

Public procurement of railway infrastructure maintenance – a literature review

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Abstract

The maintenance of railway infrastructure has in several instances been changed from government-based to being based on public procurement, with varying degrees of flexibility for the contractor to design their maintenance work. The purpose of giving contractors a larger freedom of choice of how to perform maintenance is to stimulate them to innovate and develop their maintenance processes. Since the contracts differ in between and there are changes in government policies over time that affects both existing and new contracts, a comparison between different contracts becomes challenging. A literature review has been conducted to understand the change in procurement strategy and how to encourage contractors to innovate. The research questions include: What procurement strategies are there? How is maintenance evaluated? How does procurement affect the innovation opportunities for entrepreneurs?

The literature review focuses on railway maintenance and contract design between client and contractor. In total, 17 articles matched the search criteria and were selected for the review. To have successful maintenance service, five articles suggested partnering as a strategy with common goals in combination with good communication during the entirety of the contract. When selecting incentive plan, four articles mentions that a focus on performance-based incentives in combination with risk management is better rather than actual payment schemes. The reason being that payment is often the main cause of conflicts between client and contractor. The scientific literature suggests that improvement in incentives improves quality of maintenance, decreases delays and technical failures. The conclusion from the literature review is that partnering in railway maintenance is considered successful. With accurate knowledge about railway assets the incentive plan becomes accurate which reduces costs.

The literature review is a part of a research project with an overall goal to develop a model to guide the selection of appropriate type of procurement strategy, contract and control of maintenance for a more sustainable railway system.

Keywords: Procurement, Maintenance, Railway infrastructure, Contract, Payment

1. Introduction

Outsourcing of infrastructure maintenance activities from public to private sector has become popular in Europe. One reason behind the outsourcing is to make maintenance more cost efficient (Österberg, 2003). However, there is an understanding that the public sector fail to keep up with the growing and changing industrial demands (Mattson and Lind, 2009; Vickerman, 2004b). When public organizations outsource their infrastructure maintenance they need to reorganize and handle management of contracts and suppliers instead of performing the maintenance. The design of maintenance contracts is important to preserve high infrastructure quality. One solution is to design long-term performance-based contracts where both construction and maintenance is included (Ng and Wong, 2007; Vickerman, 2004a). However, many maintenance contracts require a separation between construction and maintenance since the majority of assets to be maintained are already built.

Railway maintenance is complex where many factors need consideration, e.g. changes in train traffic, which are critical due to its impact on both the degradation and access to track (Forsgren et al., 2014). The outsourcing of railway infrastructure maintenance has to be performed without jeopardizing the infrastructure manager's task to uphold high safety, quality and availability at a low cost. In fact, the infrastructure managers have to ensure a level of railway safety that is economically sustainable for the society, i.e. balancing quality of service and cost so that the users select the safest mode of transportation. Accordingly, how the procurement process is handled therefore becomes critical. European public procurement strategies are regulated by the public procurement act. This law is sometimes considered as an obstacle that limits changes and renegotiations without a new tender after a contract has been signed (Abdi et al., 2014; Alexandersson and Hultén, 2007; Tadelis, 2012). Accordingly, the difficulty of making ex post changes to signed contract makes its design critical.

The Swedish Transport Administration (STA) has outsourced railway maintenance since 2002. In 2013 STA was obligated to change its railway maintenance procurement with the intent to motivate contractors to innovate and develop their processes. The underlying assumption was that restrictions and specifications of how the maintenance should be performed stifled innovation and process improvement potentials. Hence, the core of the change process involved increasing the contractors' degrees of freedom in performing the maintenance. There is a need for public clients to better understand how procurement strategies work and how they should be designed to maximize the outcome at the lowest cost, which in this case is high quality and availability of the railway system.

This paper aims to review how public railway maintenance procurement has been described in the scientific literature. The paper is organized into six sections, including the introduction in section 1. Section 2 presents the method and describes the literature review process. Section 3 presents the analysis and the result of the review is presented in section 4. The final sections discuss the result and present the conclusions of the study.

2. Method of literature review

A literature review was considered appropriate for condensing the current knowledge of procurement of railway maintenance. The literature review started by selecting databases that were considered appropriate for finding studies on railway maintenance contracting. The database Scopus was chosen due to its coverage of engineering-based publications. On June 3 2016 Scopus was searched using the

search string [Maintenance AND (infrastructure OR Subway OR Metro OR Tram OR Rail) AND (Procurement OR Contract OR Bidding OR Tendering) AND NOT (Sewer OR Water OR Air OR Pavement OR Defense OR Military)] in the subject fields. While this search string generated 209 hits, many of these were out of scope. Limiting the search to journals within the subjects; engineering, business, environmental, decision, economics and multidisciplinary reduced the number of uninteresting search results, leaving 109 articles for further study.

The scope for this study was discussed and defined to exclude road maintenance because of the different management practices and contract designs involved. The first author then reviewed the abstracts of these hits. Many of the articles were discarded since they were outside our scope, such as those focusing on road maintenance. Also no article published before 2001 were found to be within the scope. Finally, 20 articles remained and were selected for the review. The 20 articles were distributed among the authors for a first round of reviews.

Twelve of the initial articles were considered relevant after this first round. The low number of relevant articles was a concern, and therefore a snowballing technique was introduced to find additional interesting references. The snowballing technique involved studying the reference list of the twelve identified articles as well as studying all articles that had cited the relevant articles. An additional five references were found, which based on their abstract were considered interesting. The snowball articles were then reviewed. Of these, four were considered relevant, generating a total of 16 relevant articles.

An additional search was performed to scan other relevant databases, e.g. Web of Science (WoS), EBSCO and Emerald Insight. The same search string generated multiple hits that mostly were out of scope (mostly connected to road maintenance) or duplicates. However, one additional article that was considered relevant for this literature review was found, which brought the overall reviewed articles to 17.

A classification sheet was developed to understand and connect the articles, inspired by Siva et al. (2016). Five articles were chosen to calibrate the classification. The authors all reviewed the articles individually and then met to discuss their review and the classification sheet. The classification sheet was further developed by changing the phrasing of some aspects and new aspects were also added. The calibration showed that the reviewers classified the articles similarly with only minor differences. Table 1 shows the classifications of the review process.

Table 1 - Coding criteria, inspired by Siva et al. (2016)

Coding criteria	Description of coding
Publication year	The year of when the article was published.
Main conclusion	A short description of the main conclusion/contribution from the article.
Type of paper	Conceptual, qualitative, or quantitative.
Methodology	Data collection method (experiment, literature review, database analysis, archival study or interview study).
Empirical data	Client or supplier data, country origin of the data.
Topic	Procurement/contract, contract scope, maintenance, management/strategy or performance
Type of infrastructure	General, railway, subway or high speed rail.
Level of analysis	Contract, organization or policy.

3. Analysis

This section presents the analysis from the data classification and coding that was presented in Table 1. In Figure 1 the distribution of the articles based on the publication year is shown. The figure suggests that publications in the area have been more frequent during two time periods, 2004-2006 and 2010-2012. The relevance criterion was in fact not a dichotomous classification of relevant or not, but a six class ordinal scale between zero and five, where zero represented the non-relevant articles and five represented very relevant articles. Studying the articles that were not classified as irrelevant, three of the five articles published in 2010-2012 were classified as one in relevance but none of the articles published in 2004-2006 had a relevance classification of more than one. The conclusion is that the most significant articles related to public procurement of railway maintenance were published in 2004-2006.

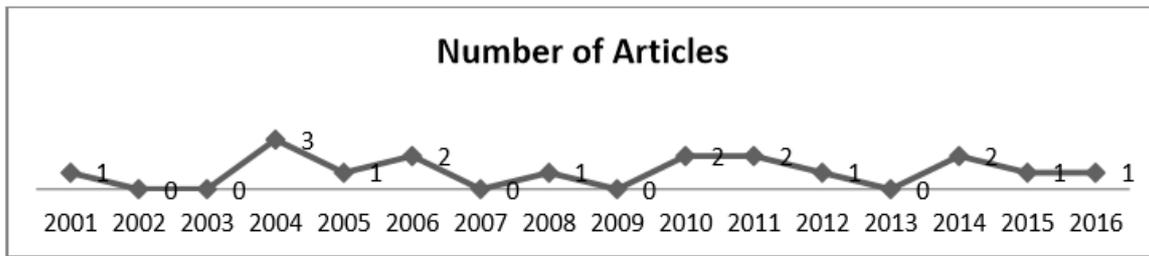


Figure 1 - Timeline of the published articles

Most of the articles were using a qualitative research approach, see Figure 3 and the distribution of methodologies is seen in Figure 2 (note that the number of articles do not always sum to 17, reflecting that articles are often classified in more than one category). Most articles were based on qualitative data based on case study research and/or interview. Of the relevant articles, Sweden stands out as being a common location to base the studies (Figure 5). The three articles that were not connected to a specific country were conceptual articles shown in Figure 3. Two articles collected empirical data from a mix of countries, where they both used interview study as methodology. Amongst the relevant articles Swedish railway is often studied, see Figure 5.

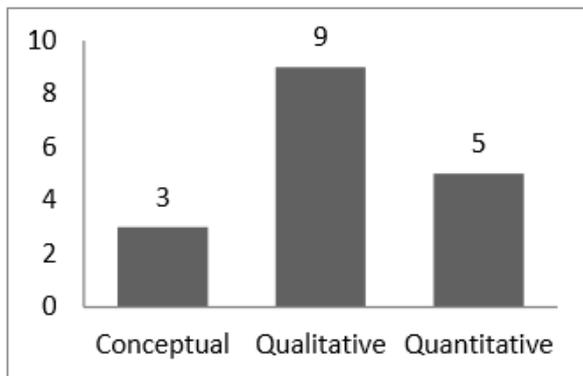


Figure 3 - Description of the type of paper

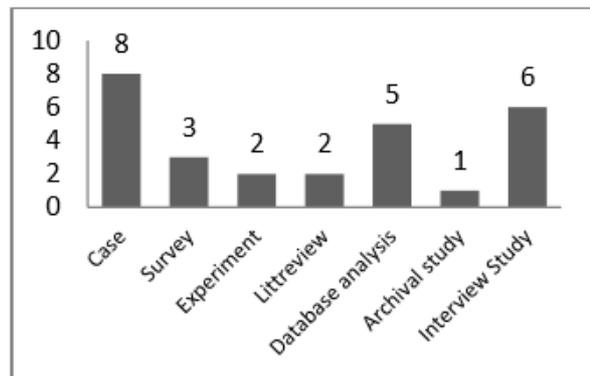


Figure 2 - Classification of the methodology used in the articles

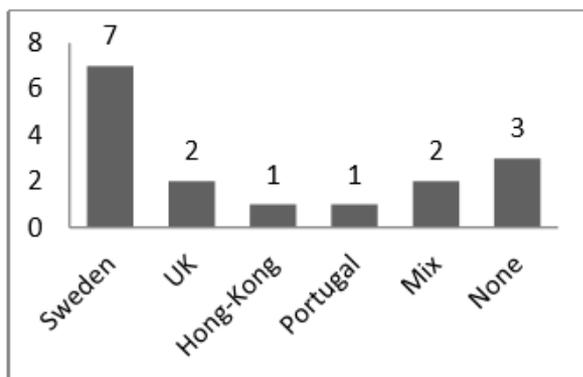


Figure 5 - Classification of where empirical data was collected

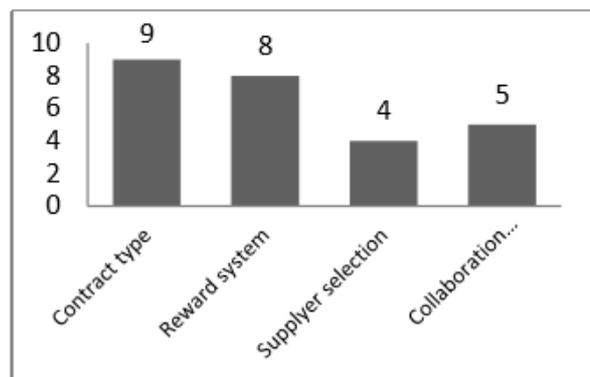


Figure 4 - Classification within the topic of procurement and contract

As seen in Figure 4 many articles focus on the contract type and reward system, whereas supplier selection and collaboration model is less studied. Figure 6 presents the topic of contract scope where the technical aspects are the most studied. Figure 7 shows that the articles focus more on preventive

maintenance than any other type of maintenance, e.g. corrective maintenance. Based on these classifications three articles present findings that contain contract type or reward system, technical scope and preventive maintenance; Kemi (2001), Espling and Olsson (2004) and Olsson and Espling (2004). From the keywords the common denominator for all three articles is partnership.

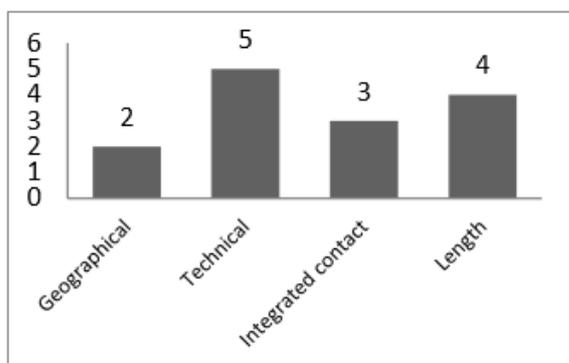


Figure 6 - Classification within the topic of contract scope

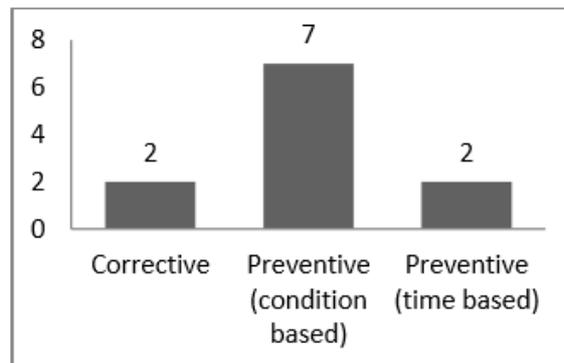


Figure 7 - Classification within the topic of maintenance types

4. Findings

The 17 relevant articles were categorized into four different areas; collaboration model, i.e. partnering (five articles), contract incentives (four articles), financing (three articles) and management (five articles). Thirteen of the articles present conclusions based on empirical evidence, six of these are studies conducted in Sweden. The remaining four base their conclusions on either experiments or archival studies.

4.1 Partnering

The five articles considered most relevant suggest partnering strategy for railway maintenance procurement. However, different authors use different definitions of partnering. Abdi et al. (2014) define partnering as “close cooperation between client and contractor that makes it possible to make adjustment and improvements during the contract period that are to the advantage to both the contractor and the client”. Espling and Olsson (2004) describe partnering as “a managerial approach used by two or more organizations to achieve specific business objectives by maximizing the effectiveness of each participant’s resources”. Kemi (2001) defines partnering as “a process by which organizations develop a more focused collaboration by defining common goals, common collaboration team and common respect for each other’s organization”. Borg and Lind (2014) and Kemi (2001) emphasize that partnering should not be seen as a specific procurement contract or a new type of contract. Instead partnering could be implemented in any type of procurement contract (ibid.). Based on these definitions we define partnering as close collaboration between partners with common goals and partners working to maximize the resource effectiveness of each organization as well as of the partnership.

Borg and Lind (2014) propose a classification framework for contract type and payment method. Their classification is based on a continuum where of the number of contractors, breakdown of responsibilities and level of construction and/or maintenance are inputs. Borg and Lind (2014) further

conclude that partnering can fit in any type of contract and contracting makes adjustments during the contract period possible.

Cruz et al. (2015) have studied two public-private partnerships in urban light railway system; the contracts were long-term and contained both construction and maintenance. One project was considered problematic and resulted in delays, whereas the other was considered successful, providing lower operating costs (ibid.). The conclusion was that the difference explaining the two outcomes was an innovative maintenance model (Cruz et al., 2015).

Abdi et al. (2014) proposed that contract design should be based on a vision of what the project should achieve for both client and contractor. They further propose that the vision should define common-goals and interests that are included in the maintenance contract. Common goals force parties to consult each other. The necessary adjustments during the contract period are easier with partnering than with other contract designs since partnering offers that flexibility. However, it is argued that the public procurement act needs to be analyzed to see if more flexible contracts are possible without a new tendering process. (Abdi et al., 2014)

Olsson and Espling (2004) present a framework for public sector infrastructure maintenance partnering. Partnering is suggested to improve communication between maintenance contracts parties. Partnering benefits are said to include improved project quality, increased flexibility, improved scheduling and lower maintenance cost. However, partnering is considered to require more management involvement, especially during the startup phase. Their analysis suggests that partnering in railway maintenance may potentially reduce overall cost up to 30 percent. An accurate description of asset condition, clear description of primary objectives and a common action plan to reach the primary objectives are all important railway maintenance factors to consider (Olsson and Espling, 2004).

Kemi (2001) suggests that partnering requires a project team consisting of the contract parties as well as a third party to ensure open and honest communication during meetings, which reduces the total meeting time. At project start and throughout the contract the project team should define common and ranked objectives and a common strategy to meet these objectives (Kemi, 2001).

4.2 Contract incentives

Payment in railway maintenance contracts often leads to conflicts (Abdi et al., 2014). The design and evaluation of payment systems must be considered carefully to handle and minimize conflicts (ibid.). Abdi et al. (2014) and Borg and Lind (2014) both argue the payment schemes distribute risk in large maintenance contracts. The allocation of risk must be carefully considered in railway maintenance since payment is related to both risk and conflicts (Borg and Lind, 2014).

The payment can be used as a tool for balancing risk allocation and risk sharing between client and contractor in their procurement contract framework. Borg and Lind (2014) list three payment systems that affect risk differently; fixed pricing, fixed pricing with general indexing and unit pricing. With fixed pricing, all risk is carried by the contractor and with unit pricing the client carries all the risk. With general indexing all risk except changes in general pricing is carried by the contractor. Both fixed and unit pricing present uncertainties and Borg and Lind (2014) suggest that risk sharing is needed in both extremes. When the contractor carries all the risk, the contract gets less attractive and this can

reduce the number of bidders. The contractor's improvement incentives are, on the other hand, reduced when all risk is allocated to the client. The risk allocation model therefore needs to give incentives to contractors as well as the client. The issue then becomes to properly select and balance incentive parameters. Reduced quality in other dimensions could for instance be an outcome of the contractor only focus on reward bringing incentives (Borg and Lind, 2014).

Tarakci et al. (2006) simulated a method of uptime target and bonus to create a win-win situation when selecting performance based incentives. The contractor gets a bonus if the uptime level exceeds a pre-determined threshold (ibid). Tarakci et al. (2006) have found an optimum threshold and amount of bonus to create the desired win-win condition. Having such performance based incentives was tested by Stenbeck (2008) and the study found that the number of delays and failures related to maintenance contracts could be reduced using this model.

Olsson and Espling (2004) argue that it is difficult to have an accurate and detailed contract design without knowledge of the asset condition. Rahman and Chattopadhyay (2010) have developed a mathematical model for the total cost of ownership for railway infrastructure that is based on previous work. They argue that when outsourcing infrastructure maintenance it is important to have an accurate description of the total cost of ownership for the procurement process. The model they present accounts for the cost of procurement, maintenance, inspection, accidents and disposal of rail. If there is a lack of understanding of total cost it may lead to uncertainties for aspects such as reliability, availability or safety.

4.3 Financing

Financing regulates the relationship between public and private sector in railway maintenance outsourcing. In different public-private partnerships, financial support from private sector has been considered as means to ease the governmental burden. The discussion is then what level of private financing is needed, if any, in outsourcing of railway maintenance (Ng and Wong, 2006).

Maintenance planning is essential to ensure good track availability (Forsgren, et al., 2014). The British railway had major problems with the lack of planning with cost increase of up to 25 % (Vickerman, 2004a). The reason behind the problems was that maintenance needs had not been properly identified and could therefore not be scheduled (ibid.). Vickerman (2004a) argues that there are benefits with maintenance outsourcing, but that outsourcing increases costs for upholding maintenance quality. Vickerman (2004a) argues that infrastructure condition quality indicators need improved definition. Economically it means that there is a need for an adequate asset condition assessment to understand its expected remaining life. Accurate estimates of asset condition provide the possibility to define good quality indicators which provides good incentives to the contractors and good maintenance (Vickerman, 2004a).

4.4 Maintenance management practices

Odolinski and Smith (2016) have evaluated the cost impact of competitive tendering in Sweden. They mention the case in Britain where the entire railway network was exposed at once to competitive tendering, which ultimately caused a drop in quality and the maintenance was brought back in house

(see Kennedy and Smith, 2004). Odolinski and Smith (2016) shows that the gradual exposure of competitive tendering has reduced cost by around 12 per cent.

Bouch and Roberts (2010) considers the logistical part of infrastructure maintenance important and argue that most infrastructure managers aim for that suppliers should plan for just-in-time warehousing to minimize costs. Long-term planning is a solution for most logistical problems within railway maintenance. However, the fluctuating level of government railway maintenance funding is problematic for long-term planning. The track quality variability that requires small and costly work packages is another challenge (Bouch and Roberts, 2010).

Infrastructure managers give higher importance to sustainability issues, and component recycling is increasingly often being used (Bouch and Roberts, 2010). Lundberg (2011) argue for an improvement in environmental follow-up system for railway maintenance. The environmental follow-up activities are defined during the procurement phase (ibid.). Lundberg (2011) further argues that the client and contractor communications needs improvement together with an environmental data memory bank to increase the organizational learning possibilities.

Maintenance planning requires an accurate knowledge of the asset condition (Rahman and Chattopadhyay, 2010; Too, 2012). The use of technological solutions to evaluate the condition of asset and the risk of failure is considered important (Too, 2012). A challenge with maintenance management is the lack of skilled personnel to both assess the asset condition and to perform railway system maintenance (Too, 2012). In Sweden, 30 % of all track related incidents have been attributed to maintenance and of among these, 79 % were related to maintenance work (Holmgren, 2005). Causes include improper communication between maintenance personnel and train dispatcher, lack of experienced maintenance personnel, which may maintain poorly if supplied with poor instructions (Holmgren, 2005).

5. Literature review discussion

Four key areas could be identified in the literature review: *partnering, contract incentives, financing and maintenance management practices.*

Three of the articles involving partnering are based on the same study of two projects that were concluded to be successful (Espling and Olsson, 2004; Kemi, 2001; Olsson and Espling, 2004). However, despite these successes, partnering seems seldom used, as stated by contractors and clients (Abdi et al., 2014). Olsson and Espling (2004) provide a framework for railway maintenance partnering, where they state that common goals, synchronized strategy and honest communication are key success factors. Espling and Olsson (2004) and Kemi (2001) studied partnering within railway maintenance, Espling and Olsson (2004) before outsourcing and Kemi (2001) after. Abdi et al. (2014) provided empirical evidence of the need for partnering from both client and contractor. The conclusion is that there is a need for partnering, there is evidence of partnering being successful in railway maintenance but it is not being used within Swedish railway maintenance.

The complexity and design of railway systems increases managing and control challenges and maintenance outsourcing further increases complexity. Since most railway infrastructure are owned by the state, a government organization sets the system requirements, e.g. availability and quality. Proper

contract incentives connected to the overall objective provide possibilities to reduce overall maintenance cost (Tarakci et al., 2006). However, incentives require an accurate calculation of total cost of ownership to create a detailed specification of maintenance assets (Rahman and Chattopadhyay, 2010).

Abdi et al. (2014) and Alexandersson and Hultén (2007) discusses public procurement laws in relation to railway maintenance and, Abdi et al. (2014) discusses public procurement laws in railway maintenance in relation to partnering. All studies conclude that legal requirements prohibit changes within a contract without renewing the tendering process. Olsson and Espling (2004) consider the ability to change and adapt the contract necessary. More research is needed to explore how the public procurement law affects partnering or can be adapted to allow partnering within railway maintenance.

As for the literature review methodology, the total of 17 articles can be considered few. Initially we discussed databases, search string and the scope of the review. Initial searches in different databases generated only duplicates or zero hits, and we concluded that Scopus provided the broadest number of hits for this review. The conclusion of these discussions was that we wanted a limited scope based on scientific publications, excluding procurement of road maintenance since railway maintenance is more complicated and maintenance contract usually are longer in time. We strongly believe that the findings would be different and ultimately misleading for railway maintenance procurement had road maintenance been included.

6. Conclusion

The purpose of this paper was to review the scientific publications on public procurement of railway maintenance. The review process identified four key areas within the subject: *partnering, contract incentives, financing and maintenance management practices*. Partnering can be a success factor in public procurement of railway maintenance. The Swedish studies often state that Swedish public procurement of railway maintenance is different compared to other countries. Partnering is seen as positive when changes can be made during the contract, something that is difficult due to the law of public procurement. Some evidence in the studied literature suggests that the law forces procurement at lowest price, something that hinders maximizing the service quality. Hence, the possibility of integrating partnering within the laws of public procurement needs more research. Since the public procurement laws usually prohibit change after the contracts have been signed, then perhaps partnering design is neglected even though it shows benefits if it can be adapted within railway maintenance. It is therefore important to improve the knowledge of how a partnering contract can be designed in accordance to the public procurement act to benefit the quality of the railway system.

6.1 Acknowledgment

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