

Review

Challenges of Electronic Reverse Auctions in Construction Industry—A Review

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Received: 13 November 2019; Accepted: 10 February 2020; Published: 14 February 2020



Abstract: The innovation of construction procurement by means of electronic reverse auctions is a controversial subject of discussion among both researchers and practitioners. This paper consolidates and critically discusses current knowledge concerning the adoption and use of electronic reverse auctions in the light of specific features of the construction industry. A systematic literature review has been employed to select papers indexed in Scopus and Web of Science databases. The findings of the study indicate that studies are addressing especially five main areas, i.e., suitability of electronic reverse auction (eRA) for construction tenders, related drivers and barriers, ethical considerations, savings potential and bidding behavior, and bid distribution. Accordingly, the authors are suggesting three directions in which future research should focus on mutual interaction of electronic reverse auctions and long-term effects on construction project outcomes.

Keywords: construction auction; electronic reverse auction; project management; public procurement

JEL Classification: D44; H57; L74

1. Introduction

Public spending efficiency is considered as a crucial step towards preventing the expansion of government expenditures. Construction is a part of the aggregate demand, e.g., in the view of infrastructure requirements (Stupnikova and Sukhadolets 2019). A considerable portion of public expenditures is spent on construction investments, such as roads, railways, hospitals, educational facilities, utilities, water management structures, etc. The development, maintenance, and improvements of the above-mentioned public infrastructure are very costly, therefore any measure that contributes to the enhanced efficiency of public construction investments is welcome. This issue is becoming even more important during the economic crisis because the construction industry belongs to the first affected sectors of the national economy. Taking into consideration that the construction sector possesses a high multiplier effect, slowdown in construction investments causes an undesirable consecutive decline in other related industries (Kozumplíková et al. 2017). According to Eurostat (2019), the construction industry creates 5.54% of the gross added value of all NACE (Nomenclature des Activités Économiques dans la Communauté Européenne, European industry standard classification system (in English)) activities in EU 28 countries, which is 783,834.2 million EUR.

One of the efforts of public agencies to realize construction investments with higher financial performance is related to effective price negotiation during the procurement process as well as to the selection of appropriate project delivery method (PDM). Traditionally, design and construction

processes are separated in the construction procurement. The contractor is selected according to the data submitted in tenders, in paper or electronic form, based on the tender evaluation rules defined in the procurement documents. However, if a electronic reverse auction (eRA) is used, the contracting authority firstly checks whether the submitted bids correspond to the award criteria. After that, contrary to traditional procurement, the authority invites all participants to submit new auction values in the electronic auction. During this auction, participants have access to information on their current rankings and/or the best bid values currently submitted. In such a way, a competitive environment in the auction is promoted.

In this relation, electronic reverse auctions can be considered as a competitive and helpful tool to select a capable contractor. Indeed, eRA represents a special case of electronic negotiation where several suppliers compete in the tender to supply products, services, and/or works by decreasing their bids, especially in terms of bid prices (Mabert and Skeels 2002; Wagner and Schwab 2004). In the case of subsidies, eRA is also very useful. Mayr et al. (2014) reported that this is especially evident in the area of photovoltaics, where it would not only increase the total electricity generation but may also lead to a reduction in public spending.

The presence of a higher number of suppliers is essential to create a competitive environment in the auction. In one of the highly cited studies on eRA, Emiliani and Stec (2002) revealed that the root cause for eRA implementation and use lies in the local organization of the business system along with financial, functional, and managerial dimensions. Furthermore, they argue that eRA can be viewed as a solution facilitating short-term financial objectives. Therefore, eRA can serve managers as a quick solution to various cost problems relating, e.g., to a company's financial performance issues coming out from the pressure from investors.

As the use of eRA can be also viewed as controversial (Charki et al. 2011), its potential adoption and implementation should be properly considered taking into consideration the features of the specific industry. Such results into various issues in public procurement regarding construction projects that can be seen as both positive and negative. In this context, Horlen et al. (2005) revealed the causes of eRA controversy in construction. In their study, it is argued that many contractors opposing reverse auctions believe that they should be allowed to submit bids based on their distinctive capabilities and unique resources. Hence, instead of having just the only one opportunity to submit their best prices (sealed bids), they are exposed to fierce and open price competition. Another aspect of the controversy is the question of what types of construction works/projects are suitable for eRA in terms of the ability to specify the subject of purchase sufficiently (Hanak 2018). Therefore, this paper aims to consolidate and critically discuss relevant issues concerning the use of eRA in the construction industry and propose future research directions.

2. Research Methodology

In order to address how the existing body of knowledge has progressed towards clarifying eRA adoption and use in the construction industry, a systematic literature review has been applied in this study. The research workflow (Figure 1) is developed to identify, examine, and evaluate all relevant literature on a particular research topic at an early stage. To do so, a systematic review was used, as "a basic and critical method for condensing topics, discovering research gaps, and building knowledge frameworks" (Zelenika 2013).

The data collection process consists of three steps. First step was database selection, followed by data retrieval, and literature screening and supplement. As there is no previous review paper of the eRA topic in the construction industry, we decided to use renowned databases Scopus and Web of Science in order to provide a global overview of the research topic. The search scope in those databases was restricted to the "Title/Abstract/Keywords" field.

The collected papers, and the review later, reflects on papers published in peer-reviewed journals, preferably articles and review papers. To ensure the high quality and novelty of knowledge being analyzed, only journal papers published from 2005 to 2019 were included. The survey was conducted

using selected keywords: electronic auction, purchasing auction, reverse auction, construction, and construction auction. They resulted into two sets of papers:

- eRA generally related papers (analyzed and discussed in Sections 3.1 and 3.2) to detect main research streams, and
- eRA related papers oriented towards the construction sector (analyzed and discussed in Section 3.3) to reveal past and present issues being studied and to formulate a call for future research.

The literature screening and supplement were performed on both sets. During the screening, both sets were checked to filter duplicates. Then, a backward search (cross-referencing) was performed along the references to avoid missing important references. This resulted in adding several older references (from 2002 to 2004) where the eRA was introduced as a new bidding tool in the construction industry.

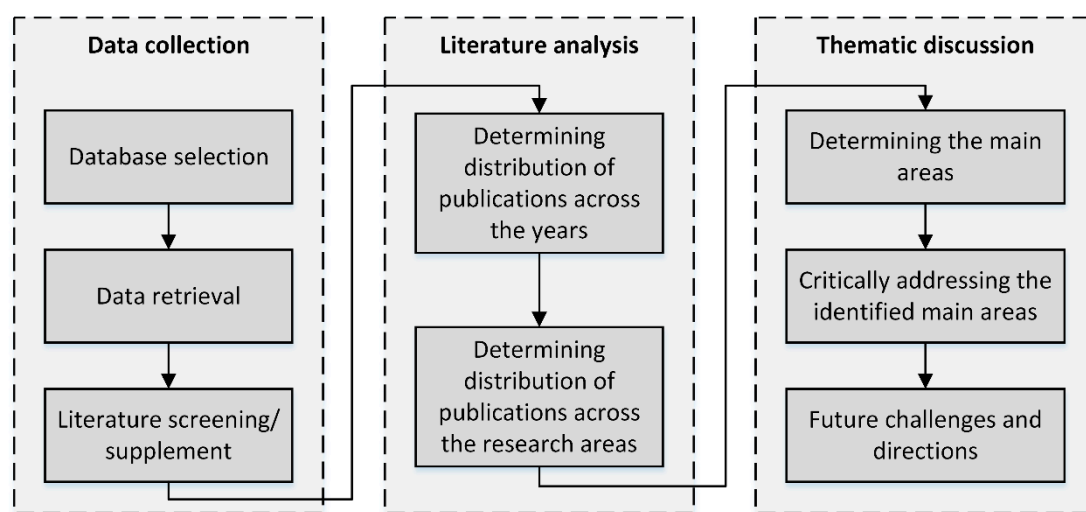


Figure 1. The research workflow.

Regarding set no. 1, the conducted survey resulted in a total number of 1378 (Scopus) and 1422 (Web of Science) papers. As this paper focuses solely on the construction industry, a detailed analysis has been conducted with respect to construction-oriented papers. For set no. 2, 215 papers were found in Scopus and 221 in the Web of Science database. Furthermore, this set has been reduced by removing duplicities (142 papers) and papers that lie out of the scope of this study (171 papers). Such a high number of papers removed by being irrelevant to this study is caused especially by the fact that they use the keyword “construction” in a different meaning. The resulting number of studies included in a detailed investigation dropped significantly to 123. As the aforementioned data indicate, a large body of knowledge on eRA exists; however, as far as papers oriented towards the construction industry are concerned, the range of available literature is significantly smaller. The resulting set of journal papers is supplemented with a few references to the official statistics and examples from practice. Furthermore, during the literature review, additional sources have been obtained when analyzing the list of references.

Such a process of data collection is followed by a literature analysis process. It consists of two-step analysis, (1) the statistical distribution of collected publications across the year of publication and (2) their distribution across the research areas. Also, no in-depth bibliometric analysis such as citation of articles or authorship and co-authorship analysis was performed. The number of publications considered in this paper and their corresponding year of publication is summarized in Figure 2, while Figure 3 provides information about research areas in which papers were categorized.

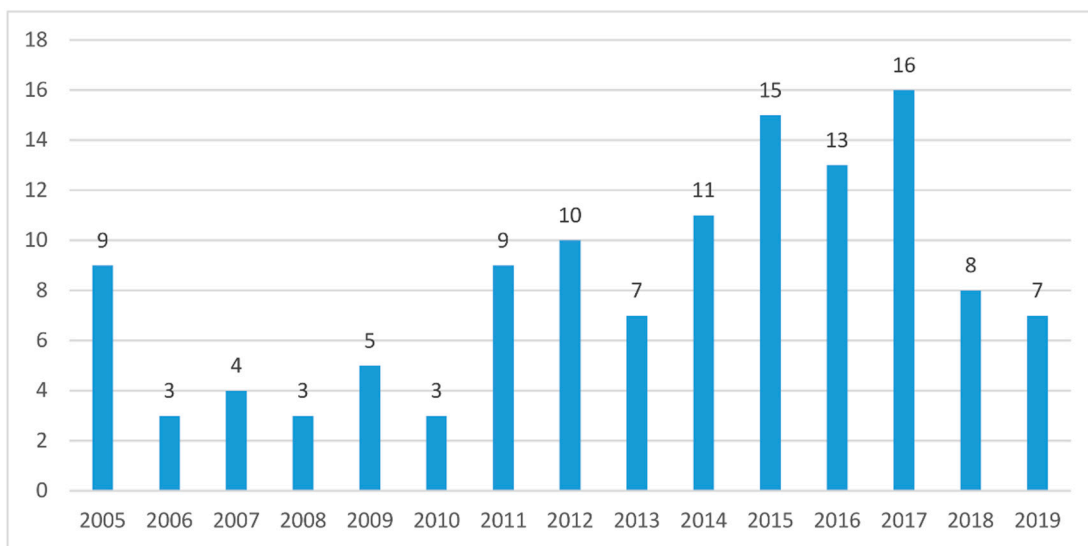


Figure 2. Number of construction auction publications and corresponding year of publication.

Regarding the time distribution of construction-oriented auction journal papers, Figure 2 indicates the increasing interest in this topic by the research community during 2010–2017, while the number of published papers decreased in 2018. For 2019, it should be noted that other papers may appear in the databases during October 2019 and later.

Figure 3 clearly shows that the majority of published papers are oriented towards business, management and accounting (34%), engineering (28%), and economics, econometrics and finance (17%) research areas. These research areas are harmonized with Scopus research areas.

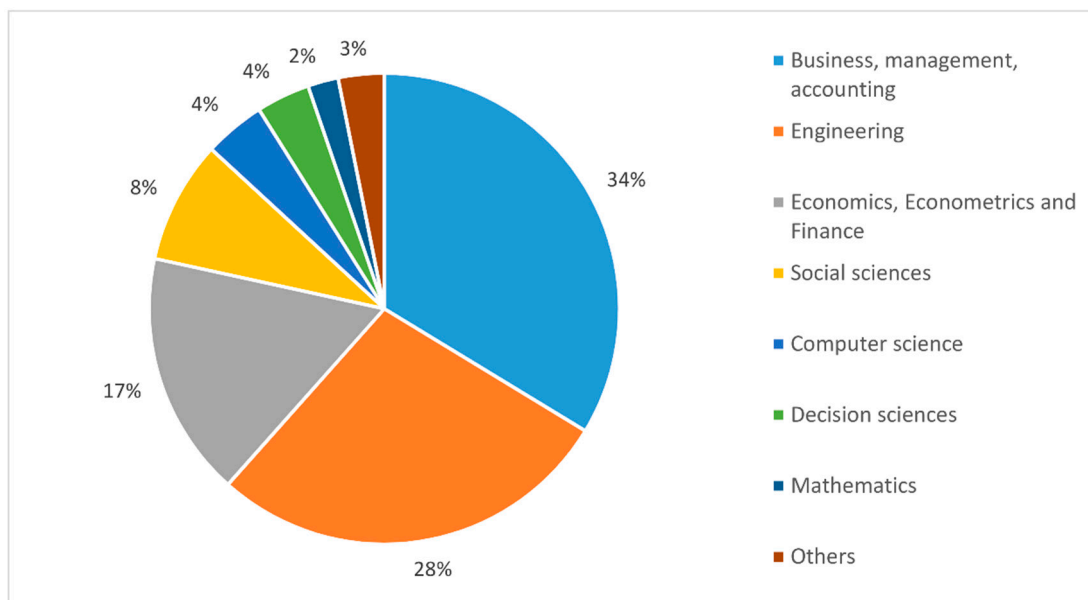


Figure 3. Research areas of published construction auction papers.

The last step of the conducted research workflow is “Thematic discussion” that consists of determining the main research areas and addressing them critically resulting in future challenges and directions. Throughout the processes of data collection and literature analysis, it was noticed that the present body-of-knowledge of eRA in the construction industry lacks a general overview and the papers are piled up in several main areas with low or no viable connections between. Those areas can be seen as the ones with solving problems that came out of specific features of the construction

sector, but also opportunities and threats for buyers and suppliers. Specifically, those main areas are the suitability of eRA for construction tenders, related drivers and barriers, ethical considerations, savings potential and bidding behavior, and bid distribution. As there is a certain gap between them, a critical overview is needed in order to open new challenges and develop new directions in the future. This is done in the following sections.

3. General Issues and Facts of eRA in Procurement

Electronic reverse auctions are often deemed as a quick and easy tool to reduce costs of purchased products (Emiliani and Stec 2002) and still can be considered as an innovative procurement route, as its use is minor in public procurement when compared to the total number of tenders. In this relation, Cabral et al. (2016) have reported only a negligible rate (0.7%) of eRA use in Portugal in the 2013–2014 period. A similarly low rate of use has been detected on the level of the European Union (European Commission 2011), and e.g., Rašić et al. (2019) found just two public tenders that used eRA in 2018 in Croatia. On the other hand, there are pioneering institutions that apply eRA in all suitable public tenders successfully, such as the town of Znojmo in the Czech Republic (Znojmo City 2012).

The relationship between buyers and sellers in public procurement in construction is complex, and there are various issues that can be seen as both positive and negative. Therefore, we address these issues of eRA in procurement through possible saving as the main benefit of such auctions, the effects on the sellers i.e., suppliers' competition, pros and cons of using eRA, as well as possible risks that could occur during bidding. Due to the sensitiveness of the process, some ethical considerations of eRA are discussed as well.

3.1. Savings as the Main Benefit and Effect on Competition

The main benefit for buyers resulting from eRA adoption is financial savings that can be achieved through effective real-time online price negotiation. Price savings are computed as a difference between historic/expected price and the lowest bid submitted. However, these savings should be viewed as gross savings, as ascertained by Emiliani and Stec (2002) and Aloini et al. (2012a, 2012b). According to them, real (or net) savings have to be taken into consideration as they reflect on switching costs, auction costs, and other losses such as the fact that the buyer may not select the lowest bid. The relative amount of savings that can be achieved in eRA supported tenders varies from 3% to 40% as reported by Pawar et al. (2017). Such a large range of relative savings reflects e.g., the type of buying situation (for straight rebuys with repeated eRA use, the amount of savings is considerably lower than for eRA supported new buys) or different supply and demand conditions on particular markets.

In light of savings potential, it should be noted that the number of bidders plays an important role among eRA variables. Wagner and Schwab (2004) note that the participation of four bidders in eRA already creates a sufficient level of competition. Increased level of competition measured in terms of the number of bidders creates pressure on suppliers to lower their margins (Jap 2007). Adding new bidders' results in higher savings achieved as proved by Delina et al. (2019), furthermore, there are also other aspects that affect savings potential such as auction format, e.g., rank-based visibility vs. price-based visibility. Yenyurt et al. (2011) claim that the effect of the number of bidders is stronger under rank-based visibility. As many buyers face the unwillingness of suppliers to participate in eRA (Wamuziri 2009), the multi-attribute auction mechanism proposed by Ray et al. (2011) could be a useful tool when limited supplier base is available.

Although the savings amount depends on a variety of influencing factors, it is not associated with the monetary value of the contract as proved by Prídavok and Delina (2013). From this perspective, it is assumed that considerable savings can be achieved even for smaller purchases. Nevertheless, Smeltzer and Carr (2003) argue that the financial volume of the purchase must be large enough to attract prospective suppliers to take part in eRA. Therefore, the low attractiveness of smaller contracts from a financial point of view must be substituted by another feature of attractiveness, such as the unique and appealing subject of purchase or high reputation of the buyer.

3.2. Pros, Cons, Risks and Ethical Considerations of eRA

Several pros and cons are associated with eRA. [Kumar and Maher \(2008\)](#) claim that eRA provides benefits to both buyers and sellers; however, buyers can benefit more. Apart from price savings, time savings and enhanced transparency of the purchasing process ([Hawkins et al. 2014](#); [Standaert et al. 2015](#); [Hanak and Selih 2017](#)) are generally considered as the other main benefits. On the other hand, the unwillingness of suppliers to participate, harm of Business-to-business (B2B) relationships, acquisition costs as well as IT requirements and skills, e.g., e-readiness, are the most often mentioned barriers for implementing eRA ([Amelinckx et al. 2008](#); [Caniëls and Raaij 2009](#); [Wamuziri 2009](#); [Hanak and Selih 2017](#); [Mora Cortez and Johnston 2019](#)). [Mora Cortez and Johnston \(2019\)](#) even argue that failed eRA often results in the termination of a long-term buyer-supplier relationship. To not get the impression that eRA contributes just to the buyers, some benefits for suppliers should also be mentioned. These benefits can be summed up in time savings, equal conditions to getting into the business (crucial in countries with a higher level of corruption), and discovering the real market price for items being purchased ([Schoenherr and Mabert 2007](#); [Hawkins et al. 2014](#); [Standaert et al. 2015](#)).

Certainly, eRA should not be considered just a margin squeezing tool, as the supplier selection can be based on multi-criteria decision-making when taking into consideration other non-price criteria ([Hawkins et al. 2010](#)) such as delivery time, the experience of suppliers, etc. This issue is also highlighted by [Cheng \(2011\)](#), who argues that eRA success depends on the awareness of the buyer's preferences. [Sambhara et al. \(2017\)](#) focused on risks associated with eRA that managers need to be aware of and must address. Pre-auction risks are of greater concern to buyers (e.g., identifying the products or services to be procured through the eRA or identifying qualified suppliers), while during- and post-auction risks are of greater concern to suppliers (e.g., aggressive bidding or to not adhere to the buyer's specifications).

One of the main risks associated with eRA is the suitability of product/service/work to be purchased. [Smeltzer and Carr \(2003\)](#) have introduced in their study appropriate conditions for successful eRA. In the first place, they refer to the requirement to clearly state commodity specifications. For this reason, [Standing et al. \(2013\)](#) recommend to apply eRA for the purchase of standardized (or low risk) products, [Pawar et al. \(2017\)](#) concretize this condition as for products with common specifications and little complexity. In contrary to these two references, there is a piece of evidence that eRA can be successfully implemented also for complex purchases (such as projects). From practice, a large project of Šance dam reconstruction can be mentioned, which had 40% gross savings achieved as a result of eRA competitive bidding ([Proebiz 2015](#)).

The final issue that should be mentioned belongs to the ethics of eRA. [Charki et al. \(2011\)](#) have investigated ethical concerns of eRA use and how they can influence eRA use in the future. In their findings, the significance of rumors in the propagation of stories about unethical behavior is highlighted. [Pawar et al. \(2017\)](#) have provided a comprehensive list of unethical behaviors in eRA on both buyers' (e.g., ambiguous or shifting auction rules, phantom bidding) and suppliers' side (e.g., collusion or unrealistically low bids). In public procurement, for bids appearing to be abnormally low contracting authority shall request in writing details of the constituent elements of the tender which it considers relevant before it may reject them ([Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the Coordination of Procedures for the Award of Public Works Contracts, Public Supply Contracts and Public Service Contracts](#), Article 55). Providing explanations for abnormally low bids enables the elimination of bids that might be subject of the winner's course phenomenon ([Soudry 2004](#)). The reasons why contractors suffer from the winner's course are given by [Ahmed et al. \(2016\)](#), such as inaccurate estimates of project cost or strong competition within the market. In this relation, [Emiliani \(2005\)](#) states that avoiding ethical misconduct, e.g., with support of codes of conduct for eRA, will lead to reducing supplier's doubts and an increased level of trust. If the eRA contributes to higher transparency of the purchasing process, all auctions rules and conditions need to be provided and clearly explained to suppliers.

3.3. Construction Industry Related Auction Issues

When analyzing eRA related papers oriented towards the construction sector by predefined keywords in detail, it has been encountered that a considerable part of papers dealing with construction auctions, in fact, do not deal (exclusively or partially) with reverse auctions. The papers that were considered highly relevant regarding their scope were kept in the set with the aim to get awareness about the main research directions relating to the specific environment of construction sector procurement, which is very close to the eRA topic.

In one of the earlier studies, [Horlen et al. \(2005\)](#) pointed out that the suitability of eRA for the construction industry should be determined. This issue is quite complex as it should be considered from different perspectives. Firstly, there is an issue of the suitability of construction products/services/works for eRA. The requirement of suitability reflects the fact whether the subject of purchase can be clearly determined. [Kaufmann and Carter \(2004\)](#) argue that high-level complexity nor specificity of the purchase should not automatically lead to the exclusion of eRA as a potential mode of negotiation. From this view, a construction project is usually very complex, however, it can be clearly specified in many aspects. For example, regarding the scope of works to be delivered in traditional DBB (design-bid-build), there is detailed project documentation with material specifications and drawings available, so the bill of quantities can be precisely determined by the buyer. Based on the bill of quantities, suppliers are able to estimate construction costs, through the bill of costs, and therefore submit their bids in eRA in an appropriate manner. However, pre-determining the amount of work to be done accurately is the main problem when estimating the bid price ([Marovic et al. 2012](#)). Nevertheless, taking into consideration specific features of the construction industry, suitability is also dependent on to what extent the subject of purchase is an intellectual property ([Hanak 2018](#)). Therefore, tender for project documentation preparation for a specific and unusual structure should not be realized with eRA as the creation of unique project documentation (or architectonic design) requires the invention of the author that cannot be considered in eRA appropriately.

Secondly, the relation between financial savings achieved as eRA benefit and quality of structures is crucial for construction projects. [Huang et al. \(2016\)](#) highlighted the contradiction between price and quality attributes and argues that they should be balanced by the buyer. Negative price-quality effects have been reported by [Pillai and Malkani \(2014\)](#). Based on the analysis of three projects, they have reported the use of cheaper and less experienced staff on the construction site as a result of eRA cost savings. In another study, the authors claim that awarding the contract to a bidder that has submitted abnormally low bids (ABL) may end up abandoning the project even before the competition ([Hatipkarasulu and Gill 2004](#)). In relation to this, a model of relationships between eRA inputs and outputs in the context of the construction sector is of particular interest as it involves and discusses post-auction effects such as supervision on the construction site or the effect of additional works ([Hanak 2018](#)). It is therefore important to pay attention when selecting capable suppliers, [Wang \(2015\)](#) proposed establishing the quality preset intervals and setting the default payment mechanism to punish the low-quality suppliers. It is desirable to prevent potential contract disputes as increased project costs might result, e.g., from resolving conflict when making the agreement for unit price payment between parties involved ([Jung 2016](#)).

Accordingly, it is becoming even more important to be aware of ABL submitted within eRA. In general, the submission of ABL and supplier's opportunistic behavior are frequently detected in all competitive bidding systems instigating the reduction of bid prices ([Lo and Yan 2009](#)). [Hanak et al. \(2018\)](#) mentioned an increased tendency to submit ABL in eRA-supported tenders compared to traditional procurement as a result of higher competition. The ability to detect ABL is crucial and belongs to the main concerns in construction procurement. In this view, [Ballesteros-Pérez et al. \(2015a\)](#) developed a quick abnormal bid detection method. They also highlighted the influence of market conditions and current workloads on the propensity to submit ABL. If the contract is awarded to ABL, there is a high probability that the winning supplier will apply some compensation strategy such as cutting corners to reduce the costs or compensation from claims to increase the payments from

the buyer. Usually, a claims recovery strategy is applied if uncertainties are detected in the project documentation or if there are expectations for potential changes in the design (Mohamed et al. 2011). In these cases, suppliers excessively raise claims in the project execution phase to maximize their profit (Yan 2015).

Thirdly, the (un)willingness of suppliers to take part in the eRA must be discussed. Olde Scholtenhuis et al. (2011) note that most construction project teams do not use available IT support. In general, the construction industry is slow in IT adoption compared to other industries despite various initiatives within Industry 4.0 such as BIM or 3D printing (Maskuriy et al. 2019). The low adoption rate also applies to eRA, Wamuziri (2009) reported a low adoption rate and claims that most suppliers view eRA as an unethical practice. In this relation, Nicholis (2018) pronounces an ethical question of whether eRA is akin to bid shopping within the construction industry. Such a low adoption rate is in line with general eRA use given in Section 3. When compared to traditional bidding, eRA tenders suffer from lower participation of bidders (Hanak 2016). Understanding and evaluation of drivers and barriers for e-procurement adoption are necessary for making the correct decision about taking part in eRA. Reasons for low e-procurement adoption are e.g., resistance to change, missing upper management support or lack of technical expertise (Eadie et al. 2010), while it may help to achieve enhanced data compatibility in transactions between the buyer and suppliers (Nesan Lenin 2011). Furthermore, there is also a noteworthy divergence in the perception of transparency, from a buyers view, transparency of eRA supported purchasing process is considered more positively than by suppliers (Hanak and Selih 2017). Enhanced transparency is actually perceived almost with the same significance as savings potential by buyers, i.e., public bodies when considering eRA adoption in construction (Hanak et al. 2018). According to Leśniak et al. (2018) and Tkac et al. (2016), financial conditions, construction conditions, type of works, past experience with similar projects, or short term for proposal preparation belong to the major criteria in the decision-making about submitting a bid for a specific tender. Definitely, the fact of whether eRA is used to select the supplier and negotiate price can be tacked to these criteria.

A significant part of research activities is related to the exploration of bidding behavior and bid distribution. These involve, for example, ascertaining differences between entrant and incumbent bidders. De Silva et al. (2003) as well as Li and Philips (2012) reported more aggressive bidding of entrant bidders and winning with lower bids. It has also been revealed that firms with experience in using eRA in bidding construction works bid less aggressively (Campo 2012). From another point of view, bid rates of diversified and specialized firms have been analyzed (Arai and Morimoto 2019). It has been revealed that bid rates of diversified firms are higher, thus, the probability to win a contract decreases with an increasing number of operational segments. From a time perspective, bidders that have lost in morning sessions tend to bid more aggressively in the afternoon compared to the bidders that won at least one contract (De Silva et al. 2002). There is also evidence about the unethical behavior of suppliers in construction tenders. One of them is collusion, which, according to Gupta (2001), is more common in larger construction projects.

Statistical analysis and models have been applied when examining bids in terms of identification of outliers (non-competitive bids, Skitmore 2002) which is of practical interest (Skitmore 2001), distribution of the number of bidders (Ballesteros-Pérez et al. 2015b), and forecasting future bids (Ballesteros-Pérez et al. 2016; Ballesteros-Pérez and Skitmore 2017), estimation of the number of new and repeated bidders (Ballesteros-Pérez and Skitmore 2016) and bidding performance (Ballesteros-Pérez et al. 2014). Soo and Oo (2014) have focused on the effect of construction demand in auctions, concluding that variations in the bid price level are influenced by varying levels of construction demand viewed from the perspective of the number of projects available for bidding.

4. Discussion and Future Directions

4.1. Future Challenges of eRA in Construction Industry

Taking into consideration that construction projects represent long-term investments, it is necessary that they provide efficiency from the entire life-cycle perspective. [Wamuziri and Abu-Shaaban \(2005\)](#) emphasize the primary objective of using eRA in construction procurement not merely to lower the contract price, but instead to obtain the best value. In addition, they claim that the best value is achievable if other criteria are taken into consideration along with the price. In such a case, the lowest-price bidder is not automatically the winner of the tender ([Ballesteros-Pérez et al. 2015c](#)). Such practice gives more opportunity to involve various multi-criteria decision methods into the process of determining the best value for the given tender.

The issue of best value has been detected in just a small number of papers analyzed. [Hatipkarasulu and Gill \(2004\)](#) argued whether the eRA process will provide the best value over the long term to the buyer. [Hanak and Selih \(2017\)](#) mentioned achieving the best value through eRA multi-criteria evaluation, which requires the implementation of scoring rules in which both bid and technical criteria are involved ([Ballesteros-Pérez et al. 2016](#)). Also, the aspect of life-cycle and life-cycle costing appears in the analyzed sets of papers rarely (e.g., in [Nesan Lenin 2011](#); [Hanak et al. 2017](#); [Hanak 2018](#)). From this point of view, best value and life-cycle issues require more detailed exploration by the research community in the specific eRA context. This relates to the exploration of the efficiency of using different multi-criteria evaluations of bids for specialized types of public projects such as roads, schools, and hospitals. For these purposes, [Marovic et al. \(2014\)](#) developed a multi-criteria decision-making model to evaluate and rank public administration projects in order to achieve higher quality and consistency of decision-making in selecting the best investment project from a public administration portfolio. They emphasized the diversity of construction projects and the need for their detailed examination while defining criteria and assigning weight for their comparison. This separate examination is really important as different construction projects have distinctive features and requirements. For example, for reconstruction of roads, the delivery time of the works is crucial in order to minimize disruption to the traffic flow; for schools, works have to be preferably planned for summer holidays, and for hospitals, it is necessary to minimize facility downtime and to enable full lift operation to provide for the transport of immobile patients. Accordingly, it is especially vital to explore the three basic project constraints (price-time-quality) in light of eRA applications in real construction projects. Especially, it is unlikely to achieve the best quality and best cost concurrently as higher quality requires the use of better materials and highly skilled workers (which require higher costs).

As mentioned above, the primary eRA benefit consists of financial savings. Accordingly, for buyers, it is vital to be able to predict potential savings. Predictive models to estimate savings amount in eRA have already been proposed by [Hanak and Serrat \(2018\)](#). However, as the construction project has several phases (planning, construction, operation, and demolition), the eRA savings potential should also be analyzed in this more detailed view. It might be interesting to reveal how eRA savings differ among the project phases. The amount of eRA savings may be related to specific features of individual phases, e.g., large reconstructions projects are typically followed with a higher level of uncertainty compared to new construction. Therefore, it can be expected that the propensity for opportunistic bidding will be higher for reconstruction projects as suppliers might achieve a financial recovery on extra works. Future research should examine this aspect further in more detail also in light of the actual price/award price ratio. Consequently, it will be possible to predict future life-cycle costs more precisely if the eRA is used.

Finally, within the literature being analyzed, the issue of the project delivery method has not appeared at all. A considerable number of papers have been published on project delivery methods, comparing e.g., the suitability/performance of design-bid-build vs. design-build ([Hale et al. 2009](#); [Park and Kwak 2017](#)) or design-bid-build vs. construction manager at risk ([Carpenter and Bausman 2016](#)). As individual project delivery methods have advantages and disadvantages, several criteria

have to be considered in order to select the appropriate one (Moon et al. 2011). From this perspective, the appropriateness and benefits of eRA use for different project delivery methods should be addressed as well, e.g., inclusion of the contractor during the design stage with the aim to provide a better design solution (Turina et al. 2013) appears to be a challenging issue within the eRA concept. The aspect of sustainability can also be involved in consideration, e.g., if speaking about public-private-partnership projects (Gao 2018).

4.2. Concluding Remarks

Based on the critical discussion of an extensive literature review, certain specific features of eRA adoption and use in the construction sector have been highlighted. Previous research focused mainly on the suitability of eRA for construction-related tenders, evaluation of drivers and barriers that affect eRA adoption, the unwillingness of suppliers to participate, estimation of savings potential, ethical considerations, as well statistical analysis of bidding behavior and bid distribution. This review opens a door for a new perspective, especially with regard to long-term effects on construction project outcomes. Therefore, the authors suggest pursuing future research in three challenging directions, namely (1) estimation of eRA effects in individual project phases and from life-cycle costs perspective; (2) considerations of achieving best value in relation with eRA use; and finally (3) exploration of the suitability and benefits of eRA for different project delivery methods.

It is believed that new findings that can be achieved within the three proposed directions that will contribute to the development of theoretical knowledge in the studied area, as well as to more informed decisions and usage of eRA by construction purchasing practitioners. In this regard, the knowledge gained in the future might significantly promote more efficient spending on the part of public agencies in construction projects.

Author Contributions: Conceptualization, T.H., I.M., and N.J.; methodology, T.H., I.M., and N.J.; software, T.H., I.M., and N.J.; validation, T.H., I.M., and N.J.; formal analysis, T.H., I.M., and N.J.; investigation, T.H., I.M., and N.J.; resources, T.H., I.M., and N.J.; data curation, T.H., I.M., and N.J.; writing—original draft preparation, T.H., I.M., and N.J.; writing—review and editing, T.H., I.M., and N.J.; visualization, T.H., I.M., and N.J.; supervision, T.H., I.M., and N.J.; project administration, T.H., I.M., and N.J.; funding acquisition, T.H., I.M., and N.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Brno University of Technology, grant number FAST-S-19-5954, and supported in part by the University of Rijeka under the project number uniri-pr-tehnic-19-18. Also, this research is partially supported through project KK.01.1.1.02.0027, a project co-financed by the Croatian Government and the European Union through the European Regional Development Fund—the Competitiveness and Cohesion Operational Programme. The APC was covered by the authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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