**Literature Review**

Public procurement is a critical component of the economy, where it constitutes a significant part of government spending. In 2023, the share of government purchases in the total budget expenditures amounted to 26%, which is 4.6% in the structure of Kazakhstan's GDP. According to public procurement policies in Kazakhstan the lowest bidder is always a winnerю That is to ensure that the maximum customer’s utility, it needs to minimize the payments at the same time ensure a required quality of service. Public procurement presents unique challenges for suppliers aiming to maximize profitability while remaining competitive lowering the price of a bid. Current systems can lead to inefficiencies and undermine supplier sustainability. Our project incorporates a key approach of calculating the difference between the first and second winners of a bid to minimize unearned revenue without sacrificing the likelihood of winning. To show the significance of unearned revenue, we calculated the missed out 300 to 600 million tenge each year from 2020 to 2024 with positive trend. This amount could sustain at least 700 medium-sized or ~5000 small companies for another year without additional revenues.

The novelty ofthis project lies not only in presenting approach of supplier-perspective view in Kazakhstan, but also leveraging Multi-Armed Bandit (MAB) frameworks and boosting algorithms. Unlike existing approaches, this model emphasizes supplier profitability and practical bidding strategies, bridging the gap between theoretical prediction models and real-world procurement needs.

**Existing approaches in public procurement studies**

* **Statistical Models**: There are models for statistical relationships for tender forecasting in capped tender (Ballesteros-Pérez, González-Cruz & Cañavate-Grimal, 2012), scoring probability graphs (Ballesteros-Pérez, González-Cruz & Cañavate-Grimal, 2013), multicriteria decision making (Dotoli, Epicoco & Falagario, 2020), the probability of bidder participation (Ballesteros-Pérez et al., 2015; Ballesteros-Pérez et al., 2016), and the optimal bidder participation to achieve the lowest procurement prices (Onur & Tas, 2019).
* **Mathematical Models**: Mathematical models include those where bidders are evaluated on the basis of price and quality through a score function (Lorentziadis, 2020), the detection of groups of bidders in collusive auctions (also called not competitive tenders or bid-rigging cartels) (Conley & Decarolis, 2016), or discriminatory competitive procedures in public procurement with unverifiable quality (Albano, Cesi & Iozzi, 2017).
* **Machine Learning Models**: Among the particular addressed problems, they are related to the behaviour of bidders: the estimation of the number of bidders in tenders (KNN) (Gorgun, Kutlu & Onur Tas, 2020), the identification of the optimal bidder (fuzzy logic) (Wang et al., 2014), creating a search engine of suppliers to recommend potential bidders for a characterized tender (random forest) (García Rodríguez et al., 2020), the detection of collusive auctions (ensemble method) (Huber & Imhof, 2019), or the proposal of an objective system (key performance indicators) for supporting the estimators (benchmarking) during the tender evaluation process (ANNs) (Bilal & Oyedele, 2020).

**Research gaps**

* Existing approaches have not focused on incorporating auction dynamics by predicting optimal bid prices, such as the second-winner price difference, it enables suppliers to minimize unearned revenue while maintaining competitiveness, which are crucial for robust and realistic price prediction models.
* Current research rarely focuses on multi-sectorial tenders and the adaptability of algorithms to diverse procurement contexts, focusing more on particular category such as high-way construction or others.
* There is limited exploration of how Multi-Armed Bandit (MAB) frameworks can independently tackle uncertainties and optimize sequential decision-making in public procurement scenarios. This stands out as it actively incorporates auction-specific variables, such as the second-winner price difference, into the prediction framework.

**Key findings of related papers**

* Artificial Neural Networks (ANNs) emerged as the most promising machine learning approach for award price prediction, outperforming alternatives like random forests and isotonic regression when carefully tuned.
* Isotonic regression serves as an efficient and fast alternative for specific scenarios, particularly in datasets with simpler structures or fewer features.
* Multi-Armed Bandit (MAB) frameworks demonstrate strong potential in optimizing public procurement outcomes through their ability to iteratively learn and balance exploration and exploitation. This dynamic decision-making process aligns with the sequential nature of procurement and bidding.
* The combination of sequential learning and adaptability highlighted in these studies reinforces the effectiveness of integrating MAB models with machine learning for tackling uncertainties in procurement, enabling more accurate predictions and optimal decision-making.

**References**

García Rodríguez, et al. (2021). Award Price Estimator for Public Procurement Auctions Using Machine Learning Algorithms: Case Study with Tenders from Spain. Studies in Informatics and Control. 30. 67-76. 10.24846/v30i4y202106.

Kim, Jong-Min & Jung, Hojin. (2018). Predicting bid prices by using machine learning methods. Applied Economics. 51. 1-8. 10.1080/00036846.2018.1537477.

Bhat, S., Jain, S., Gujar, S. et al. (2019). An optimal bidimensional multi-armed bandit auction for multi-unit procurement. Ann Math Artif Intell 85, 1–19 https://doi.org/10.1007/s10472-018-9611-0