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VULNERABILITY TO THE RISK OF HYDROCARBON EXPLOSION IN INFORMAL SETTLEMENTS IN THE MUNICIPALITY OF PUEBLA, MEXICO

VULNERABILIDAD ANTE EL RIESGO DE EXPLOSIÓN DE HIDROCARBUROS EN ASENTAMIENTOS INFORMALES EN EL MUNICIPIO DE PUEBLA, MÉXICO

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En la periferia norte del municipio de Puebla, México, existen asentamientos urbanos que presentan amenaza de explosión de hidrocarburos debido a la baja regulación del suelo y a la extracción informal del producto. Las condiciones de rezago social, marginación y la respuesta reactiva de las instituciones gubernamentales aumentan la vulnerabilidad. El objetivo es evaluar las variables sociales, urbanas e institucionales en asentamientos urbanos informales para explicar las condiciones multifactoriales de vulnerabilidad ante el riesgo por explosión de hidrocarburos. En metodología se aplicó el análisis multicriterio de 66 indicadores y el análisis socioespacial de distribución de la vulnerabilidad. Los resultados muestran distintos patrones espaciales de vulnerabilidad ante el riesgo de desastre por explosión debido a la presencia de ductos de hidrocarburos, la marginación, el rezago social, la baja organización y percepción del riesgo y las acciones de reactivas. Las conclusiones son que el procesamiento de variables de diferentes tipos explica la vulnerabilidad multifactorial y las diferencias en su distribución ante el riesgo de desastre en asentamientos informales.

Palabras clave: catástrofe, asentamientos informales, uso del suelo, sistemas de información geográfica

In the northern peri-urban area of the municipality of Puebla, urban settlements are threatened by hydrocarbon explosions due to a lack of land regulation and illegal extraction of the product. The conditions of social backwardness, marginalization, and the reactive response of governmental institutions increase vulnerability. The objective of this paper is to evaluate the social, urban, and institutional variables in informal urban settlements to explain the multifactorial vulnerability to the risk of hydrocarbon explosion. The methodology applied was the multi-criteria analysis of 66 indicators and the socio-spatial analysis of vulnerability distribution. The results show different spatial patterns of vulnerability to explosion disaster risk due to the location of hydrocarbon pipelines, marginalization, social backwardness, low organization, low risk perception, and reactive actions. The conclusions are that the processing of variables of different types evidences the multifactorial vulnerability to disaster risk in informal settlements and the differences in vulnerability distributions.

Keywords: catastrophe, informal settlements, land use, geographic information systems

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I. INTRODUCTION

Hydrocarbon networks provide energy for city operations; however, their positioning in urban areas and the mismanagement of explosive materials can cause significant damage to people's lives, properties, and the environment (He et al., 2021; Azari & Karimi, 2017). Oil pipelines, especially, have physical and management conditions that often lead to leaks and spills, posing threats to ecosystems, the population, and economic activities (Cram Heydrich et al., 2020).

Since the 1970s, risk studies have focused on demonstrating that disasters are the effect of human activities to achieve modernity (Mojtahedi & Oo, 2016), and are associated with the growing concentration of people, risk areas, and the climate crisis (Mattedi et al., 2024).

Risk analysis in hydrocarbon networks, including the spillage and/or explosion radii and the exposed population density (Azari & Karimi, 2017), focuses on the threat posed by the networks and their management, but overlooks the analysis of social vulnerability (Cutter et al., 2003). Given the social impacts they generate, it is important to examine the specific characteristics of social relations that emerge in high-risk territories (Montes-Neri, 2023).

Vulnerability refers to exposure to threats accentuated under poverty, backwardness, and marginalization (Birkmann, 2007). In urban areas, the primary settings for economic production, vulnerability increases due to low educational levels, low income, a lack of public and health services, and limited access to information (Mattedi et al., 2024).

Risk analysis in cases of informal urban settlements**5** in Latin America, characterized by marginalized conditions or located in high-risk areas (Montes-Neri, 2023), enables the generation and specification of information to assess vulnerability (He et al., 2021; Mattedi et al., 2024; Azari & Karimi, 2017). In this study, the hypothesis is suggested that analyzing variables with a multifactorial and socio-spatial approach contributes to assessing the vulnerability to the risk of hydrocarbon explosion in informal settlements that emerge outside urban planning processes and legality, where precarious sectors are denied access to housing. The objective is to evaluate the social, urban, and institutional variables, through indicators, to explain the multifactorial conditions of vulnerability to the risk of hydrocarbon explosion in the Jorge Murad Section C sector, Nueva San Salvador, located in the north of the municipality of Puebla, Puebla State, Mexico.

The study's structure presents the state of knowledge behind the multifactorial approach and the variables used to assess vulnerability first. Next, the case study of the Jorge Murad section C sector in Nueva San Salvador is discussed. This consists of two informal urban settlements exposed to the explosion of hydrocarbon pipelines in the municipality of Puebla. This is followed by a discussion of the methodology for designing and processing vulnerability indicators, the evaluation and distribution of vulnerability results, and the results and findings concerning previous studies. Finally, the study's contributions to analyzing vulnerability using a multifactorial approach are presented.

II. THEORETICAL FRAMEWORK

RECOGNIZING VULNERABILITY TO REDUCE RISK

Cities are the main space where humanity performs its activities and concentrates its assets. However, high concentrations of these increase vulnerability to all kinds of threats (Xiu et al., 2011). Vulnerability is a condition associated with a system's physical, socio-economic, and political processes that make it susceptible to potential impacts (Jurgilevich et al., 2021; Cutter et al., 2003).

Vulnerability as a concept cannot be directly measured; therefore, observable indicators for social, urban, and institutional variables are used (Birkmann, 2007; Jurgilevich et al., 2021; Mojtahedi & Oo, 2016) in a defined geographical space (Hernández Ajá et al., 2018; Cram Heydrich et al., 2020).

The ***social variable*** measures the social and economic dimensions (Lavell et al., 2020; Mattedi et al., 2024) through indicators on employment or income, unpaid work, access to education (Montes-Neri, 2023), housing quality (National Council for the Evaluation of Social Development Policy [CONEVAL], 2020), groups that require care (Cutter et al., 2003), social organization and representation, risk perception, responsiveness, and engagement with government authorities (Mojtahedi & Oo, 2016).

The ***urban variable*** measures the dimensions of habitability and environment (Acuña, 2016; Ochoa-

5 The Economic Commission for Latin America and the Caribbean (ECLAC) defines informal settlements as residential areas where inhabitants lack security of tenure over land or housing, ranging from informal occupation to informal rental housing. These areas usually lack basic services and urban infrastructure, and are often located in hazardous environmental and geographical areas.

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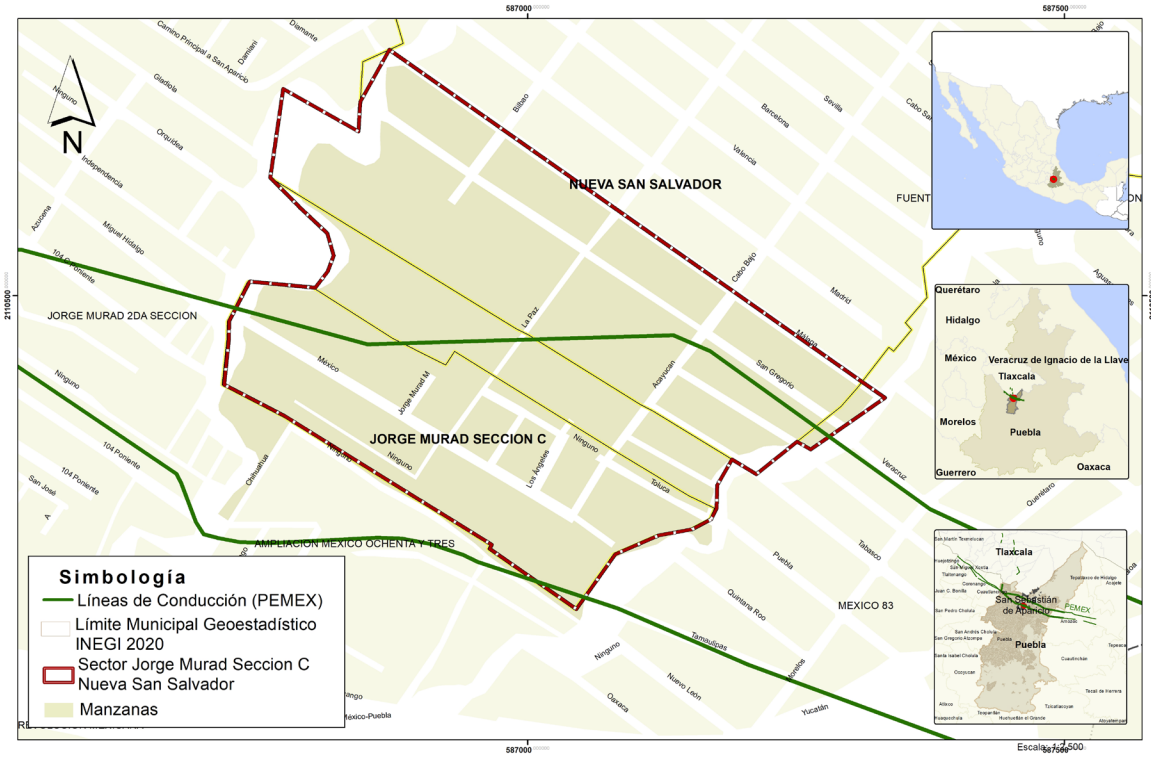

Figure 1. Jorge Murad Section C Sector - Nueva San Salvador. Source: Preparation by the authors based on the National Institute of Statistics and Geography [INEGI] (2009); INEGI (2020); Secretary of Civil Protection and Integral Risk Management (2021).

Ramírez & Guzmán-Ramírez, 2020) through indicators on infrastructure quality, coverage of health services, public security, and social assistance, risk zones, land tenure, and land planning and regulation (Cutter et al., 2003).

The ***institutional variable*** measures the political and management dimensions (Acuña, 2016; Merlinsky & Tobias, 2016) through indicators on financing and economic resources, risk identification, monitoring, evaluation, and management, professionalization, equipment, and infrastructure (Ministry of Labor, 2019). This variable is directly affected by the omission and lack of follow-up in the growth of settlements in risk areas (Abdoul Nasser et al., 2021; Cavazos-Arroyo et al., 2014).

The multicriteria analysis helps identify and classify vulnerabilities by processing indicators in different forms of land occupation (Ruiz Rivera, 2012; Mattedi et al., 2024). The socio-spatial analysis enables associating indicators with urban structure vector data to differentiate the distribution of vulnerability in a geographical space (Buzai & Baxendale, 2010; Cutter et al., 2003), facilitating data normalization and processing (Mattedi et al., 2024; Azari & Karimi, 2017). The participation of the actors involved is fundamental for recognizing and perceiving risk (Mojtahedi & Oo, 2016; Jurgilevich et al., 2021; Cram Heydrich et al., 2020).

JOREGE MURAD SECTION C SECTOR- NUEVA SAN SALVADOR

The sector comprises two informal settlements located in the north of the municipality of Puebla, State of Puebla, Mexico, with 869 inhabitants and 241 homes on the right-of-way of two hydrocarbon pipelines operated by Petroleos Mexicanos[6] (PEMEX) (Figure 1). In 1983, Nueva San Salvador was built on a 12-inch pipeline carrying liquefied petroleum gas (LPG), and in 1990, Jorge Murad Section C on the 12-inch gas pipeline and the 24-inch oil pipeline. The sector has conditions of backwardness, marginalization, risk of explosion due to hydrocarbons, and a history of gas leaks and informal extractions (Puebla Roja, 2020; Barrientos, 2020; Meza, 2017). These representative cases were chosen from

6 Petróleos Mexicanos is a national company that produces, processes, distributes, and sells hydrocarbons and their by-products in Mexico.

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the 62 settlements in the north of the municipality of Puebla that were exposed to the hydrocarbon explosion, following collaboration with neighborhood organizations that facilitated research through participatory processes.

III. METHODOLOGY

In the multicriteria analysis, 66 indicators for ***social***, ***urban***, and ***institutional*** variables were processed to assess vulnerability using a sector-wide, multifactorial approach (Cutter et al., 2003; Montes-Neri, 2023; Cram Heydrich et al., 2020; CONEVAL, 2020). The indicators were obtained from the Population and Housing Census [CPV] 2020 (INEGI, 2020), the census of 218 dwellings, 6 digital surveys and 68 applied by the authors ***in situ*** with a reliability of 90% and a margin of error of 9.61%, 4 interviews with local authorities, 5 public servants, 5 neighborhood leaders, 1 member of the board and 2 of the services committee, whose identity is kept anonymous to protect personal information.

The indicators were integrated using the mathematical expression, where the sum total ***xi*** is the total of each variable and the multifactorial one, respectively. In assigning vulnerability levels, the class limit was considered, with the upper limit ***(xmax)*** subtracted from the lower limit ***(xmin)***, and then divided into three classes to which an ordinal value was assigned for comparability: 1 (low), 2 (medium), and 3 (high) (Bollin & Hidajat, 2006, as cited in Ruiz Rivera, 2012).

The ***social variable*** considers 26 data indicators from the CPV 2020 (INEGI, 2020) (Table 1) and surveys regarding the organization, prevention, perception, and response to risk (Table 2). The ***urban variable*** considers 20 indicators obtained in nine field visits (Hernández, 2023b) and a housing census (Table 3). Urban and social indicators were added to obtain urban vulnerability (Table 4). The ***institutional variable*** considers 20 indicators on financing, identification, management, and risk reduction actions, with frequencies weighted as always (1), regularly (2), occasionally (3), and never (4) (Table 5).

The three variables were integrated to obtain the vulnerability indicators and levels (Table 6). The socio-spatial analysis was conducted in QGIS by associating the indicators with the urban block vectors (INEGI, 2016) to define the vulnerability distribution.

Economic	Economically inactive population
	Households headed by women
	Population without complete compulsory education
Population	Illiterate
	Density
	0 to 14 years old
	60 and older
	Disability
	Without health services
Housing	Without drinking water
	Without drainage
	Without electricity
	Without a slab roof
	Walls of other material
	Earthen floor
	One room
Σ xi	

Table 1. Population and Housing Indicators. Source: Population and Housing Census (INEGI, 2020)

Organization	question 4	In the sector 1, and another 0
	Organization	Board 1, Committee 2, none 3
Prevention	Question 17	None 1, I don't know 2, use WhatsApp 3, meeting for services 4, others (protect the pipelines, whistles, information for PEMEX, report activities) 5, discuss strategies with neighbors 6, disseminate information provided by the authorities 7, and convene a meeting 8
	Question 18	There isn't any 1, doesn't know 2, call a meeting 3, neighborhood alarm/notification from social media 4, turn off the light, turn off gas 5, respect the indications 6, flee 7, talk to the police/ authority/911 8, evacuate 9
Perception	Question 11	None 1, others (I don't know, I didn't know about the pipelines) 2, lack of deed of their land 3, delinquency 4, huachicol 5, risk of explosion 6, leaks 7
	Question 15	No 1, I'm not sure 2, rarely/occasionally 3, yes 4
	Question 19	There isn't any 1, neighborhood alert or communication 2, authority actions 3, surveillance 4, evacuate 5
	Refusal	Refusal to answer the survey
Answer	Question 14	None 1, federal 2, state 3, municipal 4, auxiliary board 5, board/service committee 6
	Question 16	Nothing 1, others (do not go out, avoid approaching)2, call authorities 3, neighborhood alarm 4, turn off gas and disconnect electricity 5, follow directions 6, evacuate 7
∑xi		

Table. Survey indicators. Source: Preparation by the authors, 2023 Note: Respondents could select more than one option

Habitability	Lights	1 in the whole block, 2 in a part of the block, and 3 there aren't any.
	Pavement	1 in the whole block, 2 in a part of the block, and 3 there isn't any.
	Pavement Type	1 in the whole block, 2 in a part of the block, and 3 there isn't any.
	Sidewalks	Total
Risk	Ravines	0 there aren't any, 1 there are
	Housing in a risk area	Total
	Bodies of water	0 there aren't any, 1 there are
	Pipelines	0 there aren't any, 1 there is one on one side of the block, 2 in the middle, and 3 in the whole block.
	Type of product	1 gasoline, 2 gas
	Housing in the right-of-way	Total
	High-voltage power lines	0 there aren't any, 1 there are
	Housing in the right-of-way	Total
	Industrial corridors	0 there aren't any, 1 there are
	Main roads	0 there aren't any, 1 there are
	Housing in the right-of-way	Total
Equipment	Hospital	0 in the sector, 1 in the coverage area
	Firefighters	0 in the sector, 1 in the coverage area
	Public security	0 in the sector, 1 in the coverage area
Land tenure	Urban settlement	0 incorporated into urban development, 1 registered and recognized, 2 informal
	Deed problems	0 there aren't any, 1 there are
∑xi		

Table 3. Indicators of the urban variable. Source: Preparation by the authors, 2023

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Indicator	Urban indicators	Social Vulnerability	Urban Vulnerability (Σ)
Value	1 to n	1 to n	xi

Table 4. Indicators to obtain urban vulnerability. Source: Preparation by the authors, 2023

Financing	Vertical and horizontal Inter-institutional organization
	Reserve funds for institutional strengthening
	Resource localization and mobilization
Identification	Inventory of disasters and losses
	Threat monitoring and forecasting
	Threat mapping
	Vulnerability and risk assessment
	Public information and community participation
	Risk management training and education
Management	Organization and coordination of emergency operations
	Planning emergency response and warning systems
	Equipment and infrastructure
	Simulation, updating, and testing of the inter-institutional response
Reduction	Community preparation and training
	Integration of risk in the definition of land uses and urban planning
	Watershed intervention and environmental protection
	Implementation of hazard protection and control techniques
	Improvement of housing and relocation of settlements
	Updating and application of building standards and codes
	Strengthening and intervention of the vulnerability of public and private goods
Σxi	

Table. Indicators of the institutional variable. Source: Preparation by the authors, 2023.

Multifactorial						
Variable	**Social Vulnerability**	**Urban Vulnerability**	**Institutional Vulnerability**	**Σ**	**Weighting**	**Level of vulnerability**
Indicators	n	n	n	n	1 to 3	High, medium, or low

Table 6. Multifactorial vulnerability indicators. Source: Preparation by the authors, 2023.

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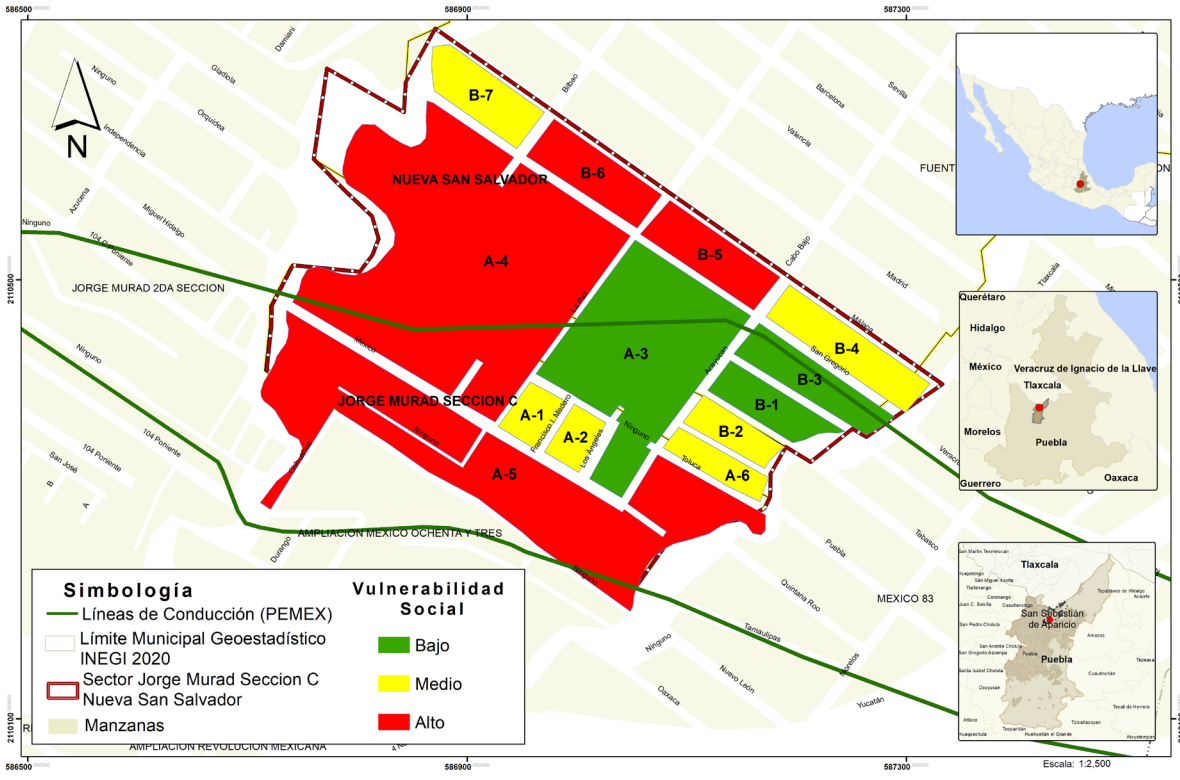

Figure 2. Social vulnerability. Source: Preparation by the authors based on INEGI (2009); INEGI (2016); INEGI (2020); INEGI (2023); Secretary of Civil Protection and Integral Risk Management (2021).

IV. RESULTS

VULNERABILITY IS A SOCIAL PROCESS

The multivariate evaluation reveals vulnerability as a process influenced by social backwardness, marginalization, omissions in urban planning, low risk perception, and reactive responses. The mapping represents the differences in vulnerability distribution across urban blocks.

A score was obtained in the socioeconomic indicators of 325; low access to education, health, and vulnerable population of 2,186; low quality of housing of 85; organization, perception, and risk prevention of 1,881, totaling 4,477 indicators. The results reveal that the perception of risk is secondary for the inhabitants, as 73.61% of the analyzed population considers crime a priority, 48.61% hydrocarbon pipelines, 44.44% the lack of public services, and 40.28% the presence of ravines. 72.22% mention that there are no actions for risk reduction.

Prevention actions are incipient, although some residents report that meetings have been called, information provided by authorities has been disseminated, and strategies have been discussed among neighbors. However, other residents indicate that these actions have not been carried out or are unaware of such efforts.

Regarding the response strategies developed by neighborhood leaders or the inhabitants themselves, it is indicated that such strategies do not exist or are unknown. In emergencies, the inhabitants evacuate their homes, follow directions, and refrain from using electricity. They also close the gas outlets, activate the neighborhood alarm, and contact the authorities. However, some inhabitants choose not to take action, unsure of what to do. Additionally, the inhabitants' lack of knowledge about the boundaries, name, and affiliation of the urban settlement to which they belong hinders the risk management processes for the municipal authorities. A high level of social vulnerability is defined in blocks[7] A4,

[7] The blocks labeled with an 'A' are part of the Jorge Murad Section C settlement, and those with a 'B' are located in Nueva San Salvador.

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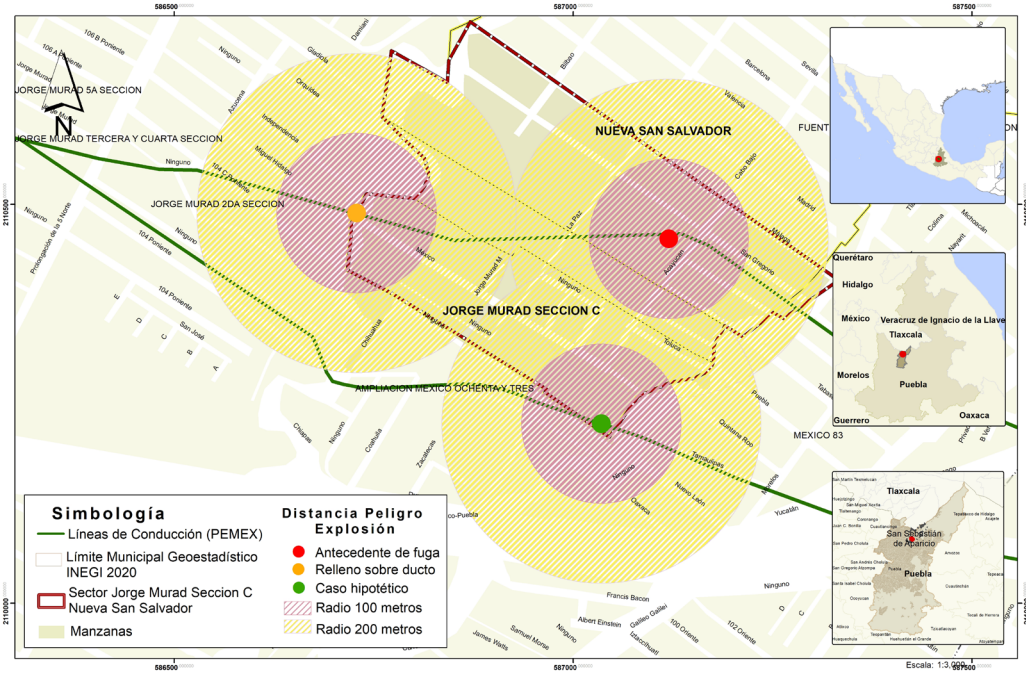

Figure 3. Danger of explosion. Source: Preparation by the authors based on CENAPRED (2021); INEGI (2009); INEGI (2016); INEGI (2023); Secretary of Civil Protection and Integral Risk Management (2021); Hernández (2023a).

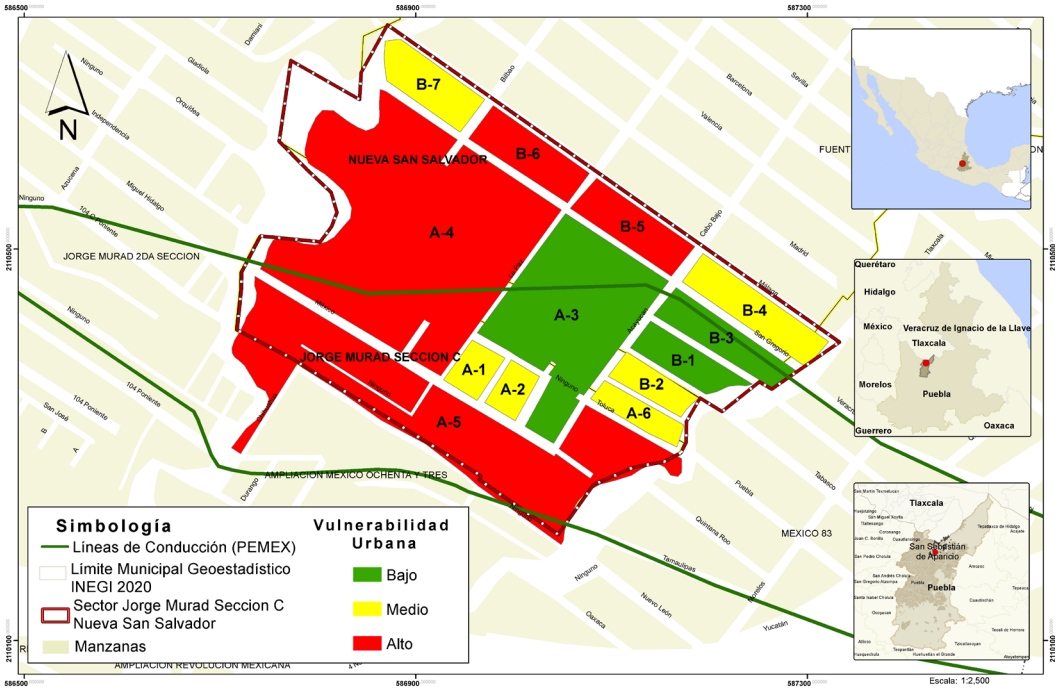

Figure 4. Urban vulnerability. Source: Preparation by the authors based on INEGI (2009); INEGI (2016); INEGI (2020); INEGI (2023); Hernández (2023a); Secretaría de Protección Civil y Gestión Integral de Riesgos (2021).

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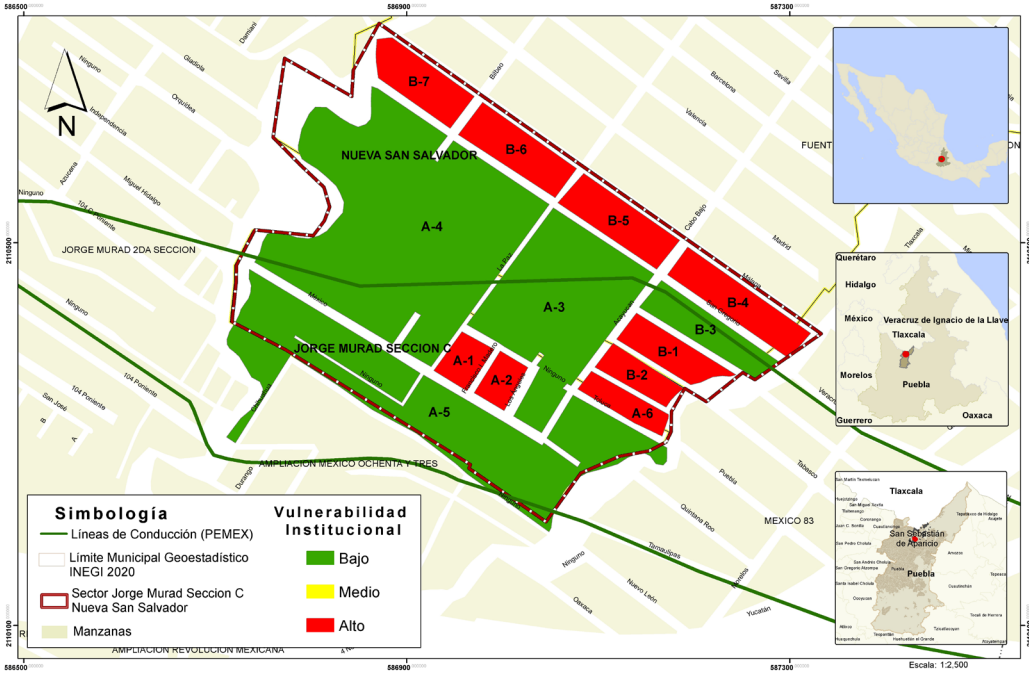

Figure 5. Institutional vulnerability. Source: Preparation by the authors based on INEGI (2009); INEGI (2016); INEGI (2020); Secretaría de Protección Civil y Gestión Integral de Riesgos (2021); Hernández (2023b).

A5, B5, and B6, medium in A1, A2, B2, B4, and B7, and low in A3, B3, and B1 (Figure 2).

A total score of 269 was obtained in the studied sectors' urban indicators. The urban conditions include unpaved roads without lighting, houses on the right-of-way of the hydrocarbon pipelines, and ravines that were filled in to build other houses. In the Jorge Murad Section C settlement, 85% of the homes do not have property deeds, and in Nueva San Salvador, the percentage is 15%[8]. The risk of a hydrocarbon explosion poses a problem for 19.44% of the inhabitants, as it makes the registration of deeds difficult. The blocks whose legal status hinders their integration into urban planning processes complicate the provision of public services.

The assistance services within the suggested radius for attention during an emergency (Secretary of State at the Office of Social Development [SEDESOL], 1999)[9] include fire stations, public security, and health centers. However, three new explosion hazard points were identified, with impact radii of 100 and 200 meters (National Center for Disaster Prevention [CENAPRED], 2021), that increase the risk zone (Figure 3).

A high level of social vulnerability is defined in blocks A4, A5, B5, and B6, medium in blocks A1, A2, B2, B4, and B7, and low in blocks A3, B3, and B1 (Figure 2).

A score was obtained in the financing indicators of 117, risk identification of 278, management of 152, and reduction of 286, totaling 883. In interviews with the technical staff of the Civil Protection Risk Management Directorate of the Municipality of Puebla (GRMPC), it was identified that limited financial resources are available for updating equipment and computer programs used for risk identification and analysis. This is because the allocation of resources depends on the Municipal Treasury, and there is no dedicated fund or economic reserve for operational purposes.

Regarding municipal information, there is no inventory, historical documentation, or monitoring of disasters or losses due to hydrocarbon explosions; instead, information

8 The municipal council has only incorporated Nueva San Salvador into its urban development plans. This process is the final step undertaken by urban settlements to request recognition for the provision of basic public services. This process speeds up the accreditation of the property.
9 In the current NOM-SEDATU-002 standard of 2022, this radius is not defined.

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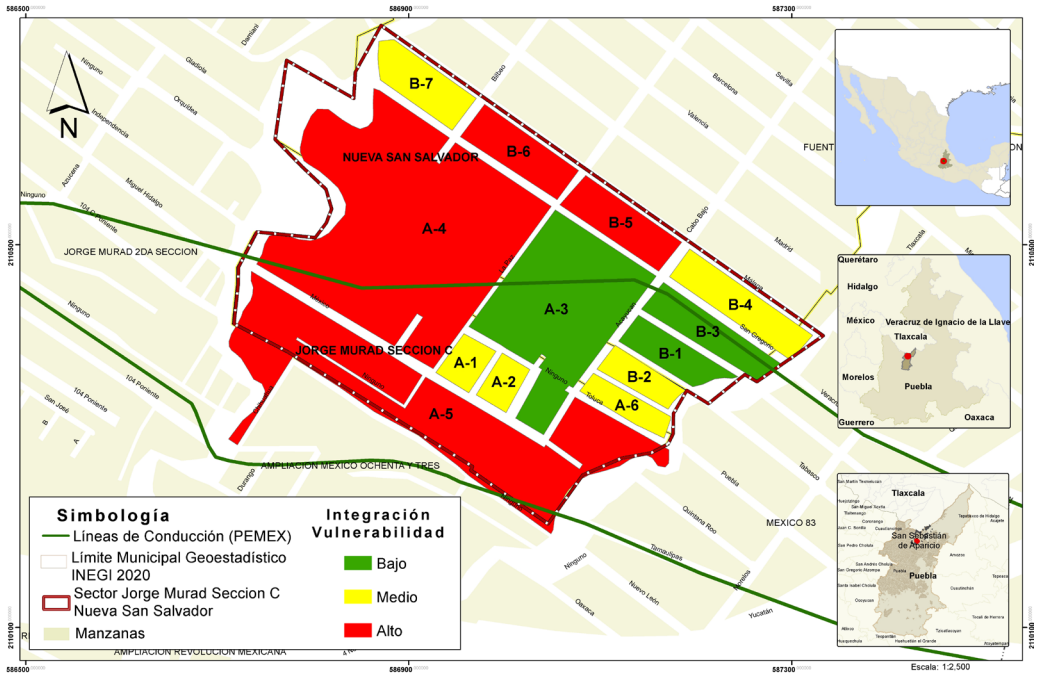

Figure 6. Integration of Vulnerabilities. Source: Preparation by the authors based on INEGI (2009); INEGI (2016).

is transmitted orally among the staff. The precise location of the pipelines is lacking, as are mapping, vulnerability, and risk assessments, and the existing information is maintained by Petróleos Mexicanos (PEMEX). Regarding professionalization, the staff does not receive continuous training, and the exchange of knowledge takes place on the staff's initiative and/or in the face of the need to solve specific management problems (Personnel-technical, personal communication, 2023).

As for risk management, although the Municipal Civil Protection Directorate (PC) is responsible for the operational phase and has the equipment needed to attend to emergencies, it lacks preventive measures for personnel and inhabitants in urban settlements. The actions of the industries and companies, such as PEMEX and Maxi Gas, are limited to technical personnel. Therefore, the Ministry of Public Security is responsible for surveillance and monitoring, which is conducted through cameras located on regulating vessels and channels with a risk of flooding.

Regarding prevention, PC conducts emergency prevention campaigns on social networks and the radio. At the same time, the Risk Management in Civil Protection Matters of the Municipality of Puebla (GRMPC) reviews civil protection plans in constructions that offer goods and services (Personal-technical, personal communication, 2023). It is worth noting that both entities lack the responsibility and resources to relocate homes.

The institutional vulnerability level is defined as high in the A1, A2, A6, B1, B2, B4, B5, B6, and B7 blocks and low in A3, A4, A5, and B3 as they are served by PEMEX (Figure 5).

Starting from a multifactorial approach, it was identified that although neighborhoods and housing conditions are characterized by backwardness and marginalization along hydrocarbon pipelines, and even though there is neighborhood organization and communication in emergencies, and engagement from local authorities to help reduce vulnerability, the threat does not disappear. Blocks A4, A5, B5 and B6 were defined as a high level; A1, A2, A6, B2, B4, and B7 as medium; and A3, B1, and B3 as low (Figure 6).

V. DISCUSSION

The vulnerability assessment, employing a multifactorial approach, involved integrating social, urban, and institutional indicators, as addressed by authors such as Acuña (2016),

Cram Heydrich et al. (2020), and Ruíz Rivera and Magaña Rueda (2020). This approach represents progress compared to other studies, such as He et al. (2021) and Abdoul Nasser et al. (2021), which analyze risk by emphasizing threats.

The study contributes to placing the profiles and capacities of the actors involved at the center of the analysis, as Mojtahedi and Oo (2016) suggested. According to Cutter et al. (2003) and Mattedi et al. (2024), the design of indicators is explored through standardization and data integration to measure and compare vulnerability at the urban block level, representing the most precise spatial approximation possible.

In social vulnerability, the indicators referring to groups experiencing backwardness (CONEVAL, 2020), lacking attention and care, and in poverty (Montes-Neri, 2023) were considered. In urban vulnerability, indicators such as marginalization, proximity to urban facilities and services, rights of way, explosion radii, and areas of affectation were considered, as mentioned by Azari and Karimi (2017). In institutional vulnerability, indicators regarding actions for financing, urban planning, access to information, professionalization, and response capacity, as a fundamental part of the management processes highlighted by Merlinsky and Tobias (2016), were considered.

It is corroborated that anthropogenic risks, such as chemical-technological ones, are often overlooked in management, and a reactive response prevails, as pointed out by Abdoul Nasser et al. (2021). As the main stakeholders, the inhabitants organize and make decisions to reduce their vulnerability. However, this is insufficient in the face of institutional omissions that fail to provide legal certainty of ownership, as noted by Cutter et al. (2003) and Ochoa-Ramírez and Guzmán-Ramírez (2020). This situation leaves disaster risk in a secondary or invisible category, as both González (1994) and Cavazos-Arroyo et al. (2014) mentioned.

VI. CONCLUSIONS

The study contributes to the lack of analyses of different types of variables that determine the multifactorial origin of vulnerability to disaster risk and its mapping (Birkmann, 2007). It is confirmed that multiple factors determine the vulnerability to the risk of hydrocarbon explosion (Xiu et al., 2011; Ruíz Rivera & Magaña Rueda, 2020). The design and processing of social, urban, and institutional indicators to define vulnerability levels (Cutter et al., 2003) in the Jorge Murad C-Nueva San Salvador Sector was provided because it represents the exposure that other informal urban settlements located in the municipality of Puebla are in (Montes-Neri, 2023). The socio-spatial analysis of indicators associated with vector data (Mattedi et al., 2024) showcases the differences in the distribution of vulnerability by urban block as the maximum possible spatial approximation (He et al., 2021; Cutter et al., 2003). The risk is presented by the population and homes' exposure to the explosion of hydrocarbons, but the vulnerability is increased by social backwardness, marginalization, and a reactive response. However, the participatory processes confirmed that the organization and outreach of the actors involved contribute to reducing vulnerability.

VII. CONTRIBUTION OF AUTHORS CRediT:

Conceptualization: R.M.H.V. and S.S.S.M.; Data curation: R.M.H.V.; Formal analysis: R.M.H.V. and S.S.S.M.; Acquisition of financing: R.M.H.V.; Research: R.M.H.V., S.S.S.M. and M.L.F.L.; Methodology: R.M.H.V., S.S.S.M. and M.L.F.L.; Project Management: S.S.S.M. and M.L.F.L.; Resources: R.M.H.V.; Software: R.M.H.V.; Supervision: S.S.S.M. and M.L.F.L.; Validation: R.M.H.V. and S.S.S.M.; Visualization: R.M.H.V. and S.S.S.M.; Writing - original draft: R.M.H.V., S.S.S.M. and M.L.F.L.; Writing - proofreading and editing: S.S.S.M.

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