PROPOSAL ABSTRACT:

Title: Strategy and unpredictability to deter crime and improve security perception in urban areas using Stackelberg games approach.

Abstract. Crime in urban environments is an inevitable phenomenon that affects society as a whole. All organizations responsible for public order seek solutions to control crime and improve citizens' perception of security. In Chile, 32% of households had a member who was a victim of robbery or attempted robbery (Ciudadana, 2022), and 67% of the population expresses great concern about crime and violence (Gebrekal, 2023). Thus, Chile is the country with the greatest fear of crime worldwide putting pressure on political and police authorities to create a safer environment for citizens.

A notable characteristic of urban crime is that the most of them are opportunistic in nature, meaning that criminals do not plan their attacks in advance but instead seek out opportunities to commit crimes and act swiftly (Zhao et al., 2020). To deter this type of crime, e.g., burglary, larceny, motor vehicle theft, assault, robbery, vandalism, public drinking, illegal street vendors, and micro-trafficking, the police authority maps crime hot spots and conduct on-site surveillance patrols (patrolling) or allocate police officers to hot spots during a given time interval (spot allocation). However, opportunistic criminals adapt their strategy by seeking opportunities to offend in less patrolled areas or where there is scarce or non-existent police presence, since their strategy depends on the risk of being apprehended, where risk is measured by the on-site police surveillance probability. Thus, two issues are relevant for the police authority seeking to reduce the crime or victimization rate: (i) determining the temporal-spatial distribution of the on-site police surveillance probabilities over the urban area (including hot spots) that deters the greatest number of opportunistic criminals and (ii) designing unpredictable on-site police surveillance schedules (patrolling and spot) from the perspective of the opportunistic offender, since a predictable on-site surveillance schedule can be exploited by potential offenders to their advantage.

The problem of determining the temporal-spatial distribution of surveillance probabilities, denoted as *on-site police surveillance strategy*, can be viewed as a Stackelberg game in which the police authority (*the leader*) sets the in-situ surveillance probabilities over an urban area, and the criminals (*the followers*), observing this strategy, decide where and when to commit the crime by maximizing their utility function, which depends on the risk of being apprehended. An on-site police surveillance strategy can be operationally implemented through an *unpredictable on-site surveillance schedule* which consists of a set of surveillance schedules with a probability of being selected. Thus, the police authority can choose each day an on-site surveillance schedule (patrolling or spot) with a probability, avoiding any regularity that can be exploited by opportunistic criminals.

As far as is known, all previous work addressing the implementation of an on-site surveillance schedule to deter urban crime, under Stackelberg game approach, provides a pure strategy for the police authority, even if this was generated by a random mechanism, e.g., Markovian processes (Wang and Cui, 2023; Zhao et al., 2020; Miyano et al., 2020; Cuya, 2019; Zhang et al., 2016; Espejo et al., 2016; Lauri and Koukam, 2014; Zhang et al., 2013; Bier et al., 2007; Santana et al., 2004). A pure strategy, under a Stackelberg game approach, is the on-site police surveillance schedule that contributes the most to the police authority's objective function. However, the daily implementation of a pure strategy does not consider that criminals are adaptive. As a result, the criminals will learn the police authority's strategy.

This research project addresses the operational implementation of an on-site police surveillance strategy (patrolling and spot) using an unpredictable on-site survaillance schedule (patrolling and spot) under a Stackelberg game approach. The challenge is to determine the set of on-site surveillance schedules and their respective probabilities of being selected whose systematic day-to-day implementation coincides with the surveillance strategy defined by the police authority in the medium term. Thus, this research project aims to expand and improve the design of on-site police surveillance strategies (patrolling and spot) and unpredictable surveillance schedule (patrolling and spot) in urban areas, from the Stackelberg game point of view, taking into account realistic models for the reaction of opportunistic criminals, realistic models for the actions of the police authority, ensuring the quality of the solutions in terms of the optimality gap, and determining the time interval of their implementation. The expected results are practical and novel mathematical tools to schedule unpredictable surveillance patrolling and spot police allocation, in urban areas, to deter the most significant number of opportunistic criminals.

The design of an unpredictable surveillance schedule to deter opportunistic criminals can be formulated as a bilevel optimization problem. At the first level, the police authority determines the set of on-site surveillance schedules (patrolling or spot) and their respective probabilities of being selected that contribute most to its objective. Then, at the second level, opportunistic passengers respond by optimizing their objective function (based on the behavior of opportunistic criminals), given the probability of being apprehended. This approach assumes that the set of all surveillance schedules is known, which is difficult to enumerate in real urban area because this set grows exponentially with the size of the urban area. In this project, we propose to explore decomposition methods to address the combinatorial nature of this problem, e.g., column generation and the Bienstock-Zuckerberg Algorithm. Another approach to formulate the unpredictable surveillance schedule is through a single-level optimization problem, where the optimal reaction of the criminals is predicted by learning method and reformulated as a constraint.

This project also explores citizens' perception of security by formulating this problem as a Stackelber game in which the police authority establishes a distribution of patrolling probabilities and citizens react by changing their perception of security.

In this project a three-year work plan is proposed, where the workload has been carefully balanced to achieve the proposed objectives.