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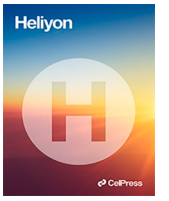

Research article

Evaluation of the impact of security perception on the structural changes of MSEs through system dynamics

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ABSTRACT

Micro and Small businesses (MSEs) face several challenges to survive in the market, some of these challenges are related to security matters which are the subject of this article. In Mexico MSEs are victims of crimes such as extortion, theft, and assaults, among others; this situation leads them to spend their economic resources to make structural changes to be able to continue with their commercial activities. This article is based on a survey conducted on 370 MSEs in the central region of the state of Veracruz in Mexico; the present study aims to evaluate the impact of structural changes made by businesspeople in their perception of business security. In this way, the decision-making process of MSEs facing insecurity is statistically analyzed through a simulation model considering the system dynamics methodology. To evaluate this phenomenon, we have identified four main subsystems: 1) Crime, 2) Security Perception, 3) Structural Changes, and 4) Government Policy Changes; at the same time three hypothetical scenarios were simulated: 1) Reduction in crimes committed against MSEs, 2) Government changes in public infrastructure, and 3) the combination of the previous two. The approach allows us to identify that companies make structural changes based on the events around them, rather than on the crimes that they suffer, making abrupt or precipitated decisions. Therefore, we have identified that it is not only necessary to eliminate crimes, but also to work with government strategies that allow MSEs owners and staff to improve their perception of security. This simulation model can be replicated to evaluate the implementation of security policies in other regions with high insecurity rates.

1. Introduction

Crime and corruption significantly threaten economic growth, affecting business development in both rich and poor countries, especially developing countries [1]. Crime and corruption can take many forms, such as robbery, extortion, kidnapping, homicide, cyber fraud, bribery, embezzlement, money laundering, and tax evasion, among others [2]. The above causes companies, regardless of their size, to take appropriate measures to not be exposed to this type of situation [3].

There is a large number of studies on the effects of crime and corruption, mainly based on one of the following approaches: i) aggregate measures of crime and corruption at the country level, ii) measures of corruption at the firm level using business surveys [4]. Although equally, numerous studies highlight the importance of crime in explaining the deficit in growth at the macroeconomic level

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(for example, [5,6]). However, a gap has been identified in the existing literature on the impacts that crime or corruption have on the decisions made by MSEs, no study has explicitly examined the structural changes that these companies have made to feel safer. This gap is probably due to the absence of particular data on crime perception rates in MSEs [7]. Therefore, the importance of this study lies in the evaluation of the impact of the perception of security that being exposed to some form of crime or corruption has on the decisions made by company administrators. Evaluating the above is considered relevant because the effect of corruption or crimes could be more serious in MSEs than in large companies for three reasons:

First, MSEs often face many obstacles in their business operations, such as difficulties in accessing external financing [8] and adapting to uncertainties in new policies or an institutional environment that would affect their businesses, for example, controlling corruption [9].

Second, these companies are more sensitive to uncertainties in economic policies compared to large companies, since the variations in the macroeconomic dynamic and business levels changes significantly affect the fragility of MSEs [10].

Third, microenterprises make up about 63–72 % of all businesses revenue globally [11], while small businesses make up about 9–18 % [12]. These percentages reflect the predominance of micro and small businesses in the global panorama, as well as their importance in the economy.

In Mexico, MSEs represent approximately 99 % of all companies, leaving a small percentage for medium and large ones. These figures underline the relevance of MSEs in the country, not only due to their number but also due to their contribution to job creation and economic development [13]. However, according to the data obtained by the National Institute of Statistics and Geography [14] in the National Company Victimization Survey (ENVE), a total of 2,868,604.6 crimes were recorded against MSEs in 2022 in the country; Among the total of crimes we can find that the more common were extortion (28.90 %), theft/assault of property or money (19.71 %), theft (12.86 %), acts of corruption (10.84 %) and fraud (10.16 %). Additionally, the states with the most crimes were Ciudad de México, Estado de México, Puebla and Veracruz; Microenterprises are the most attacked with 85.43 % of the crimes followed by small businesses with 10.32 %, the addition of these two represent 95.75 % of the crimes committed in total [15]. If the above is contrasted with the data observed in 2018, where 32.95 % of the economic units that were victims of crimes were microbusinesses and 51.40 % were small businesses, totaling 84.35 % [16], then it is possible to identify that in Mexico the Crime has increased for this sector.

Therefore, being able to evaluate the impact that the perception of security has on the structural changes made by the MSEs in Mexico, specifically in the center of Veracruz, requires a systemic approach, where the interaction that exists between the elements of the system such as: crimes, companies, security perception, policies, structural changes, and decision-making processes, among others, are complex, which is why studies without a systemic approach are considered to have a more limited perception of the situation. For this reason, in this article, the System Dynamics (SD) methodology is used, which is a methodology that allows us addressing the complex relationships between the variables of a system. Furthermore, it has been used to analyze perception in works such as those carried out by Ma et al. [17]and Zhang et al. [18].

The objective of this study is to carry out a simulation model under the previously mentioned methodology, where scenarios can be evaluated regarding changes in government policies or public infrastructure, in order to identify how this would affect the perception of security of the companies and in turn in the structural changes of the same, for which, the responses collected from a survey carried out with 370 MSEs administrators from the center of Veracruz, in collaboration with the Network of Latin American Studies of Administration and Business in 2019 [19], under the theme "Effect of crime and corruption on micro and small businesses in Latin America."

The rest of the article is organized as follows. Section 2 examines the literature on the negative externalities of crime or corruption in business. The general explanation of the field study and the methodology used for this study is presented in Section 3. A detailed description of the application of the pre-survey and the development of each of the stages of the system dynamics methodology is described in Section 4. Finally, Section 5 shows the result of the scenario evaluation using the simulation model and Section 6 offers concluding remarks.

2. Literature review

Safety perception refers to the individual feeling and understanding of various objective risks existing outside and emphasizes the influence of individual intuitive judgment experience [18]and subjective feeling on cognition to analyze, control and manage the risks [20]. The perception of security is determined by the interaction of various personal, social, and institutional factors [21]. In the case of companies, they are more likely to seek intervention strategies from personal and institutional factors of the company to improve perception [22]. According to Flores et al. [23],crime in companies includes any type of harmful behavior against personnel and the activities they carry out. In this sense, crime serves as one of the main variables that interferes in decision-making within companies, preventing growth by generating changes in the behavior of society and generating a perception of insecurity which affects management strategies. Management [24] studies have been developed to evaluate the impacts that security has on companies. For example, for extortion or theft, authors such as Besley and Mueller [25] modeled the need for companies to defend themselves against criminal activity. Their empirical analysis revealed that support protection costs led to significant production loss as a result of labor misallocation; Similarly, another study identified that extortion results in massive misallocation of resources for companies [26]; and the identification of other sources of distortion can be found in the market structure and the allocation of public resources, as illegal organizations reduce competition in the market [27].

For cybercrimes, Rae, A. and Patel, A. [28],created a simplified process for measuring cybersecurity hygiene by introducing the idea of a rating scheme within a company; A study by Renaud, K. and Ophoff, J. [29], provided an interesting insight into small and medium-sized businesses and the guidance and advice they had received from the UK government regarding cybersecurity; and Pawar,

S. and Palivela, H [30]. present an article that explores the challenges that companies face when making decisions, planning and implementing cybersecurity controls, identifying that these are no different worldwide.

Studies that analyze corruption were based on subjective measures such as the Corruption Perceptions Index [31], Global Governance Indicators [32] or the International Country Risk Guide [33] in which opinion surveys were carried out with experts; Although the effects of corruption, extortion, cyber fraud, and theft in small and medium-sized enterprises (SMEs) have been widely analyzed separately, there is still a lack of a study that analyzes the effects of these together, adding another types of minor crimes such as robbery or major crimes such as homicide in the MSEs.

As mentioned in the previous section, analyzing the interaction of all these crimes, together with the decisions made by MSEs to make structural changes, requires a systemic approach, with SD being a powerful tool that helps analyze the behavior of complex systems to evaluate [34] and feedback information [35]. Furthermore, the SD serves as a method to combine qualitative and quantitative analysis, in this case, it will allow simulation of qualitative situations, such as the perception of security in the administration of the MSEs, and quantitative situations, such as the number of crimes suffered by each company. Its most notable feature is the ability to address non-linear [36], high-order [37], multiple feedback [38], and complex time-varying system problems [39]. Similarly, SD can simulate the behavior and development trend of things by constructing a social system model, by observing the behavioral changes of the variables in the model, the effects of policies on the social system can be analyzed [40].

Taking the above into account, the gap in the literature that this article aims to address is to evaluate the impact that the perception of security has on the structural changes made by the MSEs, through a simulation model that uses a systemic approach that allows simulating different evaluation scenarios.

3. Materials and methods

As mentioned above, to meet the objective of this research article, a database obtained from a previous study is used to analyze it using the system dynamics (SD) methodology. According to Forrester [41], and, Cedillo & Sánchez [42], four stages help develop

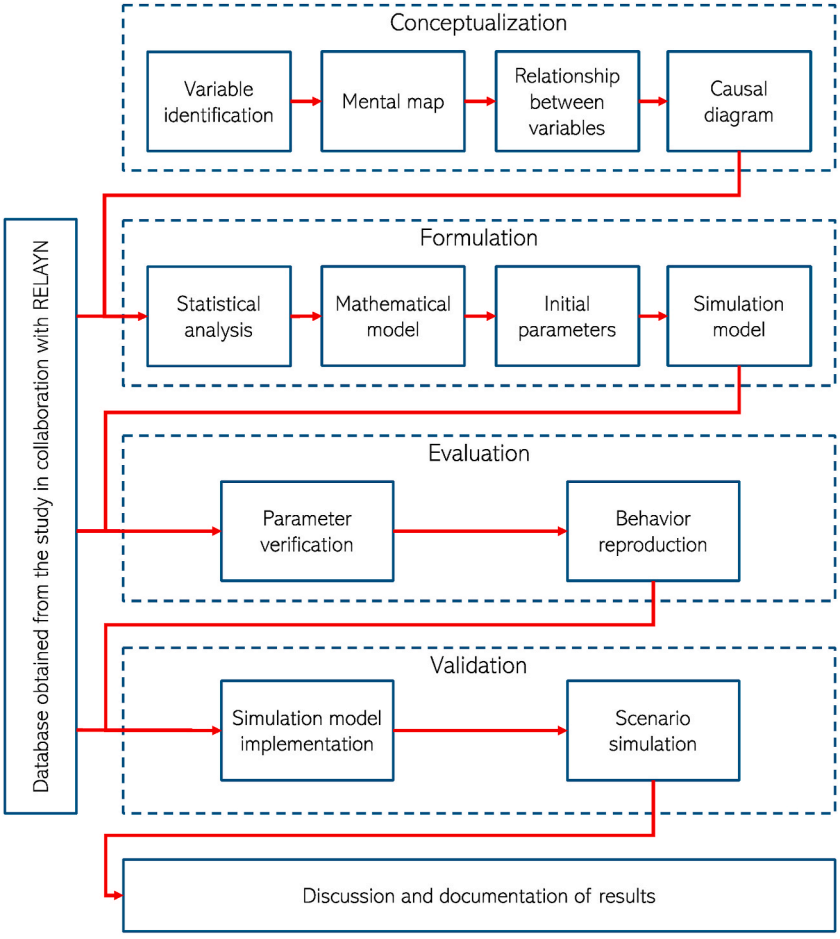

Illustration 1. Methodology used in the study.

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system dynamics models: conceptualization, formulation, evaluation, and implementation. The steps of the methodology include the previous study and the four stages of the SD. The steps are shown schematically in Illustration 1 and are described below.

a) ***Previous study.*** This study was conducted in 2019 in collaboration with RELAYN in the Córdoba, Cuitláhuac, Fortín, and Yanga regions of Veracruz, Mexico with a causal scope and quantitative approach, which is generated from a sample with proportions of 50 %, reliability of 95 %, error of 5 %. having as study subjects the directors/administrators/owners of micro and small businesses.
b) ***Conceptualization.*** In this stage, the variables existing in the system are identified, concluding in a mental map or blocks that will allow a general perspective of the system. Likewise, a causal diagram is constructed, which is a graphic representation of the relationships between the variables of the system and how they impact each other.
c) ***Formulation.*** Statistical or forecast analyses are conducted to define the mathematical behavior of the variables that impact the system studied and generate the necessary equations, with which the simulation model is programmed. In the same way, the initial values of the parameters are defined.
d) ***Assessment.*** In this stage, the verification and validation of the simulation model are conducted to ensure that it behaves as expected. There are eighteen tests to evaluate and validate dynamic simulation models. Parameter verification and behavior reproduction are used for this article.
e) ***Implementation.*** Once the model has been evaluated and validated, it can generate results, therefore, it can be used to simulate scenarios that help in the analysis of the system studied and in this specific case to identify the impact that the perception of security has. in the structural changes made by the last link in the supply chain.

4. Development

The development of the stages mentioned in the previous section will be described below.

4.1. Previous study

The Latin American Studies in Administration and Business Network (RELAYN) has worked for 10 years together with 112 research groups, from 91 universities both nationally in Mexico, and Latin America with Ecuador, Colombia, Argentina, and Peru; having 451 researchers under the same object of study: micro and small businesses, using a systemic analysis instrument focused on a particular aspect each year, in 2019 the topic was ***"The Effect of crime and corruption on micro and small business in Latin America"***. The authors have been part of the research group of the Technological University of the Center of Veracruz that has collaborated with RELAYN for 8 years.

The research and data collection process are systematically developed as follows.

- Stage 1 - RELAYN general assembly. The research begins with the RELAYN call for academics, researchers, Academic Bodies, and Research Groups in the economic-administrative area and related areas that belong to public or private universities.
- Stage 2 - Registration in RedesLA. The acceptance and registration process of the research groups that will be participating in the corresponding annual research is conducted; The work team is defined, and the activities are made official before the network and the Institution to which it belongs.
- Stage 3 - Meeting with RELAYN Academic Committee. At this time, the context of the year's research is established, the considerations for participation, the use of the RedesLA platform, and the training process for the students who will oversee collecting the data are established. In this case, we worked with 180 students from the Business Development Educational Program of the Technological University of the Center of Veracruz. The details related to the investigation are determined, which is carried out collaboratively and directly focused on the director of the micro and small business, it is a conclusive investigation, with a causal scope with a quantitative approach, which is generated from a sample with proportions of 50 %, reliability of 95 % and error of 5 %. The resulting optimal sample size was 370 MSEs.
- Stage 4 - Review of collection/training instrument. The collection instrument is a questionnaire with thirteen variables that considers the systemic aspect of the company, and 66 items designed from a five-level Likert-type scale (strongly agree, agree, disagree, strongly disagree, don't know/not applicable), except for the corruption section where it was done through dichotomous questions. The research variables were contained in six sections: a) company characteristics, b) director data, c) system inputs, d) system processes, e) system output, and f) corruption and crime; adding the variable perception of corruption.
- Stage 5 - Application of surveys and capture of results. For this point, a distribution of micro and small businesses in the corresponding region is made. In this case specifically, we worked with the regions of Córdoba, Cuitláhuac, Fortín, and Yanga of the state of Veracruz, Mexico; They are distributed in the three commercial, manufacturing and service sectors. Once the fieldwork is completed, the questionnaires are captured on the RedesLA platform specially designed for this research.
- Stage 6 - Review and validation of surveys. The research group oversees reviewing and validating the surveys on the platform. Once this review is completed, the results are analyzed.
- Stage 7 - Review and delivery of results. At this point, the research group conducts the process of validating the corresponding results. The collected database can be worked on for the analysis that the research group wishes.

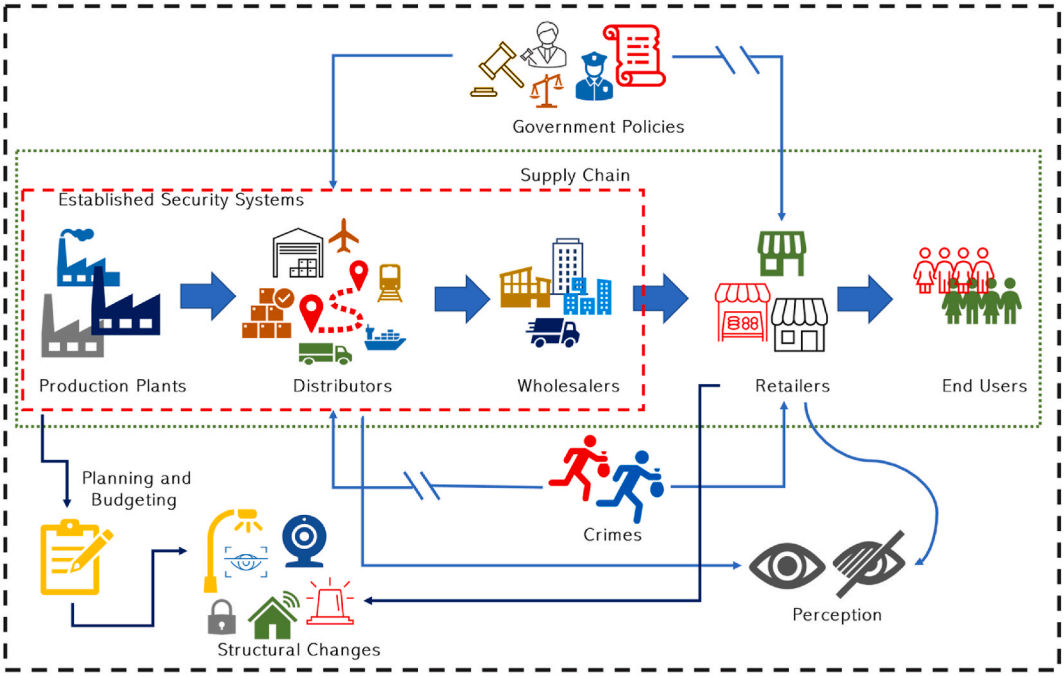


Illustration 2. Conceptual diagram of the security perception of Micro and Small businesses.

This study concludes that Micro and Small businesses consider insecurity and crime to be the main factors affecting insecurity and crime, firstly, because of the population's low purchasing power and the lack of punishment for criminals, and it is ratified as second option to insecurity and crime, corruption, and lack of punishment for criminals.

The most worrying aspect was the perception of businesspeople regarding the different crimes committed around MSEs. During the last year, 74 % consider being a victim of phenomena such as gangs and/or criminal gangs, 52.4 % indicate the existence of organized crime, 66.5 % identify vandalism against establishments, and 66.5 % the consumption and/or sale of drugs in the surroundings. Likewise, 75.7 % of companies stated that the existence of robberies or assaults is frequent; 43.2 % kidnappings, 40.3 % homicides, 50.5 % extortions by criminals, 41 % collection of apartments by criminals, and 34 % extortion by authorities against the establishment. It is important to mention that in this study it was decided to use the 2019 database because the crime data could have been affected after this year since the global concern was the pandemic that occurred from 2019 to 2023. In addition, it was possible to identify that the perception of security that MSEs entrepreneurs had strongly influenced the structural changes that they made within their companies. This situation was the basis of the present study, where the need for a methodology was identified that would allow analyzing the impact that the perception of security has on the structural changes made by the MSEs since this can mean high administrative costs that could lead to a lack of control and subsequently bankruptcy. The selected methodology was SD, the stages of which are explained in the following sections.

4.2. Conceptualization

The first stage of the system dynamics methodology is based on conceptually identifying the variables of the system, as well as the relationships between them, this process is described in the following subsections.

4.2.1. Conceptual model

As mentioned previously, this article seeks to analyze the impact that the perception of crimes has on the structural changes made in the MSEs, therefore, the conceptual model of the system is shown in Illustration 2. The green box represents the agents that interact in a supply chain: Production plants, Distributors, Wholesalers, Retailers, and End Users; where the elements enclosed in the red box are larger companies, which have well-established security systems and contingency plans for each situation that could arise, for this reason, crimes occur less frequently, or if they occur, there is a plan and budget to be able to make improvements for safety. On the other hand, outside the red box, there are Micro and Small companies, where crimes occur more constantly at the companies themselves or around them, this causes the perception of crime to be biased, resulting in decisions abrupt and hasty in making structural changes to improve safety. Likewise, it should be noted that the correct application and improvement of government policies is an important part of ensuring that crimes decrease, and that companies' perception of security improves.

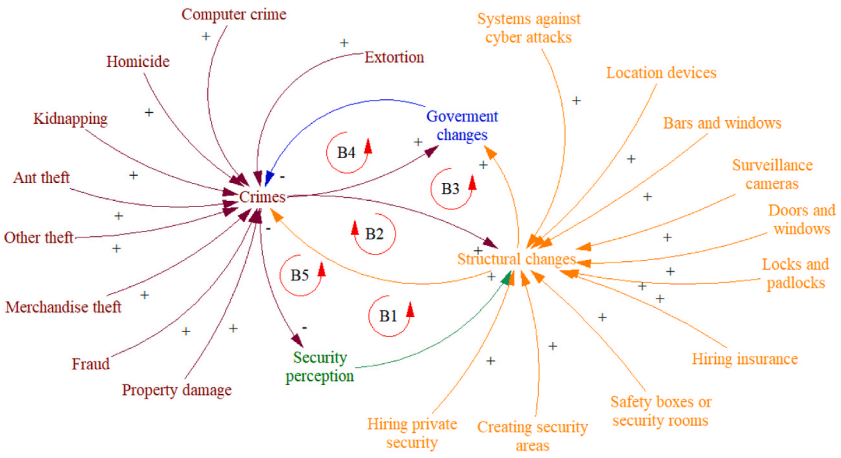


Illustration 3. Causal diagram of the security perception of Micro and Small businesses.

4.2.2. Causal diagram

The conceptual model of the system, described above, will allow the identification of the existing variables and the relationship between them. The structure of this behavior is represented by a causal diagram (CD), which is a graphic tool that serves to represent the interaction of the system variables.

A DC consists of variables connected through arrows that indicate cause → effect relationships (A →B), these relationships can be positive or negative. If the relationship is positive, an increase or decrease in the cause will respectively generate an increase or decrease in the effect. If the relationship is negative then an increase or decrease in the cause will respectively cause a decrease or increase in the effect [43].

The CD of the present study is shown in Illustration 3, where you can see four subsystems that represent the critical variables of the system: Crimes, Perception of insecurity, Structural changes, and Changes in government. The Crimes subsystem considers all the types of crimes with the highest occurrence; The Perception of Insecurity subsystem identifies the different situations in which companies feel vulnerable; The Structural Changes subsystem encompasses the changes that companies have made to improve their security levels; and finally, the Government Changes subsystem refers to the preventive or corrective measures that public administrations can carry out.

These four subsystems generate five feedback loops that generate complex relationships between the variables, which is why system dynamics is a robust methodological tool for identifying the perception of crime in MSEs. The relationships in each loop are described below.

- ***Loop B1.*** It relates the variables of *Crime, Perception of insecurity, Structural changes, and Changes in government.* When *Crimes* increase, the *Perception of insecurity* in companies also decreases, which in turn influences decisions about the *structural changes* that they could make. This loop is balanced by the *changes in the government concerning* the structural changes made by companies, since if precise policies are implemented, *crimes* should be reduced, on the contrary, if no changes are made in policies or if they are not adequate, then the *Crimes* remain or increase.
- ***Loop B2.*** This loop involves the variables *Structural Changes* and *Crimes*, where if the latter increase, companies will seek to improve their security by increasing the number of *Structural Changes*, ideally this would lead to *Crimes* being decreased.
- ***Loop B3.*** The variables of *Structural Changes, Changes in Government,* and *Crimes* are the ones that are interacting in this loop. The relationships presented are remarkably like loop B2, however, in loop B3, Changes *in government* influence the decrease and/or increase in *Crimes.*
- ***Loop B4.*** The relationship that exists between the variables *Changes in Government* and *Crimes* is equal to loop B3, however, in B4 the changes, that companies make, are not considered, if the government must have plans for the implementation of policies that improve the security of companies.
- ***Loop B5.*** This identifies the relationships between the four subsystems where the increase in *Crimes* decreases the *Perception of security* for companies, this causes them to make *structural changes* to improve security, demanding that the government make changes as well with the purpose to reduce the number of *Crimes.* in the zone.

4.3. Formulation

To conduct the simulation model, it is necessary to define the equations and parameters that will be programmed. The mathematical model used for this research is based on the data collected from the survey detailed in section 4.1. Because it is conducted punctually by asking managers to consider the information from the last year for their response, in the formulation of the mathematical and simulation model it is considered that the events occur throughout a calendar year and are identified. the probability of occurrence for each of the days.

4.3.1. Mathematical model

The mathematical equations define the behavior of the critical variables (each subsystem) and auxiliary variables (those that serve as support to adapt the desired parameters).

a) Crimes. Table 1 presents the equation corresponding to each of the crimes considered, as well as the necessary parameter. In the case of crimes, eight of them fit a Poisson distribution, except for other types of robbery, for which an adaptation to an empirical probability distribution had to be made.

To identify the total number of crimes committed against businesses during a year, we used the following equation to accumulate them in a level variable.

$$TCrimes = Crime|_{t=0} + \int_1^t Crimes\ dt$$

Where,

$$Crimes = Mt + At + Ot + Kid + Hom + Cc + Ext + Idp + Fra$$

b) Security perception. To represent the perception of security, a Likert scale is used in six main questions, with 1 being the lowest response level and 5 being the highest, the sum results in a value of 6, which indicates that there is a very low perception of security, and at most a value of 30 indicating a very high perception of security. To this end, the data from these responses are statistically analyzed and it is concluded that they have the behavior of an empirical probability distribution, which is shown in the following equation:

$$SP = \begin{cases} if\ 0 < Random < 0.06\ then & Random(0,6) \quad Nivel\ 1 \\ else\ if\ 0.06 \leq Random < 0.18\ then & Random(7,12) \quad Nivel\ 2 \\ else\ if\ 0.18 \end{cases}$$

$$\leq Random < 0.47\ then Random(13,18) Nivel\ 3 else\ if\ 0.47 \leq Random < 0.93 Random(19,24) Nivel\ 4 else Random(25,30) Nivel\ 5$$

c) Structural changes. To represent the changes made in the companies, an empirical probability distribution is made for each level of perception of insecurity and the number of crimes that the companies suffered during the year. The changes made by companies can be systems against cyber-attacks, location devices, placement of bars, windows, and doors, installing surveillance cameras, changing locks and padlocks, hiring insurance, installing safe boxes or rooms, creating security areas, and hiring private security. This is shown in the following equation:

Table 1
Mathematical models for types of crimes.

Type of crime	Equation	Parameters
Merchandise theft	$Mt = Poisson(\lambda)$	$\lambda = 0.5196$
Ant theft	$At = Poisson(\lambda)$	$\lambda = 0.5727$
Other theft	$Ot = \begin{cases} if\ 0 \leq Random \leq 0.87\ then & 0 \\ else\ if\ 0.88 < Random \leq 0.92\ then & 1 \\ else\ if\ 0.92 < Random \leq 0.96\ then & 2 \\ else & 3 \end{cases}$	$Random = random(0,1)$
Kidnapping of a team member	$Kid = Poisson(\lambda)$	$\lambda = 0.0587$
Homicide against establishment member	$Hom = Poisson(\lambda)$	$\lambda = 0.0307$
Cybercrime	$Cc = Poisson(\lambda)$	$\lambda = 0.0866$
Extortion or threats	$Ext = Poisson(\lambda)$	$\lambda = 0.2207$
Intentional damage to the property	$Idp = Poisson(\lambda)$	$\lambda = 0.0642$
Fraud	$Fra = Poisson(\lambda)$	$\lambda = 0.1397$

$$
CR = \begin{cases}
If\ SP = Nivel\ 1\ then & \begin{cases} if\ TCrimes = 0\ then & \begin{cases} if\ 0 \le random \le 0.75\ then\ 0 \\ else\ if\ 0.75 < random \le 0.90\ then\ 1 \\ else\ if\ 0.90 < random \le 0.95\ then\ 2 \\ else\ random\ (3,5) \end{cases} \\ else & \begin{cases} if\ 0 \le random \le 0.33\ then\ random(1,2) \\ else\ random\ (3,5) \end{cases} \end{cases} \\
else\ if\ SP = Nivel\ 2\ then & \begin{cases} if\ TCrimes = 0\ then & \begin{cases} if\ 0 \le random \le 0.44\ then\ 0 \\ else\ if\ 0.44 < random \le 0.56\ then\ 1 \\ else\ if\ 0.56 < random \le 0.72\ then\ 2 \\ else\ if\ 0.72 < random \le 0.96\ then\ 3 \\ else\ random\ (4,5) \end{cases} \\ else\ if\ 0 < TCrimes \le\ 5\ then & \begin{cases} if\ 0 \le random \le 0.30\ then\ 0 \\ else\ if\ 0.30 < random \le 0.40\ then\ 1 \\ else\ if\ 0.40 < random \le 0.90\ then\ 2 \\ else\ 3 \end{cases} \\ else & \begin{cases} if\ 0 \le random \le 0.33\ then\ 0 \\ else\ if\ 0.33 < random \le 0.67\ then\ random\ (1,2) \\ else\ 3 \end{cases} \end{cases} \\
else\ if\ SP = Nivel\ 3\ then & \begin{cases} if\ TCrimes = 0\ then & \begin{cases} if\ 0 \le random \le 0.39\ then\ 0 \\ else\ if\ 0.39 < random \le 0.51\ then\ 1 \\ else\ if\ 0.51 < random \le 0.65\ then\ 2 \\ else\ if\ 0.65 < random \le 0.78\ then\ 3 \\ else\ if\ 0.78 < random \le 0.88\ then\ 4 \\ else\ 5 \end{cases} \\ else\ if\ 0 < TCrimes \le\ 5\ then & \begin{cases} if\ 0 \le random \le 0.29\ then\ 0 \\ else\ if\ 0.29 < random \le 0.45\ then\ 1 \\ else\ if\ 0.45 < random \le 0.66\ then\ 2 \\ else\ if\ 0.66 < random \le 0.79\ then\ 3 \\ else\ if\ 0.79 < random \le 0.87\ then\ 4 \\ else\ if\ 0.87 < random \le 0.95\ then\ 5 \\ else\ 6 \end{cases} \\ else & \begin{cases} if\ 0 \le random \le 0.07\ then\ 0 \\ else\ if\ 0.07 < random \le 0.14\ then\ 1 \\ else\ if\ 0.14 < random \le 0.29\ then\ 2 \\ else\ if\ 0.29 < random \le 0.36\ then\ 3 \\ else\ if\ 0.36 < random \le 0.79\ then\ 4 \\ else\ if\ 0.79 < random \le 0.93\ then\ 5 \\ else\ 6 \end{cases} \end{cases} \\
else\ if\ SP = Nivel\ 4\ then & \begin{cases} if\ TCrimes = 0\ then & \begin{cases} if\ 0 \le random \le 0.44\ then\ 0 \\ else\ if\ 0.44 < random \le 0.56\ then\ 1 \\ else\ if\ 0.56 < random \le 0.77\ then\ 2 \\ else\ if\ 0.77 < random \le 0.90\ then\ 3 \\ else\ if\ 0.90 < random \le 0.92\ then\ 4 \\ else\ if\ 0.92 < random \le 0.98\ then\ 5 \\ else\ 6 \end{cases} \\ else\ if\ 0 < TCrimes \le\ 5\ then & \begin{cases} if\ 0 \le random \le 0.23\ then\ 0 \\ else\ if\ 0.23 < random \le 0.43\ then\ 1 \\ else\ if\ 0.43 < random \le 0.70\ then\ 2 \\ else\ if\ 0.70 < random \le 0.77\ then\ 3 \\ else\ if\ 0.77 < random \le 0.90\ then\ 4 \\ else\ 5 \end{cases} \\ else & \begin{cases} if\ 0 \le random \le 0.26\ then\ 0 \\ else\ if\ 0.26 < random \le 0.42\ then\ 1 \\ else\ if\ 0.42 < random \le 0.53\ then\ 2 \\ else\ if\ 0.53 < random \le 0.63\ then\ 3 \\ else\ if\ 0.63 < random \le 0.68\ then\ 4 \\ else\ if\ 0.68 < random \le 0.74\ then\ 5 \\ else\ if\ 0.74 < random \le 0.84\ then\ 6 \\ else\ 7 \end{cases} \end{cases} \\
else & \begin{cases} if\ TCrimes = 0 & \begin{cases} if\ 0 \le random \le 0.19\ then\ 0 \\ else\ if\ 0.19 < random \le 0.31\ then\ 1 \\ else\ if\ 0.31 < random \le 0.69\ then\ 2 \\ else\ if\ 0.69 < random \le 0.88\ then\ 3 \\ else\ 4 \end{cases} \\ else\ random(3,5) \end{cases}
\end{cases}
$$

4.3.2. Initial policies and parameters

The initial parameters are important to start running the simulation model. Furthermore, it is necessary to define the actual behavior of the system. For this, the descriptive analysis of the data obtained in the survey mentioned above is conducted. Illustration 4 a) presents the histogram with the number of crimes committed during a year, it is observed that the majority of companies suffered between 0 and 3 crimes; 3 b) the number of changes made by the companies, where it is observed that the majority of the companies

made between 0 and 1 change; 3 c) the level of perception of the companies where the majority of companies identify a security of 3 and 4 on a Likert scale; and 3 d) the randomness of the perception of security of businessmen where it is demonstrated that there is no bias when carrying out the surveys.

4.4. Evaluation

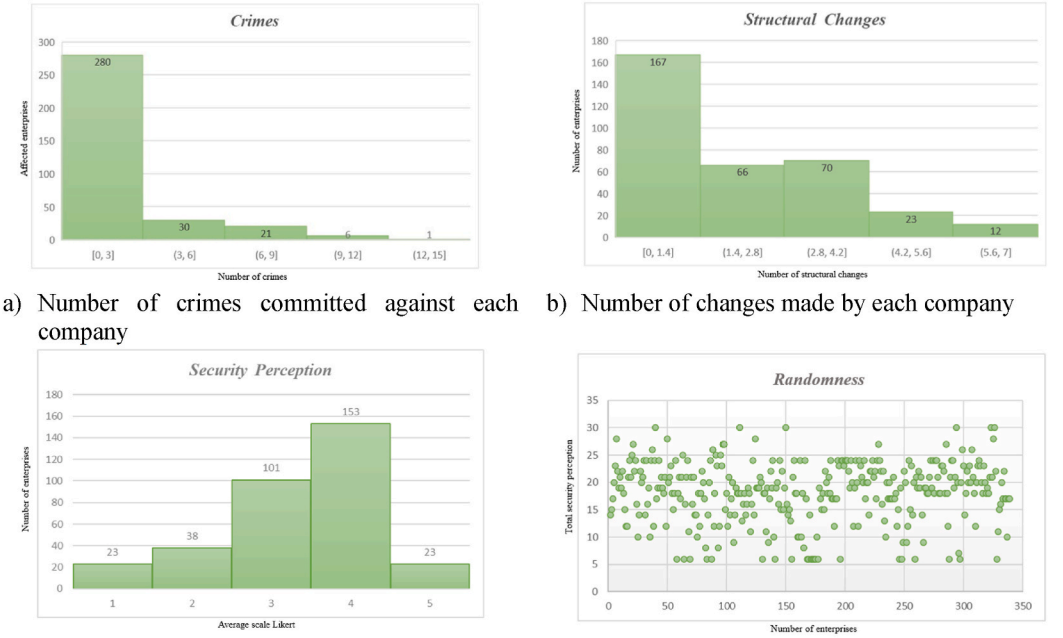
Once the simulation model has been created and the real behavior of the system has been defined, it will be necessary to conduct an evaluation to identify if the simulation is behaving like reality. To validate the simulation model, two of the eighteen tests described by Forrester and Senge [41] to verify the parameters and reproduce the behavior.

a) ***Parameter verification.*** Part of the question: do the model parameters incorporate the descriptive and numerical knowledge of the system? This test evaluates the relevance of constant parameters against knowledge of the real system both conceptually and numerically.
b) ***Reproduction of behavior.*** This test seeks to compare the results of the system dynamics model formulated with real data quantitatively and qualitatively, including behavioral models, the shape of the variables, asymmetries, and unusual events, among others. Given the above, the ability of a model to generate appropriate patterns of behavior can be evaluated through qualitative or statistical judgment.

The simulation of the real behavior of the system is shown in Illustration 5. Section a) shows the number of crimes committed, where quantitatively there are 276, 28, 25, 8, and 1, elements from class 1 to class 5 respectively against 280, 30, 21, 6, and 1 of the classes of the histogram of the real system. In section b) the number of changes made by the companies is presented where the values of each class are 168, 67, 75, 19, and 9 from class 1 to class 5 against 167, 66, 70, 23, and 12 from a real system. In section c) the level of perception in the companies is observed, obtaining data of 22, 41, 95, 155, and 26 in each class respectively against 23, 38, 101, 153, and 23 in the real system. It is important to mention that, to validate the tests, for each of the real classes a 90 % confidence interval was identified to ensure that the data produced by the simulation were within this interval. Finally, part d) shows the randomness presented in the simulation model, which graphically behaves like the real system. In addition to this, 90 % confidence intervals are made for each of the classes to ensure that the data obtained is within this interval.

4.5. Implementation

Once the simulation model is evaluated then it can be implemented to analyze the structural behavior of the system or to evaluate policies that improve the perception of security of companies, or the number of crimes committed. Therefore, considering the level of crimes and the social and economic costs that they generate, it is important for the government, through public policies, to assume preventive measures to regulate this phenomenon.



a) Number of crimes committed against each company
b) Number of changes made by each company
c) Level of perception in businesspeople
d) Randomness in the perception of businesspeople

Illustration 4. Real behavior of the perception of security of Micro and Small businesses.

Taking this into account, the behavior of the real system is simulated. Illustration 6 shows the simulated behavior where most companies make between 0 and 2 structural changes, however, their perception of security does not exceed the Likert scale of four.

5. Discussion

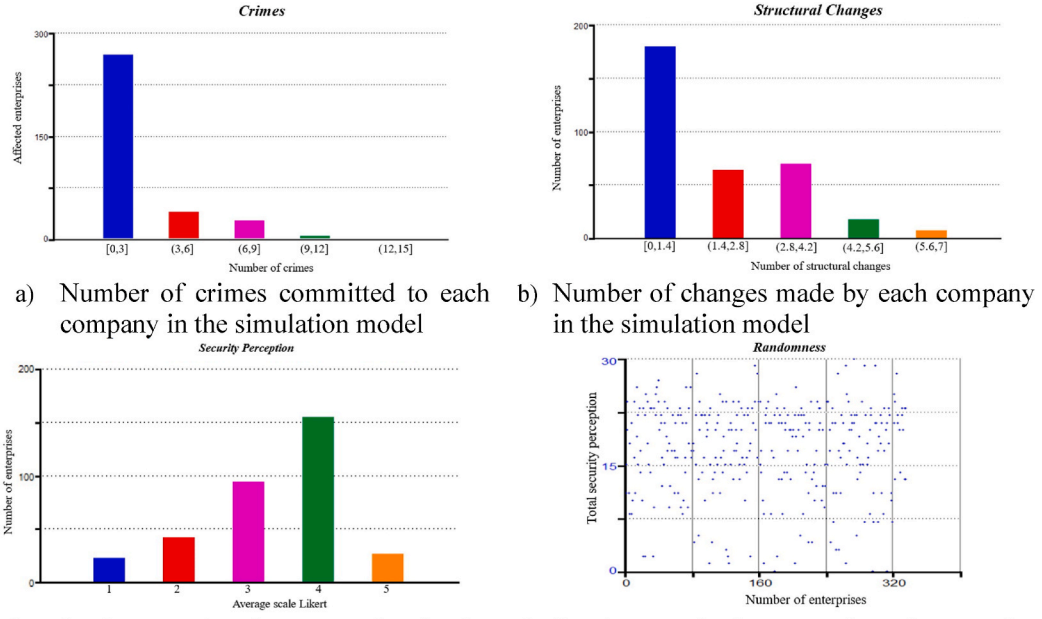
The simulation allows us to observe that MSEs perception of security does not depend directly on the crimes they have suffered, but on the situations that happen around them, resulting in structural changes made with the intention of increase their security. Torres E. et al. [44] mention that the Mexican government establishes strategies to combat crime through domain extinction, considering security as a governance issue with the intervention of federal, state, and local governments, however, the MSEs must receive more support to ensure that they can adopt cost-effective strategies that are practical and viable. To exemplify what the behavior of Micro and Small businesses would be, given possible changes in the country's government policies that may especially benefit this type of companies, three scenarios are generated in the simulation model: 1) reduction in crimes in its entirety for particular companies but not their surroundings; 2) changes in infrastructure around the MSEs to improve security and 3) decrease in crime along with infrastructure changes.

Illustration 7 shows the behavior of Scenario 1 that considers the decrease in crimes in its entirety, that is, zero crimes are placed for each company in the simulator; but the crimes committed around them continue. As a result, it is observed that the number of companies that do not make any structural changes increases, since the business owner does not suffer crimes, he does not make structural changes; However, it does not significantly increase his perception of security, because the business owner continues to feel insecure, even though nothing has happened to him.

This phenomenon can be related to the "security paradox" theory, where the perception of security does not always directly correlate with the objective reality of crime levels [45]. Research has shown that factors such as police visibility, media coverage, and personal experiences influence perceptions of safety more than actual crime statistics [46].

Illustration 8 shows the results of Scenario 2 where it is assumed that the government can implement policies to support the infrastructure around companies, and with this improve the perception of security that business owners have. A meaningful change is observed in the perception of security of businesspeople. This relationship can be supported by studies that have shown how government support and investment in infrastructure, such as lighting, pavement, and surveillance, among others, can strengthen the resilience of companies and increase trust in the socioeconomic environment [47,48]. Perception of security can also improve when entrepreneurs feel that there is strong institutional support [49]. However, as crimes continue to exist and MSEs are victims of them, the number of companies that make structural changes increases significantly.

Finally, Illustration 9 shows the behavior of the system if the government design policies to support in infrastructure and crimes were also significantly reduced. In this scenario, the perception of security has a notable change, that is, businesspeople feel very safe as crimes decrease and observe that the government is investing in infrastructure around companies for their security, therefore, the MSEs do not amend their infrastructure increase. This can be interpreted through the theory of "minimum effective intervention",



a) Number of crimes committed to each company in the simulation model

b) Number of changes made by each company in the simulation model

c) Level of perception in companies in the simulation model

d) Randomness in the perception of companies in the simulation model

Illustration 5. Simulation model results.

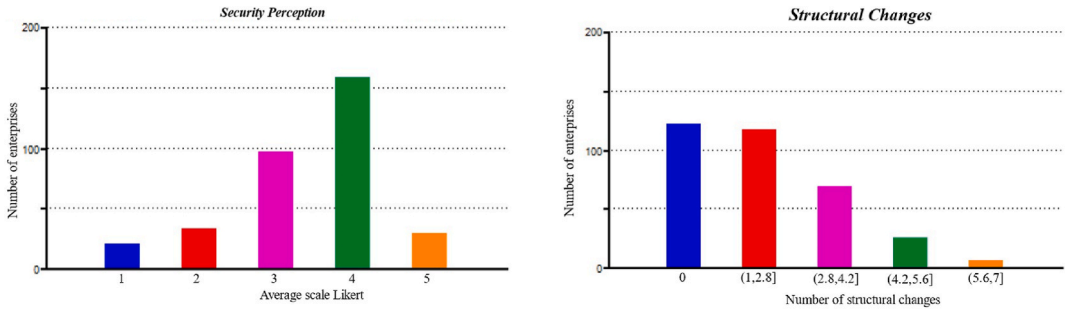


Illustration 6. Simulated behavior of the real system.

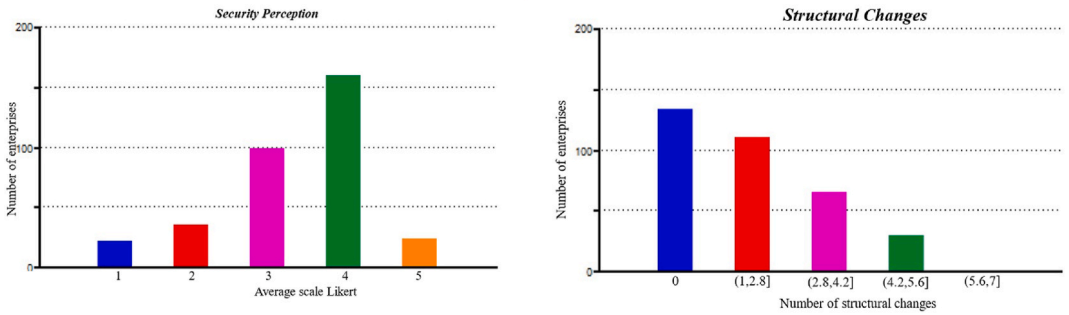


Illustration 7. Scenario 1 – Decrease in crimes.

where a combination of strategic government interventions and significant crime reduction creates an environment perceived as safe and stable, which is crucial for business trust [50]. This scenario is the one that presents a balance between structural changes and the perception of security.

The security model developed in this study for MSEs in Veracruz, Mexico can be compared to models and strategies implemented in other countries that face similar challenges in terms of business security and have high crime rates. For instance, Brazil has developed specific security policies for MSEs, where the implementation of these policies has resulted in a significant reduction in criminal incidents [51]. Similarly, South Africa has seen how collaboration between the public and private sectors has been crucial in improving the security of MSEs [52]. In contrast, in Germany, a country with a more developed economy and lower crime rates, MSEs have adopted advanced technologies to protect themselves against cyber threats. This priority, though different in nature, reflects the importance of security in the business environment, regardless of the context [53].

These international examples suggest that, while contexts may vary, security remains a critical component for the sustainability of MSEs in various regions. As in Mexico, the perception of insecurity in other countries significantly influences business decisions and the organizational structure of these companies. However, the approaches adopted may differ according to the predominant threats in each region, highlighting the importance of adapting security policies to specific contexts.

6. Conclusions

This study confirms that the System Dynamics (SD) methodology is a robust tool that allows ~~for~~ systemic analyses by combining qualitative and quantitative data. Through SD, it was possible to identify the impact that security perception has on the decision-making processes of Micro and Small Enterprises (MSEs) entrepreneurs, particularly focusing on the structural changes they make to enhance their security.

Three hypothetical scenarios were evaluated, considering the participation of municipal authorities in two main actions that promote asset security: 1) crime reduction and 2) improvement of public infrastructure around MSEs. After analysing and contrasting the results of these scenarios, it was concluded that businesses are more concerned about the fear of experiencing a crime, not necessarily about having been direct victims, but rather about observing irregularities in their surroundings. This reinforces the idea that a combination of government interventions, such as improving public infrastructure and significantly reducing crime, creates an environment perceived as safe and stable, which is crucial for business confidence. Furthermore, the third scenario was considered to show a balance between business improvement and security perception, as although companies continue to make structural changes, the reduction in the need for such changes may reflect a stabilization and optimization of business resources. Additionally, the security perception among MSE entrepreneurs significantly improves when there is strong institutional support.

It is important to highlight that the developed model was tested solely in the High Mountains region of Veracruz, Mexico, which may limit the generalization of the results to other areas with different socio-economic contexts and levels of insecurity. However, as

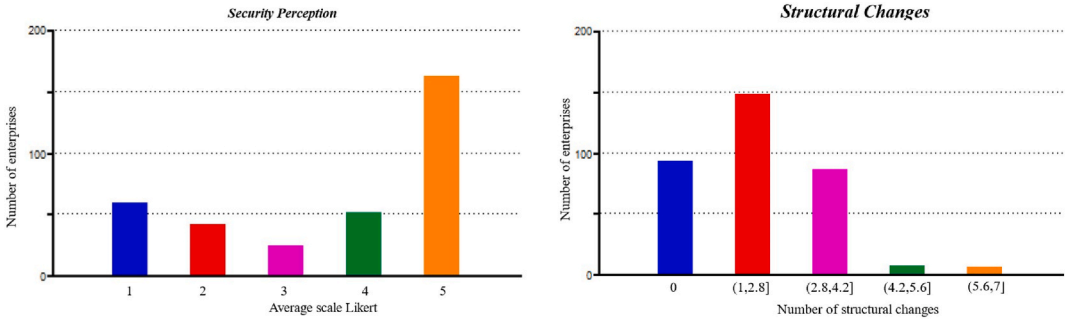


Illustration 8. Scenario 2 - Infrastructure changes to improve security.

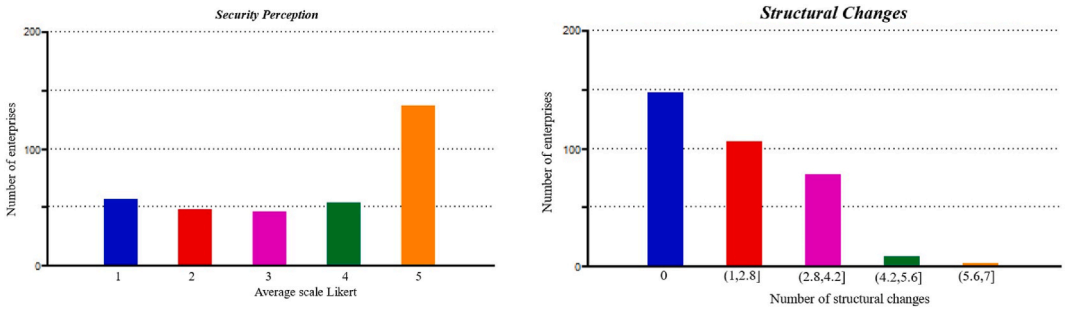


Illustration 9. Scenario 3 - Decrease in crime and changes in infrastructure.

previously mentioned, although contexts may vary, security remains a critical component for the sustainability of MSEs in various regions. Therefore, despite the inherent limitations of this study, its results provide a solid foundation for formulating strategies that can significantly enhance the security and sustainability of MSEs. By continuing to research and apply these insights in different regions, more comprehensive solutions can be developed that benefit both the business community and society at large.

For future work, it is recommended to evaluate specific strategies or policies that could improve the security of MSEs in different regions. To this end, the results of this research have important practical applications: 1) Policymakers can use these findings to design support programs that mitigate the negative effects of insecurity on MSEs, fostering a safer and more stable environment for entrepreneurship and investment; 2) MSEs owners can apply the study's recommendations to improve the internal security of their businesses, thereby strengthening their resilience against external threats; and finally, 3) municipal authorities can benefit by gaining a better understanding of the insecurity dynamics affecting MSEs, enabling them to intervene more effectively in crime prevention and the promotion of a safer business environment.

CRediT authorship contribution statement

Jesabel Gómez Sánchez: Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Rocío Ramos Hernández:** Writing – review & editing, Supervision, Software, Resources, Methodology, Investigation. **Paula Rosalinda Antonio Vidaña:** Writing – review & editing, Validation, Resources, Investigation. **Ivette Pérez Hernández:** Writing – review & editing, Validation, Resources, Investigation.

Ethics statement

Review and/or approval by an ethics committee was not necessary for this study because it was based on a proprietary database, and no personal information of the participants was used; it does not require ethical approval. The database generated by the researchers in collaboration with the *Red de Estudios Latinoamericanos en Administración y Negocios* (RELAYN) in the specific study area is their own.

Data availability

The data in this study are available from the corresponding author upon request.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Jesabel Gomez Sanchez reports administrative support and article publishing charges were provided by Technological University of the Center of Veracruz. The database was generated by the researchers in collaboration with the Red de Estudios Latinoamericanos en Administración y Negocios (RELAYN) in the specific study area is their own. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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