

Public Procurement of Railway Infrastructure Maintenance: A Linear Regression Analysis

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Abstract

Swedish railway infrastructure maintenance has been outsourced through gradual exposure since 2002. The idea behind outsourcing was to reduce cost and improve efficiency. However, railway maintenance cost has increased faster than railway maintenance operations, resulting in neglected railway maintenance. Since railway operation is governed by the contract design the purpose of this paper was to explore the relationship between contract design and maintenance outcome within Swedish railway infrastructure maintenance. To explore this relationship linear regression analysis was used. The result indicates that asset knowledge and accessibility to the track are important to consider for improving maintenance operations.

Keywords: Public Procurement, Railway Maintenance, Contract Design

Introduction

Railway maintenance outsourcing has been a popular choice for European countries during the last decades. One motivation behind the outsourcing decision is to reduce overall cost without jeopardizing track quality. According to Odolinski and Smith (2016), outsourcing through gradual exposure has reduced cost by 12 per cent in Sweden. Gradual exposure creates a learning process for railway custodians regarding both procurement strategies and contract design (ibid.). However, large changes in the contract design can only occur during the procurement process not during the contract period, since the law of public procurement only allows for smaller changes (Lagen om offentlig upphandling [LOU], SFS 2016:1145). Smaller changes include unpredictable circumstances, minor additions and changes as well as change of contractor (ibid.). However, the contract is arguably fixed during the contract period, making design especially important. Hence, there is a need to understand the impact of contract design on maintenance outcome.

In Sweden, railway maintenance has been outsourced through gradual exposure since 2002, with the last contract exposed to competition in 2013. Due to expensive machines, there is a high economical barrier for maintenance companies to enter the market (Lingegård, Lindahl 2015). Therefore, the railway maintenance market in Sweden is oligopolistic, that is, it only involves a few actors. Alexandersson and Hultén (2007) indicates that a market with few actors open for more negotiation than actual competitive tendering during a procurement process. However, governments often try to avoid such collaboration techniques (i.e. negotiations) during a public procurement process (Meehan, Ludbrook et al. 2016). Another unique characteristic in a client-contractor relationship in maintenance is that the infrastructure already exists. Usually client-contractor relationships involve construction of infrastructure (sometimes including maintenance). When the infrastructure is new the knowledge about the condition is high, and the predictability for maintenance needs is also peaking. However, most railway infrastructure is several decades old, complicating maintenance requirement predictions. Hence, an accurate description of the condition of the railway infrastructure is needed. Without accurate knowledge of the railway infrastructure there is a risk of inaccurate contract design (Olsson, Espling 2004), causing a misalignment between infrastructure condition and contract design (Andersson, Hultén 2016). Andersson & Hultén (2016) suggest that Swedish railway maintenance costs are increasing four to five times faster than railway operations, caused by a misaligned governance structure of railway maintenance, costing up to 2 billion SEK annually. Governments need to better understand the effects of procurement strategies and contract design, especially since railway maintenance has received little research attention. Hence, the purpose of this paper is to examine the relationship between contract design and maintenance outcome.

Theoretical perspective

Maintenance Contracts

The purpose of a contract is to have a written agreement between different economic actors on a subject that they may have a different perspective on (Borg, Lind 2014). However, it is difficult for the client to design a contract that minimizes its cost without changes to the overall quality of the railway infrastructure. While minimising cost and maintaining asset quality, the contractor's payment should be sufficient enough to minimise moral hazard (Borg, Lind 2014), something that is hard to achieve in practice. The contract design within railway infrastructure maintenance depends on the asset knowledge and pricing of these assets (Olsson, Espling 2004). Cross (1988) mentions three factors that affect maintenance services; pressures for reducing costs; reorganization to allow an improvement of the service given; withdrawal from providing a particular service towards introduction of suppliers (i.e. outsourcing of the maintenance service). Today, client organizations often try to find an optimum between cost control and operational improvements through outsourcing. Contracts need to specify the content of service as accurately as possible in order to design financial incentives (Rahman, Chattopadhyay 2010, Olsson, Espling 2004, Tarakci, Tang et al. 2006), otherwise there is a risk of conflicts (Abdi, Lind et al. 2014, Borg, Lind 2014). In Sweden, the overall contract describes a function that the contractor has to satisfy, e.g. the track should be available for traffic 24 hours every day of the year. However, the working instructions for each railway asset are specific resulting in procurement of a contractor that only follows specification (Lingegård, Lindahl 2015). Creating a situation where the contractors have freedom to organize the maintenance activities (i.e. logistical solutions), but not the maintenance itself.

Pricing and payment are sources for conflict in contract situations (Abdi, Lind et al. 2014) and as such, the payment scheme must be designed carefully (Borg, Lind 2014). The careful consideration in designing this payment schemes is of vital importance to minimise conflicts and to distribute the right amount of risk. Simplified, there are two types of pricing; fixed-price and actual cost. Fixed price is simply fixed payment for the maintenance activities. Actual cost is payment according to reality, including factors such as time, personnel and equipment. Railway maintenance contracts in Sweden have, of course, a mixture of the two payment types. However, Sultana et al. (2013) mentions problems with such traditional way of contacting and procuring. Procurement of the lowest cost may result in a neglect of quality for the reduction of cost. The client has to ensure, by either inspections or governance, that the quality is not jeopardized.

Partnering in railway maintenance contracts has been used in the Swedish contracts. The main idea is to make contracts more flexible to change by close cooperation between client and contractor (Abdi, Lind et al. 2014). By close cooperation, the aim is to drive innovation, increase productivity and implement new ways of working (Eriksson 2015). The client is expected to drive both the partnering process and the knowledge transfer by encouraging to partnering activities (Havenvid, Hulthén et al. 2016, Olsson, Espling 2004). However, clients have had problems with both understanding and implementing

partnering (Eriksson 2008). Because railway maintenance is complex by nature, there is a need for partnering in such an environment (Pesämaa, Eriksson et al. 2009). Olsson and Espling (2004, p. 245) mentions four key factors to partnering within railway infrastructure maintenance: requirements for partnering; partnering process; success elements; measurements. Requirements for partnering handles the complexity of the project (i.e. complex projects requires more partnering). Partnering process handles the type of collaboration and has to be driven by the client (Eriksson, Larsson et al. 2017, Eriksson, Westerberg 2011). Success elements regard knowledge transfer of tacit knowledge between maintenance personnel and honest communication. Measurements regard the performance of the contractor and should be done in such a way so that the client can assess both the railway assets and the contractors' performance, agreeing with the findings of Sultana et al. (2013). However, Tadelis (2012) suggest that the law of public procurement hinders the partnering process. He argues that the flexibility of the partnering process is difficult since larger changes cannot be done due to the law. Partnering can be used in any type of contract (Borg, Lind 2014) and the law of public procurement can be managed (Abdi, Lind et al. 2014).

Methodology

The case study was related to Trafikverket (Swedish transport administration) and empirical data was mainly collected from two sources. One source is the contract data base, where the contracts and their design are described together with additional information such as contractor and covered geographical area. The other source is LUPP, which is Trafikverket's tool for business intelligence within the maintenance area, i.e. SAP BusinessObjects. Through LUPP information about events that occur can be collected. Examples of information that have been used in this study is the occurrence of faults, which can be related to the spatial domain (e.g. contract area and track section), the temporal domain (e.g. year, month, week and day), the system domain (e.g. track, signalling and power supply). Also time measures related to corrective maintenance activities initiated by occurred faults can be extracted, e.g. time to respond and be at the location, active maintenance time, and total correction time. Also consequences due the faults, such as number of disturbed trains and delay times can be extracted. The two sources of data are then related to each other by specific contracts as the common denominator. Hence, in this way the contract design are related to the occurred events and its consequences within the geographical area that the contract covers. Data was exported from LUPP and the contract data base to Excel, where they were combined by the logic described above. Thereafter, the combined data base was imported to statistical tools such as Minitab for linear regression analysis.

Collected data covers the time period of 2010-2017. The lower limitation is based on the coding structure of occurred events, which was changed by STA in 2009. This means that data before 2010 is difficult to compare with later data. The upper limitation of 2017 is due to the fact that whole years were preferable to be used within the study. 22 out of 34 different contracts from different regions in Sweden were collected and analysed to be able to connect to the maintenance data. These contracts are procured under different times and contain both high and low amount of traffic.

Contract data were qualitative and describes for instance contractor name, contract type, length of contract, type of pricing, etc. Most of the data were in written form and had to be manually transformed to a data sheet. LUPP data were quantitative and describes number of inspections, error reports, inspections errors, response time, repair time, train delays, etc. LUPP data were connected to the contract data via contract number and track section number to create one common database. Most of these quantitative measurements can be affected by the maintenance contractor. However, some of them can be disrupted by external factors. These external factors could be age of the track, condition of the track, traffic intensity, animal or vegetation. There is also a gap of information between maintenance outcome and maintenance activities. The railway assets condition could have been improved by either reinvestment or maintenance actions. However, this information is not available in the LUPP data, causing uncertainties regarding the estimates of asset condition.

Data analysis

Railway maintenance contracts in Sweden contain many work descriptions and regulations regarding how maintenance should be performed. Since contractors are obliged to follow these regulations, contractors can, in practice, only affect logistical solutions. By logistical solutions we mean how contractors get to the railway tracks and how they organize maintenance activities. Hence, response time to corrective maintenance was selected as response variable for the regression analysis. However, there are some aspects that need to be considered. Firstly, larger contact areas will have a longer response time, simply because of geographical distances. To accommodate for these geographical differences the response time was divided by the length of the track section. Secondly, the contact state that contractors cannot exceed a fixed response time without receiving a fine. These fixed response time are adjusted according to traffic amount, i.e. a track section with heavy traffic have a lower time limit before a fine. Since this paper seeks the outcome of maintenance activities derived from the contract, this aspect is noted but not adjusted for in the regression model.

When the response variable has been selected the data must be cleansed of errors and irregularities. Firstly, response time plus repair time of more than one day or negative amount of time was removed ($t < 1$ and $t > 1441$ minutes). This limitation accounted for around 13 percent of the data. Secondly, the data is divided into 64 different railway assets. To determine what asset types that are relevant for a regression analysis a pareto-chart was constructed, Figure 1.

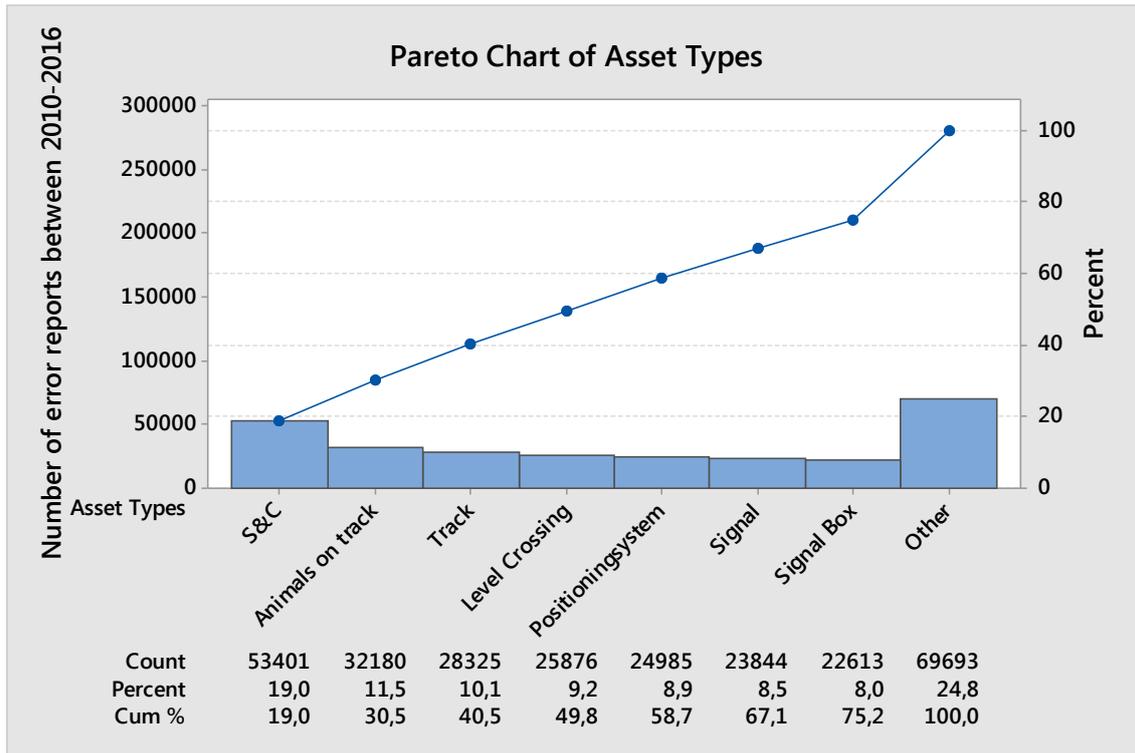


Figure 1 - Pareto chart displaying the total amount of error reports divided into the 64 different asset types

Seven of the 64 railway assets are responsible for 75 percent of all errors on the railway tracks. Three of these seven was selected for the regression analysis; Switches and Crossings; Track; Level Crossing. These three was selected because they are primarily affected by the contractors' maintenance activities and can be reduced by preventive maintenance. Because there is a significant difference in repair time between these three assets, they have to be analysed independently.

From discussions with experts in the field they gave a unanimous view that it takes three years for a contractor to establish themselves within the contract. Therefore the data was divided into two observations (where possible), one during the first three years and one during the last three years. Of the 22 contract, 10 were able to be divided into two observations. Another aspect of a three year average is the reduction of seasonal dependence. Maintenance during winter conditions takes longer than during the summer. Also, contracts in the north have a longer winter period than contracts in the south of Sweden. By having a three year average this effect is reduced.

An initial residual analysis concluded that the response was not normal distributed. To resolve this issue the response was transformed by a logarithm transformation. The residuals then took a more normally distributed form. This indicates that the normal distribution assumption cannot be discarded, making the regression analysis valid. Non-significant regressors were then eliminated by backwards elimination with a level of 10 %.

Findings

The result from the three separate regression analysis determined that four regressors had a significant correlation with response time; number of operating places; number of safety inspections; contract area and track classification. Each data point is the average response time of a track section over a period of three years. The result indicates that more operating places and safety inspection could result in a lower response time for the contractors. The R^2 values were 71.54 % (Track), 63.37 % (S&C) and 76.56 % (Level Crossing), with a significant p-value for the models (all ≤ 0.05) there is a statistical significant relationship between the variables.

Discussion

From the linear regression analysis two continuous variables were significant (number of operating places and number of safety inspections) and two categorical variables (contract area and track classification). When selection response time as the response for the linear regression analysis we initially had two considerations, seasonal and traffic variation. Seasonal variation was adjusted for by using a three year average. Traffic variation was associated with the track classification and was not adjusted for in the model, since we are seeking the relationship between contract and maintenance. Therefore, the two categorical variables were not surprisingly significant for the response. Since the contracts regulates the response time according to the track classification, it would have been a surprise if the variable was not significant. The same argument can be made for the contract area, since there is a difference between contract areas in both the contract themselves but also in geography (e.g. seasonal variation). Although contract area and track classification was expected the results indicate that there is a difference between the contract areas in Sweden. As previously stated, since 2013 STA has moved to a more standardized approach for maintenance contracts in Sweden. The result of this paper indicates that maintenance contracts need less standardization and more individualization. The contract for each contract area should be designed according to the preconditions for the specific area. However, more research is needed to determine this relationship.

Number of operating places is strongly connected to the length of the track, i.e. a longer track section will have more operating places. To simply construct more operating places on a smaller area is therefore not the solution. However, the result does indicate the importance of logistical solutions (as were one of our prerequisites) by the active contractor. When procuring new contracts, number of operating places can indicate the accessibility to the tracks for a contractor. Track sections with high accessibility can have a stronger connection with maintenance outcome, and be more favorable for a contractor to place a bid, although more research is required.

Arguably there is a connection between individual contract design and track accessibility. Today, contractors receive a fine if they exceed a preset limit for the response time. This limit is mostly regulated according to the track classification, rather than existing accessibility. Since number of operating places had the strongest correlation with response time of the four significant factors, accessibility should have a

strong effect on maintenance outcome. This result further emphasizes the need for individualization of the maintenance contracts.

Number of safety inspection was significant in all three regression analysis, with more inspections leading to a lower response time. One interpretation of the significant correlation could be that the contractor that performs more inspections can use the opportunity to fix issues directly, reducing the inspection time. However, the same argument can be made for maintenance inspections, which were included in the linear regression analysis. Maintenance inspections did not have a significant correlation with the response. The differences between these two types of inspections are that safety inspection are much stricter and follow a detailed instruction from the client. Maintenance inspections are described as a more “gut feeling” approach, and result differ between the technicians performing the inspection. Due to the more technical focus of a safety inspection the reason behind the correlation can be in the learning process for the contractor. By performing many technical safety inspections the contractor gains knowledge about the asset condition. With this increased amount of knowledge the contractor can plan and predict maintenance more efficiently. Also, the contractor learns the geography of the track and where the assets are. This in turn can reduce the response time for corrective maintenance activities.

Conclusion

This research is a first step of investigating the relationship between contract design and maintenance outcome using linear regression. In this paper three separate linear regression analysis was performed on maintenance and contract data for three asset types: track, S&C and Level Crossings. With response time as response four factors had a significant correlation with the response in each of the three linear regression analysis: contract area; track classification; number of operating places and number of safety inspections. Contract area and track classification were expected to be significant, since response time is regulated via fines in the contract. However, the factors number of operating places and safety inspections were not expected. The results indicate three primary conclusions; individual contract design; accessibility to the track and asset knowledge.

Since the response in the linear regression analysis was response time for corrective maintenance, there is still a need for more research to create a larger picture. However, the research does agree with previous findings of individual contract design (e.g. Abdi, Lind et al. 2014) and the importance of asset knowledge (e.g. Espling, Olsson 2004). For railway clients the procurement and contract process should value asset knowledge, both in-house and by their contractors. With accurate asset knowledge the contract should be designing individually based on the prerequisites of the contract area. By doing so there is a possibility of the increased efficiency of predicting and planning maintenance activities.

Future research should conduct additional analysis on other response variables (e.g. repair time). Response time is only one aspect of the contractor’s ability to conform to the contract design. To fully understand the relationship between contract design and

maintenance outcome, additional variables should be explored. Also, a multivariate analysis (e.g. principal component analysis or cluster analysis) could be beneficial to explore the relationships between the different variables in the dataset.

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References

- ABDI, A., LIND, H. and BIRGISSON, B., 2014. Designing appropriate contracts for achieving efficient winter road and railway maintenance with high performance quality. *International Journal of Quality and Service Sciences*, **6**(4), pp. 399-415.
- ALEXANDERSSON, G. and HULTÉN, S., 2007. High and low bids in tenders: Strategic pricing and other bidding behaviour in public tenders of passenger railway services. *Annals of Public and Cooperative Economics*, **78**(2), pp. 161-194.
- ANDERSSON, M. and HULTÉN, S., 2016. Transaction and transition costs during the deregulation of the Swedish Railway market. *Research in Transportation Economics*, **59**, pp. 349-357.
- BORG, L. and LIND, H., 2014. Framework for structuring procurement contracts. *Australasian Journal of Construction Economics and Building*, **14**(4), pp. 71-84.
- CROSS, M., 1988. RAISING THE VALUE OF MAINTENANCE IN THE CORPORATE ENVIRONMENT. *Management Research News*, **11**(3), pp. 8-11.
- ERIKSSON, P.E., 2015. Partnering in engineering projects: Four dimensions of supply chain integration. *Journal of Purchasing and Supply Management*, **21**(1), pp. 38-50.
- ERIKSSON, P.E., 2008. Procurement Effects on Coopetition in Client-Contractor Relationships. *Journal of Construction Engineering and Management*, **134**(2), pp. 103-111.
- ERIKSSON, P.E., LARSSON, J. and PESÄMAA, O., 2017. Managing complex projects in the infrastructure sector — A structural equation model for flexibility-focused project management. *International Journal of Project Management*, **35**(8), pp. 1512-1523.
- ERIKSSON, P.E. and WESTERBERG, M., 2011. Effects of cooperative procurement procedures on construction project performance: A conceptual framework. *International Journal of Project Management*, **29**(2), pp. 197-208.
- ESPLING, U. and OLSSON, U., 2004. Part II. Partnering in a railway infrastructure maintenance contract: a case study. *Journal of Quality in Maintenance Engineering*, **10**(4), pp. 248-253.

- HAVENVID, M.I., HULTHÉN, K., LINNÉ, Å and SUNDQUIST, V., 2016. Renewal in construction projects: tracing effects of client requirements. *Construction Management and Economics*, **34**(11), pp. 790-807.
- LAGEN OM OFFENTLIG UPPHANDLING (SFS 2016:1145). Stockholm: Finansdepartementet.
- LINGEGÅRD, S. and LINDAHL, M., 2015. Integrated Product Service Offerings for rail infrastructure – benefits and challenges regarding knowledge transfer and cultural change in a Swedish case. *Journal of Cleaner Production*, **98**, pp. 166-174.
- MEEHAN, J., LUDBROOK, M.N. and MASON, C.J., 2016. Collaborative public procurement: Institutional explanations of legitimised resistance. *Journal of Purchasing and Supply Management*, **22**(3), pp. 160-170.
- ODOLINSKI, K. and SMITH, A.S.J., 2016. Assessing the cost impact of competitive tendering in rail infrastructure maintenance services: Evidence from the Swedish reforms (1999 to 2011). *Journal of Transport Economics and Policy*, **50**(1), pp. 93-112.
- OLSSON, U. and ESPLING, U., 2004. Part I. A framework of partnering for infrastructure maintenance. *Journal of Quality in Maintenance Engineering*, **10**(4), pp. 234-247.
- PESÄMAA, O., ERIKSSON, P.E. and HAIR, J.F., 2009. Validating a model of cooperative procurement in the construction industry. *International Journal of Project Management*, **27**(6), pp. 552-559.
- RAHMAN, A. and CHATTOPADHYAY, G., 2010. Modelling Total Cost of Ownership of Rail Infrastructure for Outsourcing Maintenance Services. *Definitions, Concepts and Scope Of Engineering Asset Management*. Springer, pp. 115-122.
- SULTANA, M., RAHMAN, A. and CHOWDHURY, S., 2013. A review of performance based maintenance of road infrastructure by contracting. *International Journal of Productivity and Performance Management*, **62**(3), pp. 276-292.
- TADELIS, S., 2012. Public procurement design: Lessons from the private sector. *International Journal of Industrial Organization*, **30**(3), pp. 297-302.
- TARAKCI, H., TANG, K., MOSKOWITZ, H. and PLANTE, R., 2006. Incentive maintenance outsourcing contracts for channel coordination and improvement. *IIE Transactions*, **38**(8), pp. 671-684.