terms of ID and error ratio (Höök, 2009; Johansson, 2009).

Total system uptime was measured taking partial availability into account, based on how many lanes was affected by a system outage, so that the metric used “lane minutes” of availability divided by total number of lanes times number of minutes of expected uptime. Thereby, the measurement would approximate the revenue lost from the downtime – a 50% drop in availability meant that about half of the passages being recorded. The availability ratio calculated like this was to meet or exceed 0.999, or the supplier would be financially penalized.

To meet this high requirement, the prime contractor designed a system where (almost) every component was duplicated, so that a service outage would only occur if two parallel components malfunctioned at the same time. Additionally, spare parts were obtained in large quantities and trained staff were made available to do on-site service with short notice. For the core IT system, technical support was initially on standby 24/7. A system design with so much redundancy is obviously more costly than one where a larger degree of failures is accepted, but which needs only one of each component, and where a longer response time can be accepted. (Höök, 2009; Johansson, 2009)

It can be reasonably argued that a congestion charging system is delivering an equal amount of traffic reduction whether it is operating at 99.9, 99, or even 95 per cent availability. After all, the travellers are making their decisions as to whether to drive or not based on the fact that they are highly likely to have to pay if they do so. From this perspective, availability requirements could have been relaxed substantially, and thereby also system build costs, without losing any of the ultimate effect on the traffic situation.

But there is another side to this availability than just lost revenue and behaviour influence. Gunnar Söderholm (2009) is certain that if the system would have been anything but perfectly available and functioning from day one, public support would vanish quickly, fuelled by media attention. It just had to work perfectly from the beginning, according to him. Höök (2009) agrees in that in order to win legitimacy for the system, the accuracy had to be high, and contrasts to Norway, where a lower degree of accuracy could probably be tolerated, as the systems there are already in place and accepted by the public.

In this respect, the service levels might not at all have been excessive, but just about right. The system was thus not designed only to work, but also to win and retain the trust and support of its users.

Cost consequences: It is not possible to state how much could have been saved if the performance indicators had been relaxed, without making far-reaching hypothetical assumptions about what alternative design decisions would then have been taken. But it is safe to say that a significant portion of the hardware and connectivity cost stemmed from redundancy requirements. It is for example likely that the system could have run with half the number of cameras, taking pictures only from the front instead of both from front and back (Johansson, 2009; Höök, 2009).

Lessons learned: Consider what the cost-efficient targets of service levels are, given what the goals of the system are and how different service levels affect the intended function of the system. Going from, say, 95% to 99% or 99% to 99.9% on any given service level may be a significant cost driver.

Project owner and scope changed mid way

System procurement started with a prequalification during the autumn of 2003, followed by a request for proposal including a detailed requirements specification issued in November, bids to be submitted in February 2004. Prospective suppliers were asked to commit to a long and detailed list of functional and non-functional requirements, all in all describing an “environmental charge system” (Swe: miljöavgiftssystem). As the political and legal process happened, the environmental charge became a congestion tax, and the laws to underpin it were different than what was assumed when the request for proposal was issued.

When the prime contractor was selected, and only signing of the contract remained in July 2004, the Congestion Tax Law (SFS, 2004a) was passed in the parliament. This made clear what most people involved had understood since long: that the congestion “charge” was in fact a “tax”, from a legal point of view (Söderholm, 2009; Höök, 2009). But it was only now that it began to become clear what this change actually meant in terms of practical changes to the system being procured (Johansson, 2009). Among the new features required by the system was the ability to appeal any tax decision. It was also clear that the Tax Authority and the Royal Collection Agency had to become administrative users of the system.

In November 2004, the Congestion Tax Ordinance (SFS, 2004b) was issued, with an additional range of requirements added. All in all, more than 200 change requests were handled by the system development project from the time the contract was signed to the time of go-live. Having absorbed such an amount of changes, the system delivered was vastly different from the system initially designed. Since the changes were issued while building, parts of the system were first built according to original specifications, and then rebuilt according to the changes, which obviously adds to the cost of construction (Johansson, 2009; Höök, 2009).

Stating that it would be less costly if all was known upfront and no changes were made is a truism for any information technology project. But it is hardly reasonable to expect that to be a true condition. On the contrary, one could argue that one should expect a project of this magnitude to evolve with time, and make sure that it is planned for in a way that can cope with change. Höök (2009) lists among the success factors that the prime contractor was a single company and not a consortium, since that makes for less internal quarrelling and better chances of dealing quickly with changing circumstances.

In addition to leading to higher cost, the project delays caused by the changes in project ownership and legislation may very well have helped making the system finally put in place successful. According to the contract (Road Administration 2004, pp. 16, 37) the prime contractor committed to delivering 11 months after the contract was enacted. Had everything happened according to the initial plan, this would have meant entering live operation in June 2005. Thanks to the legal processes that followed, the final date set for go-live was not until January 3 2006. These six months of additional calendar time may very well be an important factor standing between successful operation and failure on day one.

Cost consequences: It is impossible to give a certain figure of the costs associated with the total set of changes made. Some changes reduced the scope and made the system simpler, while others made it more complex. All of them, however, interfered with the already made design and plan, and some had cost consequences. A tentative estimate is that 15-25% of implementation costs were derived from changed requirements and managing the consequences of those changes.

Lessons learned: It would have been possible to identify the charge/tax distinction earlier, and to foresee the consequences in terms of changing requirements. Generally speaking, not having the legal setting clear is likely to induce costs in unforeseen ways. For anyone contemplating congestion charging, fitting the project inside one election cycle might be needed. Accepting that this makes it impossible to foresee all requirements that come out of the political process, it is still likely that this type of fundamental legal requirement can be identified and planned for in advance.

CONCLUSIONS

All things considered, was the Stockholm congestion charging trial unnecessarily expensive? It did not exceed its budget, and there are other comparable projects that were more costly. Still, there are several cost items to indicate that it was. One way of interpreting “unnecessarily expensive” is to ask whether it would have been possible, knowing what is known today, to establish a system such as the Stockholm congestion charging system, for a lower cost. The answer is clearly “yes”. IBM even claims that half the cost would be possible, assuming that the specifications were describing a system as it is today, and there were no major change orders to deal with during construction time (Johansson, 2009).

Note that this question is not just a philosophical counterfactual, but the relevant question to ask for anyone considering to invest in a similar system today. But if the question is instead interpreted this way: “Given the knowledge and political circumstances at the time, is it reasonable to expect that any other combination of planners, government officers and suppliers would have been able to provide the same or better results to a significantly lower cost?", then the answer is, at least, not as clear.

The criticism raised against the project, represented in this study by Dagens Nyheter, the Automobile Association, and the Chamber of Commerce, fail in two important aspects; First, they do not compare the cost of establishing the system to the value it generates, in terms of reduced traffic congestion, only in terms of the revenue collected, which is an irrelevant measurement. Congestion charging is by no means the most effective way to collect tax revenue. Rather, tax revenue is a positive by-product, while congestion relief is the major value generated.

Second, they fail to recognise the extraordinary performance in getting a fully functional system in place in time for launch – politically, administratively, commercially, organisationally, and technically. Complex IT projects, using new technologies in a previously untried configuration, have a well-earned reputation of failing to deliver on time and budget, if at all. Listing all the factors that in hindsight could have been done better, or at a lower cost, moves focus away from the remarkable fact that the Stockholm congestion charging was put in place quickly enough and at sufficient quality to swing the opinion in time for the referendum.

> *The basis for the yes [in the referendum] was that it worked technically, it gave visible and tangible effects that people liked, and one was paying for a just cause. […] it is a necessary but not sufficient condition for a successful trial that it works really well technically.*
>
> Söderholm (2009)

For a full understanding of the project, it is necessary to remember the high risks, real or perceived, at all levels. With the high risks involved, marching order from the politicians was not to build the most cost effective system, but to build one that worked. Gunnar Söderholm summarises the overall attitude from the political sphere:

> '*It may cost whatever it costs. This shall be executed.' This doesn't mean we were sloppy with public money. Just that function was the over-arching priority.*
>
> Söderholm (2009)

Risk reduction was at the centre of the procurement strategy. The Road Administration used a contracting form where a single prime contractor is trusted to deliver a turnkey solution. This is the Road Administration's preferred way, in comparison to managing a consortium, in a situation like this, as the risk for getting delayed by conflicts among the consortium members, where one party can take the whole project hostage, is lower (Höök, 2009). This way, the risk that was delegated from the politicians to the Road Administration, was delegated further to the prime contractor, with both rewards and risks to go with it. Höök was quite clear with IBM concerning the responsibilities:

> *I told IBM several times: 'It is fully possible that this all goes to hell. But if it does, I will make sure you are going down with me.'*
>
> Höök (2009)

Insurance comes at a cost

The way the Road Administration and other agencies dealt with risk can thus be comparable to an insurance premium. When a future event risks having a large negative effect if it happens, it can be rational to pay for insurance, even if the event is unlikely to materialise.

Throughout the execution of the congestion charging project, the prime contractor, the Road Administration and other agencies were faced with unknowns factors, where the potential downside was unacceptably large. Their actions can be interpreted as rational insurance policies. Those insurances came in the form of more staff in the call centres, more technical staff on stand-by, more cameras, more spare parts, redundant network connections, and in the form of not pushing every negotiation over a change order the last bit to get to the lowest price.

Since a breakdown in any part of the system was perceived as potentially crucial, such extra layers of safety were added in many places, leading to a high total cost. And like any insurance, it risks looking unnecessary and expensive in hindsight, when the event insured against did not materialise.

However, unlike a typical insurance, which is a sunk cost after the insurance period, some of the “insurances” purchased by the Road Administration have a residual value, available long after the referendum. While the cost for the first months of overstaffing is never recovered, the insurances built as technical redundancies are still there. By building the system more solidly than required, the Road Administration today operates a system with close to zero downtime, and with a world unique share of automatic photo identification. With these benefits still in the system, the operational costs are gradually moving down to more moderate levels as well.

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