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# THE IMPACT OF A NATIONAL INSURANCE DATABASE ON CONSTRUCTION CONTRACTORS' SAFETY COMMITMENT

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## Abstract

Contractors' safety behavior is shaped by various factors, including whether a national insurance database exists. Such a database, which allows insurers to adjust premiums based on a contractor's safety history, can motivate safer practices. However, in many developing countries, the absence of this system may reduce contractors' motivation to enhance safety. This research introduces an agent-based simulation model to explore how a national insurance database affects contractors' safety performance. The findings indicate that having such a database boosts overall safety awareness in the industry and strengthens incentives for contractors to improve their safety measures.

## Introduction

The construction industry is a labor-intensive sector and is thus considered one of the most hazardous industrial fields due to its uncertain and harmful nature (Elbashbishy & El-adaway, 2024). Workplace accidents continue to significantly affect the construction industry despite an abundance of regulatory frameworks and safety recommendations, causing serious injuries and deaths along with heavy economic costs (Shao et al., 2019). Nearly one-fifth of all United States work-related fatalities affected construction workers in 2022 (US Bureau of Labor Statistics, 2022). The average medical cost per workplace injury in the construction field amounts to $42,000 — approximately double the average expense incurred in other private sector industries (National Safety Council, 2023).

Consequently, many developed countries have invested in substantial safety development by adopting new safety systems, standards, and technologies to prevent accidents on construction sites (Awwad et al., 2016a; Okpala et al., 2019). However, construction safety is still at its lowest levels of performance, especially in developing countries, due to various factors, including the lack of safety awareness, poor implementation of laws and safety practices, and the absence of safety regulations monitoring by governmental bodies (Awwad et al., 2016a).

Developed countries often possess national databases that collect information on construction incidents, accidents, and safety performance (Chan et al., 2023). In the United States, the Occupational Safety and Health Administration (OSHA) collects accident data and compiles it in a national database. This data is accessible to contractors, who use it to monitor their safety performance and identify industry-wide trends. Similarly, in the United Kingdom, the Health and Safety Executive (HSE) maintains a comprehensive database on construction accidents. Studies show that contractors who actively engage with this data show improved safety outcomes, such as reductions in the frequency and severity of accidents (Gibb and Haslam, 2007). These databases serve as valuable resources for analyzing trends, identifying areas of improvement, and implementing targeted safety measures. In contrast, the lack of comprehensive data collection systems and resources poses challenges to construction safety in developing countries (Zhang et al, 2020) where contractors' safety records are not shared between insurance companies nor are made available to governments, which encourages contractors to switch between insurance companies when premiums are raised. In many developing countries, regulations related to data sharing and insurance premium calculation may not be strictly enforced and even when data is available, it may be incomplete or inconsistently reported and not regularly updated (Sadrul & Saad, 2017). Therefore, insurance companies mostly rely on internal claims history data or manually submitted reports about past accidents for risk assessment. This could mean that when a contractor switches insurers, their safety record may not be transferred or considered by the new insurer and thus may be lucky enough to not have his premium rate affected by his safety records (Moreno & Carnero, 2019).

The objective of this study is to develop a framework that mimics the construction bidding environment in a developing country and helps to assess the impact that the presence of a national database of contractors' safety records would have on the future decisions of insurance companies, contractors' decisions to improve their safety plans, and the overall safety awareness level of the market (Awwad et. al., 2016b). Such a framework can assist

national policy makers and convince insurance companies as well as contractors about the benefits of building a national insurance database despite the aforementioned challenges.

## Background

### Construction Safety Commitment

The construction industry is known for being one of the most hazardous industries globally, due to the numerous health and safety hazards associated with it (Chan et al., 2023; Baniassadi et al., 2018). The construction sector has gained a strong negative reputation for being a risky industry as a result of an increase that is seen in accidents, and resulting workplace injuries (Chan et al., 2023).

Construction injuries not only have direct costs of treatment and compensation but also have several indirect impacts on the workers such as low morale and loss of productivity (Chahrour et al., 2021; Fang et al., 2015). This also affects the project progress including completion delays, resource replacement costs, and higher insurance premiums (Buniya et al., 2021). To remedy this situation, safety measures and programs have been introduced and have even become required by law in some countries. A cost-benefit analysis of accident prevention conducted by previous studies showed that the benefits of accident prevention significantly outweigh the costs of accidents (Chahrour et al., 2021).

Implementation and commitment to safety standards vary across construction industries. In the United States, Occupational Safety and Health Administration (OSHA) regulations ensure workplace safety (Akroush et al., 2019). The European Union enacted construction safety principles in 1989 (Directive 89/391/EEC) to improve occupational health and safety, placing responsibility on employers and workers (Akroush et al., 2019). However, the construction industry in the Middle East lacks attention to site safety and worker health despite significant construction growth (Bou Hatoum et al., 2022). In the UAE, while federal law addresses health and safety, specific legislation dedicated to construction safety is lacking. A study in the UAE revealed that inadequate use of personal protective equipment contributed to a majority of injuries on construction sites (Baniassadi et al., 2018). Similarly, Kuwait's construction industry lacks safety standards and proper implementation of worker safety rights, as evidenced by data on construction site accidents (Baniassadi et al., 2018). Inspections and enforcement of labor laws are often lacking in Kuwait. In Egypt, workers on construction sites often lack training programs and safety budgets are minimal (Baniassadi et al., 2018). Another study exploring the Lebanese construction market, revealed that inadequate government enforcement of safety regulations, insufficient training and safety certifications, employee overload, and limited employee involvement in safety decisions are major factors behind the construction industry accounting for the highest number of fatal and non-fatal injuries (Bou Hatoum et al., 2022).

### Construction Safety Models

In recent decades, safety research has focused on improving contractors' safety behavior through various models. In 2013, Zhang et al. developed a BIM add-on that automatically identifies and corrects safety hazards during the design phase. This platform generates a report outlining necessary safety measures to prevent fall-related accidents resulting from planning and design (Zhang et al., 2013). Goh and Askar Ali (2016) proposed a construction management (CM) hybrid simulation framework for construction safety design. It enables information sharing and project collaboration, allowing designers and constructors to assess the impact of decisions on workers' risk exposure and incorporate safety management concerns. Awwad et al. (2016b) developed an agent-based model to simulate interactions between stakeholders during bidding and construction. This model incorporates the consideration of government fines, insurance premiums, and their relationship to contractors' safety performance. Choi et al. (2017) developed an agent-based model that explores the influence of workers' socio-cognitive processes on safety behavior and the interaction with management interventions. Baniassadi et al. (2018) developed a planning framework using discrete event simulation (DES) to improve project safety performance and productivity in complex and hazardous construction operations. DES allows for assessing alternative construction operation scenarios and selecting those that address safety and productivity concerns.

### Construction Insurance National Database

Insurance is one of the tools most often used to manage risk in connection with construction projects. There are many types of construction insurances used in the construction field worldwide including but not limited to builder’s risk, contractor general liability, and worker’s compensation insurances. Insurance premiums are determined based on specific project characteristics such as project cost, sum insured, project size, project nature, project period, location, contractor experience, and coverage limits.

A contractor’s experience and safety records have a major influence on the insurance premiums he is being charged with. A common pricing strategy for insurance companies is to use an experience modification rating (EMR) based on contractors' past safety performance to determine their future premiums (Al-Kasasbeh et al., 2021). However, reliable and up-to-date data is crucial for accurate premium pricing. Hassanein and Hanna (2008) found that the Egyptian construction market struggled with poor safety management and record-keeping practices which is the case in most developing countries.

Tracking safety records through a national database incentivizes safety compliance and accident tracking within companies and can thus help reduce the likelihood of accidents (Pi et al., 2019). However, a preliminary barrier to organizing a national database is standardizing data entry, collection and bookkeeping standards across

insurers (Kimura et al., 2020). Insurers need to see the added value in participating in the data sharing scheme and be convinced that it is worth the additional effort required to log records into the national database (Kimura et al., 2020). Furthermore, maintaining the database requires the allocation of the necessary resources from the state or otherwise an organizational effort from insurance companies among themselves. The data would also need to be stored in a way that protects insurers' and clients' privacy.

This study aims at developing a construction bidding framework where contractors are bidding against each other on different projects over several bidding rounds. This bidding process simulation is used as a platform to study the impact of having a national insurance database that stores information about safety records of all contractors from one bidding cycle to the next and updates insurance premiums accordingly. This allows to assess the influence of such a database on the market safety climate and to depict evolving contractors' safety patterns as a result of possible changes in stakeholders' safety-related decisions. Such decisions include those taken by (1) insurance companies regarding whether to insure contractors and to increase or decrease premium rates and (2) contractors vis-à-vis enhancing their safety practices and developing full-fledged safety programs.

## Methodology

### Model Description

Agent based simulation (ABS) is a simulating tool that models complex dynamic systems consisting of autonomous agents (individual or collective entities) with several attributes and interactions, and assesses the resulting emergent patterns at the system level (Bonabeau, 2002).

In this case, the agents are those contributing to the establishment of the safety culture within a construction market: Contractor, Owner, Insurance Company, Government, National Database and Project. Primary attributes and functions will be defined for each agent, along with their interactions and the impact that each agent can have on the others.

The model is initiated in the bidding stage where contractors learn about newly advertised projects and evaluate their interest and capacity in bidding on these projects. Contractors determine their bid prices based on the project cost and their insurance provider's imposed premiums. It is at this stage that contractors can try to change insurance providers to avoid premium increases in the case where a national database does not exist. If the database is active, the insurance premium increase or decrease reflects contractors' previous safety performance. The bid price is then calculated as a function of the project cost, the contractor's markup and the insurance premium.

Upon project completion, the profit is calculated as the ratio between the expected profit and the actual profit, taking into account premium increases. The difference between the expected and actual profit is stored in the contractor's profit history. If this difference exceeds a threshold set by the contractor, then it can serve as motivation for an upgrade in his safety performance.

### Agents' Attributes

The key stakeholders involved in establishing a safety culture in a construction market are mainly the following: Contractor, Owner, Project, and the Environment representing the market. The model is an improvement of an existing model developed by (Awwad et al., 2016a), which simulates the construction market as a competitive bidding environment where contractors compete against each other to win and maintain a maximum number of active projects. Table 1 describes the main characteristics of the involved agents.

*Table 1: Agents' Attributes*

| Agent | Attribute | Description |
|---|---|---|
| Owner | Owner Safety Awareness Level (OSAL) | Extent to which an owner is committed to safety |
| Contractor | Contractor safety awareness level (CSAL) | Reflects the safety measures adopted by a contracting company on its projects |
| Project | Project hazard level (PHL) | Reflects overall risks and uncertainty associated with project activities |
| Environment | Environment Safety Awareness level (ESAL) | The average CSAL of all contractors in the market at any given time |

The projects are instantiated with specific attributes, including cost, size, hazard level, and duration. Each project acts as an agent and progresses through various stages from creation to completion. For each project, a preliminary screening stage is conducted where contractors that fail to meet the safety requirements by the corresponding owner (CSAL>=OSAL) and/or the project safety hazard level (CSAL>=PHL) are not considered. If there are fewer than three contractors meeting the bidding criteria, the project is canceled.

From one bidding cycle to the next, contractors will decide to enhance their safety performance and thus upgrade their CSAL to a higher value in case any of the below conditions apply:

- Invitation Loss: Contractors may be excluded from bidding on a project if their CSAL is lower than the OSAL (Owner Safety Awareness Level). The ratio of projects lost due to not meeting this requirement to the total number of projects in the market is calculated. If this ratio exceeds 1, the contractor will upgrade their CSAL.
- Insurance Loss: Similar to invitation loss, this criterion considers projects that contractors cannot bid on because their CSAL is lower than the PHL (Project Hazard Level). The ratio of such projects to the total number of projects in the market is calculated, and if it exceeds 1, the contractor will upgrade their CSAL.
- Critical Profit: If a contractor completes a project and their profit is less than or equal to the critical profit, they will upgrade their CSAL by one level. The critical profit represents the maximum combined value of insurance premium increase and government fines that a contractor is willing to accept before upgrading their CSAL. It is calculated using the same method as actual profit calculation, with the fine and premium change levels set to the thresholds that would necessitate a CSAL upgrade.
- Critical Premium Increase: During the bidding phase, if the premium increase imposed on contractors (set by the user) exceeds a threshold randomly generated for each contractor, they will upgrade their CSAL.

For this purpose, a function Upgrade Safety Level is defined under the Contractor agent that helps decide whether a safety program upgrade is needed (Awwad et al., 2016). As aforementioned, this decision is triggered by two factors: (1) an internal evaluation of the contractor's bidding competitiveness in the market, and (2) reformative actions imposed by two main construction constituents, namely insurance companies and the government. It is to be noted here that the Contractor agent is designed in a way to make a tradeoff between upgrading its CSAL or coping with an insurance premium increase. In other words, if an insurance company imposes a premium increase on a contractor's new project as a consequence of its prior poor safety performance, the contractor has the choice to remain with the same insurance provider and pay the premium increase or switch to a new insurance company that may provide lower premium rates (Awwad et al., 2016).

The study assumes that a contractor's upgrade of its CSAL takes one year to be implemented. In other words, a contractor's new CSAL will not take effect in ongoing projects, but rather when bidding on projects one-year from the time the upgrade decision was made. This is to reflect the time frame that it normally takes companies to develop and implement company-wide safety programs. This is normally coupled with a financial investment allocation from the contractor's retained earnings, however, this was not taken into consideration in the current version of the model to avoid further complexity.

**Simulated Scenarios**

Improvements to safety behavior are reflected through tracking the environment safety awareness level (ESAL) and the average contractor safety awareness level (CSAL) over the simulation time during two distinct scenarios:

1. Database inactive: When the database is inactive, contractors have the option to change insurance providers to avoid paying higher premiums for having a low CSAL during the bidding stage. Furthermore, the insurance premiums imposed are based on their performance on individual projects rather than their cumulative safety performance.
2. Database active: When the database is active, contractors can no longer evade higher premiums and their total number of accidents impacts the premium they have to pay. Contractors who have a greater number of accidents will thus have higher premiums and be less competitive during the bidding phase. Furthermore, the increased premiums mean that profits will be lower which can trigger the motivation to upgrade.

To understand the effect of the national insurance database on the contractor's and eventually the market's safety performance, several variables are monitored and analyzed. These variables include:

1. Environment Safety Awareness Level (ESAL): ESAL serves as an indicator of the overall safety level in the market. It is calculated by tracking the average CSAL of all active contractors. Monitoring ESAL allows for observing trends in safety behavior over time and assessing whether the database's activity leads to improvements and generates a higher ESAL.
2. Number of contractors who upgrade their CSAL: Tracking the number of contractors that upgrade their CSAL provides insights into the database's impact on improving safety behavior among contractors.

## Results

Findings of this study showed that the national insurance database plays a significant role in improving environmental safety, resulting in a notable increase in its value. The comparative analysis in Figure 1 demonstrates the disparities between the active and inactive scenarios, showing the evolution of ESAL with time. When the database is active, the Environmental Safety Awareness Level (ESAL) reaches 2.08, compared to 1.82 when the database is inactive.

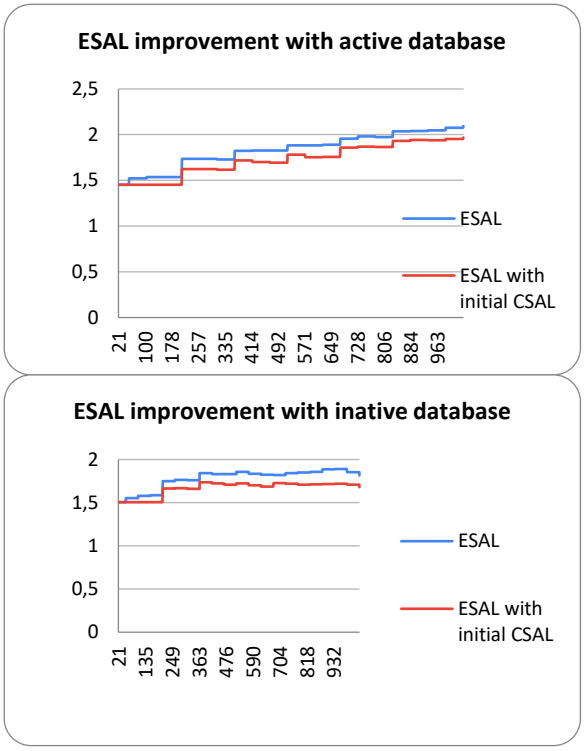


*Figure 1: Active vs inactive database effect on ESAL*

Figure 2 shows the total number of contractors who have upgraded their CSAL within an active database versus an inactive one.

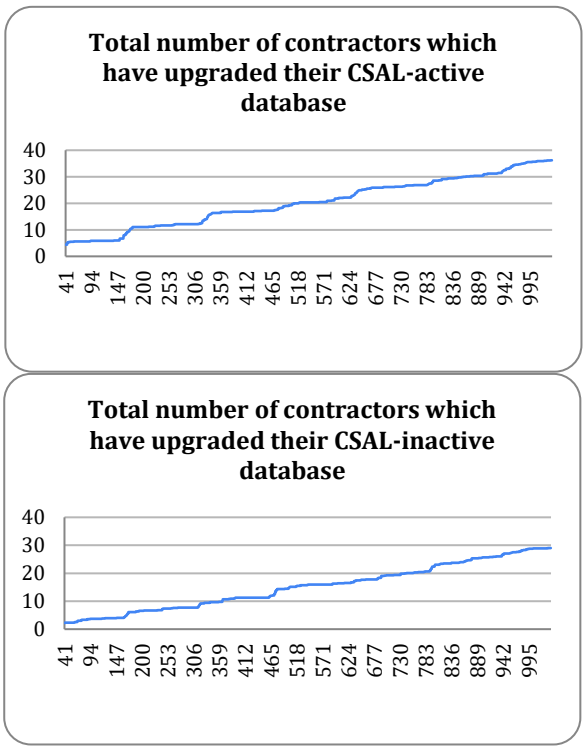


*Figure 2: Active vs inactive database effect on CSAL upgrade*

It is observed from Figure 2 that the database acts as a compelling incentive for CSAL upgrades by reducing profits for contractors with a high number of accidents, thus accelerating their progress towards the upgrade threshold. Furthermore, the database promotes the survival and prominence of contractors with higher CSAL by eliminating contractors with poor safety performance. This observation is also evident in the smaller gap between the ESAL derived from initial CSAL values and the ESAL that considers upgrades. The pronounced spikes in ESAL depicted in Figure 1 indicate the systematic removal of contractors with substandard CSAL values.

## Conclusion

This study presented a construction bidding framework that was used to study the impact of a national insurance database on contractors' safety performance evolution. The model depicted a competitive bidding environment where contractors, operating at three safety levels, compete for a limited number of projects or choose to remain inactive. Safety levels are measured by the average safety level of each contractor, with provisions for upgrades under certain conditions.

The database prevents contractors from avoiding higher insurance premiums by considering their overall safety performance, including the number of accidents. The study shows a significant increase in the number of contractors upgrading their Contractors' Safety Attitude Level (CSAL) and improved overall safety awareness in the market.

This paper proved that improvement to safety behavior can be realized through a unified safety records database, providing a particularly useful avenue for policy makers and action within developing nations where the sector continues to grow rapidly while construction safety enhancements are direly needed. The results of this study offer a concrete timeline for safety improvement, demonstrate a noticeable impact in terms of overall safety performance explicable by the added incentive for contractors to upgrade their behavior and the loss of market viability incurred by poor safety records. Future work will explore the option of inter-insurer accident history sharing agreements as a potential less challenging and more achievable replacement of a national database. This also provides the opportunity to assess the impact of transparency and level (partial versus full) of data sharing among insurance companies on the improvement of safety commitment and practice in the construction sector.

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