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A probabilistic method for forensic cost estimating of infrastructure projects

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ABSTRACT

To determine the existence of overpricing in infrastructure projects a deterministic approach has been typically used by the Brazilian Federal Police. Yet, Judges have often found it too difficult to determine if overpricing had occurred as contractors have tended to claim their projects were 'unique' and therefore subjected to price increases. Consequently, Judges have had to consider the likelihood of an error occurring, which has more often led to application of the *in dubio pro reo* principle. To address the pervasive issue of overpricing in Brazilian infrastructure projects, a novel and robust probabilistic method that utilizes 'distribution fitting' using empirical data to forensically determine its occurrence is presented. Considering the limited research that has examined forensic cost estimating in construction, it is promulgated that the proposed approach can be used to support the legal fraternities worldwide to obtain a criminal conviction for overpricing of public infrastructure projects.

1. Introduction

Corruption is the abuse of bestowed power or position to acquire a personal benefit. It includes activities such as overpricing, extortion, bribery, theft, and embezzlement [1]. According to Kenny [2] the construction industry is the most corrupt sector around the world, particularly in the case of public infrastructure procurement where large payments to gain or alter contracts and circumvent regulations are common. Consequences of corruption is far-reaching: it can result in poor economic returns, reduced funding for maintenance and poor quality construction, and can potentially jeopardize work's safety. The bigger spoils are imposed to the most vulnerable people, who have no access to welfare and often to basic services as health and safety [3].

Addressing corruption in construction is a pervasive challenge and on-going problem; it is a function of human nature and thus can only be minimized. It is, however, a criminal act and therefore the consequences of being found guilty of

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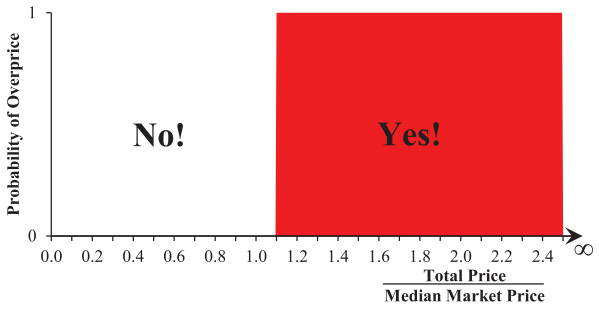

Fig. 1. Deterministic approach.

corruption can be severe (e.g., imprisonment, fines, and loss of reputation). In the context of the construction industry, it is important that authorities are equipped with the appropriate investigative techniques to address corruption [4].

In Brazil, for example, corruption is an endemic problem within the construction industry, particularly in the case of public works. Like many governments worldwide, Brazilian law requires firms to tender for the work required to delivery infrastructure projects. Yet, during the bidding it has been revealed by the Brazilian Federal Police that contractors are able to circumvent this process and overprice their contracts [5–7]. However, it is often difficult to detect and prove how overpricing has occurred; as a result to obtain a criminal conviction has been a problematic issue for the Brazilian Federal Police.

This paper builds upon the deterministic approach that has been used and reported in Signor et al. [8], and presents a novel and robust probabilistic alternative to forensically determine if overpricing has occurred in infrastructure projects. Considering the limited research that has examined forensic cost estimating in construction, it is promulgated that the proposed approach can be used to support the legal fraternities worldwide to obtain a criminal conviction for overpricing of public infrastructure projects. There have been a limited number of studies that have specifically examined nature of overpricing in infrastructure projects (e.g., [9–12]), though an extensive review of the guises of corruption can be found in Sohail and Cavill [13]. Moreover, specific details of corruption in the Brazilian construction are presented in Lopes [6].

In the next section of this paper, the approach that had been traditionally used by the Brazilian Federal Police to determine if overpricing was occurring in infrastructure projects is examined and the case for a probabilistic approach based on the use of 'distribution fitting' is then made. This novel approach is being developed by the Brazilian Police Forensic Experts through extensive workshops and will form an integral part of its arsenal of tools that can be applied to obtain a criminal conviction.

2. Moving beyond a deterministic approach

Under the existing system, experts that integrate the Brazilian legal system are required to produce court evidence to identify that overpricing has occurred. Several forms of assessment can be used such as a simple parametric method, which estimates a unitary price for each project depending on its type and characteristics. While this method may provide an initial indication that overpricing has occurred, the unitary values that are derived are not considered as valid evidence in court as they cannot be used to prove the defendants' misconducts. Thus, experts are required to re-calculate the specific point where overpricing occurred taking into account externalities that could have influenced the prices to avoid incorrect decisions being made. Accordingly, experts calculate the price and quantities of materials and labor using the median market values derived from the *National System of Costs Survey and Indexes of Construction* (SINAPI), which has been indoctrinated into Brazilian Law. The system is maintained by the Brazilian government's financing agency, Caixa Econômica Federal (CAIXA).

The law established the SINAPI's median as a clear and rigid parameter. However, contractors' defendants often argue that their client's project was unique and there were externalities not considered by SINAPI, suggesting that despite the work's price being above the legal limit a conviction would be unfair. Judges have limited engineering knowledge and hence reasonable doubt is created (Poder [14]). Acknowledging this problem forensic experts have established an agreed margin of 10% over and above SINAPI's median price (total budget) due to the variability that may exist in a market (Fig. 1). Notably, for a single item such as cement, forensic experts may allow a 30% increase over the median.

The deterministic approach provides a basis for identifying overpricing, although it does not consider underpricing. In addition, defendants can question its validity and reliability essentially because it lacks scientific rigor [8]. The deterministic approach's reliability is dependent on the *Law of Large Numbers* (LLN) (i.e. as a sample size grows, its estimate will converge to the true value). While this may be appropriate for items that are well balanced within a given budget, it is unsuitable for those that are not. For example, if a contractor's bid for a school project is 30% lower than SINAPI's median, then all legal requirements are deemed to have been met and a profit may still be obtained. Such conclusions are based on the assumption that there is a high degree of variability for quantities and unit prices available from suppliers. However, if the same contractor is hired to construct a metal structure 30% lower than SINAPI's median, then there is a likelihood that he will lose money or fail to meet his contractual obligations; the quantities (i.e., productivity) of this highly industrialized

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