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The key role of risk perception in preparedness for oil pipeline accidents in urban areas: A sequential mediation analysis

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ABSTRACT

Effective disaster risk reduction requires conducting research within communities that gave recognized natural or technological risks, to foster the development of more resilient societies. However, limited information is available regarding risk perception and preparedness for technological hazards in disaster-prone urban areas of South America. The aim of this study is to investigate the factors that influence public risk perception regarding the Trans-Ecuadorian Oil Pipeline System and its relationship with household preparedness for a potential accident in the Metropolitan District of Quito (Ecuador). We assess the link among knowledge, trust in authorities, risk perception, intention to prepare, and preparedness. Results from a sequential mediation analysis reveal that risk perception partially and positively mediates the relationship between knowledge and preparedness and acts as a negative full mediator between the latter and trust. These findings provide valuable information for future risk governance and communication strategies, aimed at enhancing risk perception and improving individual preparedness of individuals, as well as risk mitigation procedures.

1. Introduction

Disaster risk management, as part of sustainable development, seeks to reduce exposure and vulnerability to hazards, involving all members of society and creating a culture of prevention and resilience to address multiple and interacting hazards (UNDRR, 2019). Disaster-prone developing countries deserve special attention due to their higher levels of vulnerability, which often far exceed their capacity to cope with and recover from disasters (Bowonder and Kasperson, 2005). Developing resilience is particularly challenging in high-risk urban areas which experience rapid and poorly planned urbanization and where poverty is widespread (Dickson et al., 2012). This urbanization process may create informal settlements around metropolitan areas (Niva et al., 2019) usually on land that is more prone to natural and technological hazards and disasters (e.g., steep slopes, riverbanks, etc.) (Pelling, 2012). This situation increases exposure to hazards and even the creation of further ones with serious consequences for more highly-vulnerable populations.

Making urban areas more resilient requires the active and concerted effort of all those involved in the disaster risk management process, especially individuals and communities in danger (Strong et al., 2020), as a prerequisite for developing risk reduction initiatives, and therefore develop preparedness strategies (UNDRR, 2019). For this purpose, it is necessary to conduct research in places where natural or technological risks have been recognized in order to understand residents' knowledge of hazards and risk perception.

Extensive research exists on risk perception for natural hazards, mostly linked to large-scale and rapid-onset disasters affecting urban areas (e.g., Shrestha et al., 2018; Gomez-Zapata et al., 2021; Rana et al., 2020; Arias et al., 2017), and technological risk related with existing industrial facilities (e.g., Lei et al., 2013; He et al., 2018; Ren et al., 2016; Steinberg et al., 2004; McEvoy et al., 2017). However, less attention has been paid to the study of risk perception of communities residing close to oil pipelines (e.g., Onuoha 2008; Bessette et al. 2021; Jalbert et al., 2023), with limited exploration into the influence of risk perception on disaster preparedness.

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Pipeline accidents may be caused by technical or operational failure, vandalism, or sabotage, but can also be triggered by natural hazards (e.g., earthquakes, landslides, etc.) that can magnify their effects (Mesa-Gómez et al., 2020). In addition to environmental and economic damage caused by a pipeline rupture (e.g., Hongfang et al. 2023), if fires or explosions occur, they can lead to significant damage to properties, injuries, and loss of life (e.g., Chen et al., 2020; Omodanisi et al., 2015), causing enormous financial losses (Zhu et al., 2015; Umar et al., 2021).

Whether a pipeline route is aboveground or underground, it is possible to identify the places where impacts could occur. Therefore, a right-of-way is usually granted for its construction to ensure a safe space on both sides of the route. It is also common for these infrastructures to be initially located in unpopulated rural areas, although in some cases they end up being in densely populated urban areas, due to rapid and unplanned urban sprawl (Liu et al., 2015). Thus, sometimes, buildings even encroach on the pipeline route, posing a risk to inhabitants and to the pipeline itself (Ramírez-Camacho et al., 2017), significantly increasing the consequences of accidents (Chen et al., 2020). Consequently, oil pipelines may become invisible or part of the landscape, eventually passing unnoticed by the local population (Sandri et al., 2020). Moreover, although an adverse event leads to an increase in perceived risk, the effect decays considerably with distance from the pipeline and over time (Hansen et al. 2006). In consequence, the presence of pipelines may not be perceived as a risk and the population is practically unprepared for the threat. In fact, some authors have concluded that poor pipeline monitoring, low awareness of risks among the public (Mbara and Van den Berg, 2011; Macey and Schneider, 2004) and land-use planners (Hayes et al., 2021), and their lack of preparedness (Onuoha, 2008, 2010; Omodanisi et al., 2015; Johnson and Leon, 2020) may contribute to disasters.

This study addresses a significant gap in the existing literature by examining public risk perception and its impact on preparedness in the context of oil pipelines traversing residential urban areas in developing countries. Our investigation focuses on the Trans-Ecuadorian Oil Pipeline System (SOTE) within the Metropolitan District of Quito (MDQ), chosen due to Ecuador's heightened exposure to natural hazards (Toulkeridis et al. 2015). Knowledge about public awareness of the pipeline site and an understanding of the safety concerns and risks associated with the SOTE are vital to ensuring its safe operation. Furthermore, this information is necessary for the development of policies aimed at improving preparedness and responses to potential accidents, thereby reducing the risk of disasters and enhancing the resilience of the population. Thus, the MDQ's residents' perception of this infrastructure is key because it influences people's behavior, prevention policies, and the implementation of action plans as an essential part of disaster risk management.

Our primary objectives are twofold: (a) to explore the factors that influence public risk perceptions in relation to the SOTE and (b) to find relationships between risk perception and the public's preparedness to deal with a disaster that a potential accident of the SOTE could cause. To achieve these objectives, we conducted a survey among households in the MDQ and developed a sequential mediation model to examine the relationship between knowledge, trust in authorities, risk perception, intention to prepare, and preparedness.

In the next section, we discuss our theoretical framework drawing on the literature related to natural and technological hazards and risk. This is followed by the materials and methods section with a description of the study area, data collection, measures considered and the estimation methodology. Next, our empirical results are presented followed by a discussion of the policy implications of our findings, and the main conclusions, and limitations of the study.

2. Theoretical framework and research hypothesis

This research has been built upon existing theoretical approaches related to Protection Motivation Theory (PMT, Rogers 1983), and risk perception (Fischhoff et al 1978; Slovic 1987). PMT suggests that individuals facing a risk decide to take protective measures based on three cognitive components: the assessment of the probability of an event occurring, the consequences or severity of the impact due to exposure to the event, and the perception of the efficiency of the protective measures taken (Rogers 1975). Additionally, risk perception is the subjective assessment of the probability and the consequences of a negative outcome, which may be influenced by psychological, social, institutional, and cultural factors (Slovic et al. 2000; Backer-Grondahl and Fyhri, 2009), as well as an affective component, level of worry or how individuals feel unsafe faced with a hazardous scenario (Terpstra, 2011; Nordfjærn and Rundmo, 2015). This constitutes a theoretical alternative that also points out the quick, instinctive, and intuitive reaction to deal with a risk (Slovic et al., 2004). That is, the emotional response to risk often differs from the response generated by its cognitive evaluation (Loewenstein et al., 2001), and shows an individual̓s perception of risk.

Abundant research indicates that direct and indirect experiences of a hazard and trust in authorities and experts have the most substantial impact on risk perception (Wachinger et al. 2013), as well as potential predictors of mitigation behavior (Papagianannaki et al. 2019). Thus, we examined the interrelation among risk perception, trust in institutions, past experience, and knowledge with the hazard generated by the presence of the SOTE for determining population intention to implement protective measures, and the level of preparedness behavior in order to mitigate the severity of disaster impacts. Below, we provide a review of the literature on the conceptualization of these constructs and empirical evidence supporting our hypothesized associations, followed by a description of our hypothesized model.

Knowledge can be obtained directly by experiencing a hazard event or indirectly through external information which includes media, education, and other individuals' experience. Some studies confirm that past experiences, recent repetition of related events, and repeated exposure to information influence the perception of risk (Harlan 2019). Thus, those who directly experiences a disaster or accident may see a substantial increase in their perception of risk due to the knowledge acquired (Rundmo and Iversen 2004; Wachinger et al., 2013; Wolff et al. 2019). However, direct experience with most technological hazards is limited, and individuals usually receive information from third parties (Renn and Beninghaus 2013). This may lead to a superficial or partial knowledge of the seriousness of a risk, which can generate an excess of confidence in individuals, reducing their capacity to recognize the real risk faced (Slovic et al. 1980). In addition, some studies show that a population that faces a risk for long periods becomes familiar with it, experiences a decrease in its perception of risk and even forgets that it exists (Lund and Rundmo 2009). This can also occur in the case of infrequent or less serious events, which are often unfamiliar and can lead to a false sense of security and the ability to cope with the hazard. Thus, due to the scarce knowledge, and direct personal experience associated with events that have not already harmed them significantly, they are more likely to think that future events will not negatively affect them and, therefore, their perception of risk will be low (Wachinger et al 2013). In the case of SOTE, low-risk perception may be related to the lack of knowledge about the infrastructure itself. Therefore, we hypothesize that the more knowledge the population has regarding the presence of the SOTE, the greater the risk perception will be:

H1. *Knowledge is positively related to risk perception.*

There is also a great deal of literature that goes beyond analyzing risk perception as an individual process, seeking to understand how social processes shape individuals' views. A very relevant factor is trust in experts and authorities and confidence in protective measures. Individuals are not able to obtain information about all threats that they face, and they do not usually have any knowledge about the technological risk implied (Renn and Beninghaus 2013). Thus, due to this lack of knowledge, they have to rely on trust which becomes essential when decision makers face uncertainty (Paton 2008). Siegrist and Cvetkovich

(2000) proved that the greater the knowledge individuals believe they have about a technological risk, the less trust they have in the advice received from the authorities. Thus, we hypothesize that the lower the knowledge, the higher the trust in authorities:

H2. *Knowledge is negatively related to trust in authorities.*

Trust is also suggested as a factor to explain risk perception in the absence of knowledge (Visschers and Siegrist 2018). Although trusting in others poses a risk (Mayer et al. 1995), the lack of trust can make individuals feel more at risk because trust is a mechanism that allows for complexity reduction (Siegrist et al. 2021). Therefore, it is considered that high levels of trust lead to lower risk perception (Slovic et al., 1980; Terpstra, 2011; Ross et al., 2014; Simon-Friedt et al., 2016), which can sometimes lead people to overestimate their capacity to control and delegate their responsibilities to third parties (Scolobig et al., 2012). On the other hand, Siegrist et al. (2007) indicated that the relationship between trust and risk perception is complex and contextual, depending on several factors, such as knowledge and consensus on the evaluation of the hazards. Thus, there are studies that show contrasting results, indicating that, while trust in information provided by independent media sources increases the perception of risk, trust in public authorities may decrease it (Lobb et al., 2007). However, trust in experts, institutions, and the media may be used in personal risk assessment, especially when it is beyond the capacity of laypersons, when subjects believe that the risk should be handled by authorities, or when individuals ́ past experiences are scarce as may be the case for the population of Quito in relation to the SOTE. We hypothesize that the higher the trust in authorities, the lower the risk perception the population has in relation to the SOTE:

H3. Trust in authorities is negatively related to risk perception.

An important distinction in the literature is the difference between intention to prepare and preparedness, assuming that intentions are the antecedent of behavior (Ajzen, 1991). According to the PMT, individuals' risk perception is key in the intention to prepare (Rogers 1975). In fact, some literature has found a positive relation between risk perception and the intention to adopt protective behavior (Terpstra and Lindell 2013), and between the intention to prepare and the adoption of protective measures (Botzen et al 2009, Terpstra 2011, Zaalberg et al. 2009). However, previous studies often reveal a strong correlation between risk perception and the intention to prepare, but a lower correlation between intention to prepare and preparedness (Bubeck et al. 2012). This may be due to the social conditions (e.g., resource limitations), which are very important in risk perception, but are determinative in turning intentions into action (Thistlethwaite et al. 2018).

In addition, some authors point out that risk perception and preparedness are determined by the personal assessment of a disaster's consequences (Lindell and Perry 2012). In other words, a high-risk perception should imply a high intention to take protective measures, which would contribute to improving the decision-making process (Ferrer et al. 2018; Greiner et al., 2009; Scolobig et al., 2012). In fact, several studies indicate that risk perception and risk concern are positively related to risk preparedness (e.g., Terpstra, 2011; Miceli, 2008). Similarly, other studies show that risk perception (Rundmo and Moen 2006) and severity of consequences (Sjöberg 1999) are significant predictors of mitigation demand. Thus, it is argued that individuals with low-risk perception are less likely to respond to warnings and undertake preparedness measures than those with high-risk perception (Wachinger et al. 2013). Therefore, we expect a positive relationship between risk perception and preparedness, meaning that the higher the perception of risk, the higher the level of the population's preparedness. At the same time, we expect a positive relationship between risk perception and intention to prepare, which means that the higher the perception of risk, the higher the intention to prepare. Lastly, we also expect a positive relationship between intention to prepare and preparedness, meaning that the higher the intention to prepare, the higher the preparedness:

H4. *Risk perception is positively related to preparedness.*

H5. *Risk perception is positively related to intention to prepare.*

H6. *Intention to prepare is positively related to preparedness.*

However, research shows that perceived risk is not a sufficient factor for driving risk mitigation intention and behavior (Wachinger et al. 2013). A recurrent hypothesis in scientific literature is that previous experience in a disaster, and adequate information contribute to creating awareness in the population about a hazard (Wachinger et al., 2013; Hernández-Moreno and Alcántara, 2016), and will make individuals more likely to apply protective measures (e.g., Bubeck et al. 2012; Wachinger et al., 2013). Thus, we expect that the higher the knowledge about the SOTE, the higher the preparation for potential accidents and disasters:

H7. *Knowledge is positively related to preparedness.*

In addition, some studies indicate that trust in authorities is negatively related to the intention to prepare, and the number of protective measures taken (e.g., Tepstra 2011; Hung-Chih 2009). Trust is even more important in reducing the intention to prepare when the population has limited knowledge of the hazard they face, meaning that they have a false sense of security (Wachinger et al. 2013). Thus, we hypothesize that the higher the trust in authorities, the lower the intention to prepare for disasters and accidents:

H8. *Trust in authorities is negatively related to intention to prepare.*

Hence, based on the preceding discussion, the relationship among constructs in our conceptual model is summarized in Fig. 1.

3. Material and methods

3.1. Study area

The state-owned SOTE, the most important oil pipeline in Ecuador in terms of volume transported (84%) (EP-Petroecuador, 2019), is an infrastructure vulnerable to seismic and volcanic activity along its whole route; it is 520 km long and runs from the Ecuadorian Amazon to the Pacific coast via the Andes (EP-Petroecuador, 2011). Primarily in the Amazon region, one of the most biodiverse areas in the world (Lessmann et al., 2016), deforestation and oil spills cause significant damage to the environment, economic activities, and human health (e.g., Lucero, 1997; San Sebastián et al., 2002, 2004; Cepek, 2012; Coronel et al., 2020; Rivera-Parra et al., 2020). This situation has generated conflicts (e.g., Widener, 2007, 2011; Welford and Yarbrough, 2015; Hess, 2023), and intense political mobilizations (e.g., Valdivia, 2008; Fontaine, 2019; High 2020).

In the MDQ, the SOTE's vulnerability seems evident because it is located at an altitude of 2,850 m where there is a high risk of volcanic eruptions, landslides, floods, and earthquakes (Zevallos, 1996). The high exposure of the MDQ's inhabitants, which currently number 2.8 million (MDMQ, 2021), is especially worrying because its population has quintupled since the construction of the SOTE in 1972. This rapid growth has created major concerns due to the existing gap between urban development and land management policies (MDMQ, 2015). For decades, urban expansion towards the south of the MDQ has led to an unplanned urban sprawl in areas at high risk of landslides and floods (Gómez and Cuvi 2016; Puente-Sotomayor et al. 2021), concentrating impoverished migrant families (Bayón and Moreano, 2023). Moreover, the encroachment of informal settlements into the pipeline's safety zone (15 m wide on both sides) (EP-Petroecuador, 2011) has increased the original risk associated with this infrastructure when it was first designed and built. Under these circumstances, the occurrence of pipeline ruptures may have serious consequences for the population, as it has

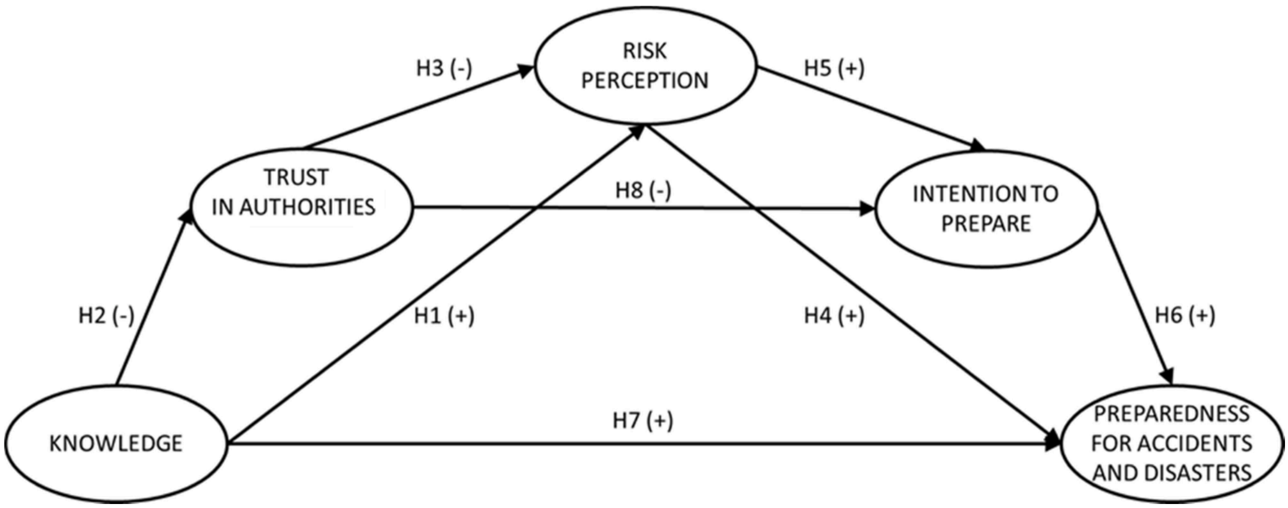

Fig. 1. Conceptual model.

already had in the Ecuadorian Amazon (e.g., Poma et al., 2021; Ramírez et al., 2022) and in Quito with the contamination of water sources in 2003 (D`Ercole and Metzger 2004), especially because it constitutes a new latent and invisible risk that may not be directly perceived by communities or decision-makers (Pisaniello and Tingey-Holyoak, 2017; Hayes et al., 2021).

3.2. Data collection and sample

For the empirical analysis, we collected data with the completion of a questionnaire survey developed after a comprehensive review of the literature, and consultations with experts in oil infrastructures risk and safety. In addition, a pilot survey was conducted to detect unclear elements. The questionnaire included scoring selection and was structured into three parts: (1) a general section related to various natural and anthropic hazards affecting the population of the MDQ; (2) a specific section related to SOTE; (3) the socioeconomic characteristics of the interviewee. The information was collected based on the knowledge and experience of the interviewees, that is, without their providing us with additional information before they were asked the questions from the questionnaire, to ensure reliability of the data and to diminish the potential for random and systematic sources of error (Hambrick, 2007; Huber and Power, 1985).

We conducted stratified random sampling method with proportional allocation to select households located in the MDQ' urban area based on the eight administrative zones, gender, and age. The questionnaire was administered through face-to-face interviews to the senior member of the household. All participants were informed about the purpose of the study, and that their participation was voluntary and anonymous. Likewise, the reasons why the interviewees did not want to collaborate in the study and their basic characteristics were identified, and replacement were found. Thirty-four non-valid questionnaires were dropped, which resulted in a sample composed of 400 households from the eight administrative zones of the MDQ.

We also analyzed the nonresponse bias by testing for significant differences between early respondents and late respondents, i.e. the first 75 % of questionnaires returned versus the late 25 %, following Armstrong and Overton (1977) and Weiss and Heide (1993). To do so, t-tests on these subsamples were performed, considering several individual characteristics (such as area, gender, and age), yielding no significant differences (at the $p < .05$ level). Thus, the results indicate that there is no problem with the nonresponse bias.

Finally, we also tested for common method bias, considering the Harman one-factor test (Podsakoff and Organ, 1986) which showed that this was unlikely to be significant, as a single general factor did not account for most variance in the exploratory factor analysis (only 20.82%). In addition, we also considered the method indicated by Podsakoff et al. (2003), in which a new model loading on one factor with all the observed variables was re-estimated. This test again yields unacceptable results (Chi-square=3,547.34; df=152; RMSEA=.237). In sum, the common method bias appears not to be an issue for this study.

All respondents were distributed by zonal administrations: 51 % were women, average age was 43 years old with most of the respondents concentrated in the age ranges of 19–35 (46 %) and 36-64 (43.8 %), and, finally, most of those respondents lived in their own homes (69.0 %), mainly inhabited by two (33.3 %) or three members (40.8 %).

3.3. Measures

For the present study, the measurement items considered were based on previously validated scales in studies related to natural and technological hazards (e.g., Terpstra 2011; Nordfjærn and Rundmo 2015; Liu et al. 2020; Zhang et al. 2021) and were measured on a seven-point Likert-type scale ranging from 1 (completely disagree/very low/highly unlikely) to 7 (completely agree/very high/highly likely). We measured knowledge about the pipeline route and disasters or accidents related to the SOTE using the following four items: *I know the route of the pipeline through the urban area of the MDQ; I know about the disasters or accidents which have already happened; I have had previous experience with disasters or accidents; I have relatives who have had experience with disasters or accidents*. We used the following three items to measure trust in the authorities: *I trust in the actions taken by the authorities to prevent emergencies; I trust in the actions implemented during an emergency; I trust in the proper use of resources during an emergency*. Three items were used to measure risk perception: *probability of a disaster or accident caused by a spill or explosion of the SOTE; severity of a disaster or accident caused by a spill or explosion of the SOTE; worry about a disaster or accident caused by a spill or explosion of the SOTE pipeline*. Regarding intention to prepare, three items were used: *I intend to seek information on disasters or accidents related to the SOTE; I encourage others to take an interest in safety in the event of disasters or accidents caused by the SOTE; I intend to seek helpful information about any type of disaster or accident*. Finally, we measured preparedness to face a disaster or accident caused by the SOTE using the following four items: *I have made inquiries and I know the safety procedure established by the authorities; the information has been widely disseminated so that I can take action; the information has been disseminated using communication channels that I usually use; I comply with the safety procedure established by the authorities*.

3.4. Data analysis

The data analysis was performed with Confirmatory Factor Analysis (CFA) and Structural Equation Modelling (SEM), established methodologies widely recognized in the study of risk perception (e.g., Li et al., 2018; Li and Liu 2020; Fatemi et al., 2021; Oktari et al., 2022; Mooney et al., 2023). After a preliminary descriptive analysis of the key variables, an initial Confirmatory Factor Analysis (CFA) was performed to assess the convergent validity, discriminant validity, and reliability of the proposed measurement, following the guidelines set forth by Gerbing and Anderson (1988), Hu and Bentler (1999), and Hair et al. (2019). Then, considering the complexity of the conceptual model (Fig. 1), Structural Equation Modelling (SEM) was employed to simultaneously test the proposed hypotheses, following the guidelines of Kline (2015) and Hair et al. (2019) for testing direct relationships, and the guidelines of Zhao et al. (2010) and Hayes (2022) for mediation analysis through bootstrapping.

4. Results

4.1. Descriptive analysis

Table 1 shows the descriptive statistics of all items included in the constructs considered. Respondents' knowledge of the SOTE was very low, not only in terms of previous experience and knowledge of related disasters, but even in relation to the SOTE's route in the urban area of the MDQ. In relation to trust in authorities, all the items obtained similarly high scores (4.5 on average). The perception of risk, measured through the variables concern, probability, and severity of consequences in the case of an oil pipeline accident (SOTE) is low, although the severity of consequences scores higher than the other items. The scores of intention to prepare were between 3.95 and 4.30. In contrast, preparedness presents lower scores for all items, ranging from 2.79 to 3.15.

Table 1
Descriptive statistics

CONSTRUCT AND ITEMS	Mean	Standard Deviation
KNOWLEDGE		
- I know the route of the pipeline through the urban area of the MDQ	2.12	1.77
- I know about SOTE disasters or accidents which have already happened	1.96	1.62
- I have had previous experience with disasters or accidents related to SOTE	1.76	1.43
- I have relatives who have had experience with disasters or accidents related to SOTE	1.86	1.57
TRUST IN AUTHORITIES		
- I trust in the actions taken by the authorities to prevent emergencies	4.56	1.42
- I trust in the actions implemented during an emergency	4.57	1.42
- I trust in the proper use of resources during an emergency.	4.37	1.45
RISK PERCEPTION		
- Probability of a disaster or accident caused by a spill or explosion of the SOTE	3.64	1.67
- Severity of a disaster or accident caused by a spill or explosion of the SOTE	4.14	1.63
- Worry about a disaster or accident caused by a spill or explosion of the SOTE	3.76	1.69
INTENTION TO PREPARE		
- I intend to seek information on disasters or accidents related to the SOTE	4.22	1.59
- I encourage others to take an interest in safety in the event of disasters or accidents caused by the SOTE.	3.95	1.74
- I intend to seek helpful information about any type of disasters or accidents	4.30	1.79
PREPAREDNESS		
- I have made the inquiries and I know the safety procedure established by the authorities in the event of disasters or accidents related to the SOTE	3.15	1.43
- The information to face a disaster or accident of the SOTE has been widely disseminated so that I can take action.	2.93	1.51
- The information to face a disaster or accident of the SOTE has been disseminated using communication channels that I usually use	2.79	1.53
- I comply with the safety procedure established by the authorities for disasters or accidents related to the SOTE.	2.94	1.53

4.2. Reliability and validity

The requirements for content validity were established by means of the literature review and the opinions of experienced researchers and experts. As evidence of discriminant validity, convergent validity, and scale reliability, we estimated Confirmatory Factor Analysis (CFA) and followed Anderson and Gerbing (1988) (Table 2). The results indicate an overall chi-square of 259.17 with 102 degrees of freedom. We also examined the following measures of fit: the comparative fit index (CFI=.971); the incremental fit index (IFI=.971); the Tucker-Lewis index (TLI=.961); the normed fit index (NFI=.953); the root mean square error of approximation (RMSEA=.062). All the results are within conventional cut-off values and allow us to consider the model to be acceptable (Vandenberg and Lance, 2000).

Table 2
Confirmatory Factor Analysis summary: measurement results, validity, and reliability

	Standardized Loadings
KNOWLEDGE (CR=.956; AVE=.844; CA=.954)	
- I know the route of the pipeline through the urban area of the MDQ	.856
- I know about SOTE disasters or accidents which have already happened	.903
- I have had previous experience with disasters or accidents related to SOTE	.962
- I have relatives who have had experience with disasters or accidents related to SOTE	.951
TRUST IN AUTHORITIES (CR=.867; AVE=.688; CA=.859)	
- I trust in the actions taken by the authorities to prevent emergencies	.716
- I trust in the actions implemented during an emergency	.970
- I trust in the proper use of resources during an emergency.	.781
RISK PERCEPTION (CR=.820; AVE=.604; CA=.820)	
- Probability of a disaster or accident caused by a spill or explosion of the SOTE	.797
- Severity of a disaster or accident caused by a spill or explosion of the SOTE	.832
- Worry about a disaster or accident caused by a spill or explosion of the SOTE	.697
INTENTION TO PREPARE (CR=.899; AVE=.751; CA=.861)	
- I intend to seek information on disasters or accidents related to the SOTE.	.873
- I encourage others to take an interest in safety in the event of disasters or accidents caused by the SOTE.	.997
- I intend to seek helpful information about any type of disasters or accidents	.704
PREPAREDNESS (CR=.903; AVE=.701; CA=.927)	
- I have made the inquiries and I know the safety procedure established by the authorities in the event of disasters or accidents related to the SOTE	.900
- The information to face a disaster or accident of the SOTE has been widely disseminated so that I can take action.	.892
- The information to face a disaster or accident of the SOTE has been disseminated using communication channels that I usually use	.785
- I comply with the safety procedure established by the authorities for disasters or accidents related to the SOTE.	.763

Model Fit Summary
Chi Square=259.17; df=102; χ^2/df=2.54
CFI=.971; IFI=.971; TLI=.961; NFI=.953; RMSEA=.062
Notation:
CR: Composite Reliability; AVE: Average Variance Extracted; CA: Cronbach Alfa; CFI: Comparative Fix Index; IFI: Incremental Fit Index; TLI: Tucker Lewis Index; NFI: Normed Fit Index; RMSEA: Root Mean Square Error.

The individual loadings displayed are high and significant, and all the items are related to their specified latent variables, therefore indicating convergent validity (Anderson and Gerbing, 1988). In addition, we observed the squared inter-construct correlations and the explained variance in order to evaluate discriminant validity (Table 3). The results show that the explained variance per construct in the items is higher than the inter-construct correlations (Fornell and Larcker, 1981), indicating that discriminant validity is adequate for all latent variables. Finally, we followed Bagozzi and Yi (1988) to assess reliability. The results show acceptable levels of composite reliability (CR) for all the constructs considered, as it exceeds the recommended level of .60, namely, knowledge (CR=.956), trust (CR=.867), risk perception (CR=.820), intention to prepare (CR=.899), and preparedness (CR=.903). What is more, the level of average extracted variance of the latent variables exceeded the recommended level (.50). Consequently, the measurement model specified for the considered variables is adequate.

4.3. Testing of hypotheses

Based on the complexity of the model and the need to test the relationships between the different constructs at the same time, we used Structural Equation Modelling (SEM) by applying the maximum likelihood method. Following this procedure, the conceptual model was estimated, whose results are shown in Table 4. The fit indices were adequate and within the recommended cut-off value, so the model was considered acceptable (Vandenberg and Lance, 2000).

On the one hand, considering distal antecedents of preparedness and their relationships, the results of the hypothesis testing proposed in our model offers support for H1, with a significant and positive relationship between knowledge and risk perception being found (.454; $p < .001$), H3 with a significant and negative relationship between trust and risk perception (–.122; $p < .05$), and H5 having a significant and positive relationship between risk perception and intention to prepare (.442; $p < .001$). On the other hand, the results do not offer support for H2, with a positive but not significant relationship between knowledge and trust, (.057; p=.275), or for H8, with a negative but not significant relationship between trust and intention to prepare (–.078; p=.097). Nonetheless, regarding proximal antecedents of preparedness, the results of the hypothesis testing proposed in our model offer support for H7, with a significant and positive relationship between knowledge and preparedness being found (.404; $p < .001$), H4, having a significant and positive relationship between risk perception and preparedness (.141; $p < .05$), and H6, with a significant and positive relationship between intention to prepare and preparedness (.123; $p < .05$).

Finally, Table 5 presents direct, indirect, and total effects of knowledge and trust on preparedness through risk perception, tested by means of bootstrapping, for mediation analysis.

The presence of a mediating effect requires the fulfillment of two conditions (Kenny et al., 1998): the independent variable must be significantly related to the mediating variable, and this mediating variable must be significantly related to the dependent variable. In addition, it is necessary to assess the significance and the sign of direct and indirect effects between the variables to determine the nature of such mediation (Zhao et al. 2010; Hayes, 2022).

Table 3
Confirmatory Factor Analysis (CFA): Correlations between constructs and AVE

Factor	1	2	3	4	5	AVE
1. KNOWLEDGE	**.919**					.844
2. TRUST	.057	**.829**				.688
3. RISK PERCEPTION	.426	–.098	**.777**			.604
4. INTENTION TO PREPARE	.355	–.124	.443	**.866**		.751
5. PREPAREDNESS	.507	.053	.364	.325	**.837**	.701

Note: Diagonal is the square root of the AVE.

Table 4
Structural Equation Modeling (SEM): model fit summary and parameters estimates.

HYP.	RELATIONSHIPS	Stand. Coeff.	*p-value*	Significance
H1	KNOWLEDGE → RISK PERCEPTION	.454	.000	***
H2	KNOWLEDGE → TRUST	.057	.275	*ns*
H3	TRUST → RISK PERCEPTION	–.122	.019	*
H4	RISK PERCEPTION → PREPAREDNESS	.141	.031	*
H5	RISK PERCEPTION → INTENTION TO PREPARE	.442	.000	***
H6	INTENTION TO PREPARE → PREPAREDNESS	.123	.019	*
H7	KNOWLEDGE → PREPAREDNESS	.404	.000	***
H8	TRUST → INTENTION TO PREPARE	–.078	.097	*ns*

Model Fit Summary
Chi-square=278.61; df=15; χ^2/df=2.68
CFI=.968; IFI=.968; TLI=.958; NFI=.949; RMSEA=.065
Note: * p < .05; ** p < .01; *** p < .001; ns=not significant
Notation:
CFI: Comparative Fix Index; IFI: Incremental Fit Index; TLI: Tucker Lewis Index; NFI: Normed Fit Index; RMSEA: Root Mean Square Error.

Table 5
Direct, Indirect, and Total Effects of Knowledge and Trust on Readiness through Risk Perception (SEM): parameter estimates and bootstrap confidence intervals.

PATH	Coeff.	LCI	UCI	*p*	test
KNOWLEDGE → TRUST → RISK PERC. → INTENTION TO PREPARE → PREPAREDNESS					
DIRECT EFFECT	**.338**	.236	.432	.001	
IE1: KNOW → RISK PERC. → PREP	***.053***	*.008*	*.104*	*.024*	
IE2: KNOW → RISK PERC.→ INTENT → PREP	***.021***	*.003*	*.046*	*.025*	
IE3: KNOW → TRUST → RISK PERC.→ INTENT → PREP	***.000***	*–.002*	*.000*	*.163*	*ns*
IE4: KNOW → TRUST → INTENT → PREP	***.000***	*–.003*	*.000*	*.113*	*ns*
TOTAL INDIRECT EFFECT	**.073**	.031	.121	.001	
TOTAL EFFECT	**.411**	.321	.498	.000	
TRUST → RISK PERC. → INTENTION TO PREPARE → PREPAREDNESS					
IE1: TRUST → RISK PERC. → PREP	***–.021***	*–.059*	*–.002*	*.029*	
IE2: TRUST → INTENT → PREP	***–.012***	*–.039*	*.001*	*.070*	*ns*
IE3: TRUST → RISK PERC. → INTENT → PREP	***–.008***	*–.027*	*-.001*	*.034*	
TOTAL EFFECT	**–.042**	–.089	–.014	.004	

Note: * *p* < .05; ** *p* < .01; *** *p* < .001; *ns*: Not Significant. *Bootstrap confidence intervals derived from 5,000 samples (95% level of confidence).*

On the one hand, regarding knowledge, since the confidence intervals estimated for coefficients by bootstrapping are significant and non-zero (at a 95% confidence level), direct effect (.338, $p < .001$), total indirect effect (.073, $p < .001$), and total effect (.411, $p < .001$) of knowledge on preparedness are significant and positive. In addition, two indirect effects of knowledge on preparedness through the paths risk perceptions (.053, $p < .05$) and risk perceptions – intention to prepare (.021, $p < .05$) are also significant and positive, whereas indirect effects through the paths trust – risk perception – intention to prepare and trust – intention to prepare are not significant, which shows the key role of risk perception on this mediating effect. These results support a sequential mediation effect through the path knowledge – risk perception – intention to prepare – preparedness for accidents and disasters, failing in the paths through trust. In this case, considering that direct and total indirect effects are significant and positive, risk perception is a positive partial mediator in the relationship between knowledge and preparedness, solely and altogether with intention to prepare.

On the other hand, regarding trust, since the confidence intervals estimated for coefficients by bootstrapping are significant and non-zero (at a 95% confidence level), the total indirect effect (–.042, $p < .01$) of trust on preparedness is significant and negative. In addition, the only two indirect effects of trust on preparedness through risk perceptions, the paths risk perceptions (–.021, $p < .05$) and risk perceptions – intention to prepare (–.008, $p < .05$), are also significant and negative, whereas indirect effect through intention to prepare is not significant, which also shows the key role of risk perception on this mediating effect. These results also support a sequential mediation effect through the path trust – risk perception – intention to prepare – preparedness for accidents and disasters. In this case, considering that a direct relationship does not exist and that total indirect effects are significant and negative, risk perception is a negative full mediator in the relationship between trust and preparedness solely and jointly with intention to prepare.

5. Discussion

To the best of our knowledge, this is one of the few public risk perception studies on the presence of a pipeline located in an urban area, specifically analyzing its relationship with preparedness. The results obtained supported most of our initial hypothesis, particularly those associated with the threat appraisal within the framework of the PMT, also referred to as risk perception. The findings show the factors that influence public risk perceptions and the relationships with public's preparedness to deal with an accident caused by the SOTE in the MDQ.

A direct and positive relationship has been identified between knowledge and risk perception, which indicates that the greater the knowledge of the danger, the higher the perception of risk. This suggests that the low perception of risk detected for the SOTE may be more related to the low level of knowledge that the population declares to have than to the lack of concern that its presence may cause. The same result was found by Liu et al (2020) who considered that public perception may be higher when the public's knowledge about a technological risk increases if it is not accompanied with information about how to reduce it effectively. Consistently with this is the negative relation found between knowledge and risk perception among experts (Siegrist and Árvai, 2020).

In this regard, the limited knowledge of the population about the SOTE, specifically about first-hand experience of disasters or accidents, makes it difficult to assess the actions of the authorities which would explain the non-significant relationship found between knowledge and trust in the authorities.

Nevertheless, trust in the authorities negatively influences the risk perception of the SOTE, which could mean that the increase in trust would lead the population to becoming unconcerned about risk management, decreasing their perception of risk. Similar results have been obtained by Terpstra (2011), who shows that an increase in trust would reduce the risk perception of floods, and by other studies dealing with technological risks, such as electronic commerce (Pavlou 2003), shale gas fracking (Whitmarsh et al. 2015), oil spills (Simon-Friedt et al. 2016), and hazardous chemicals (Liu et al. 2020). Conversely, Goebel and Wardropper (2023) identified a positive relation in the case of lead exposure, while Jeong and Yim (2023) found a similar relationship in the context of COVID-19.

Our results show that risk perception has a positive relationship with intention to prepare to deal with a disaster or accident caused by the SOTE, and a positive but lower relationship with preparedness. This means that an increase in the perception of risk would have a lower direct effect on preparedness but a higher influence on intention to prepare. Likewise, as in previous papers (e.g., Botzen et al. 2009, Terpstra 2011, Terpstra and Lindell 2013), our results show that, although there is a strong correlation between risk perception and the intention to act, the connection between intention and action is positive but weaker. A possible explanation for this result is that people with positive attitude to proactive behavior may not be able to afford preparedness measures due to lack of resources (Wachinger et al. 2013; Thistlethwaite et al. 2018).

A strong and direct positive relationship has also been detected between knowledge and preparedness to face a disaster or accident caused by the SOTE, like several previous studies have found (e.g., Hoffman and Muttarak 2017), but contrary to the paradox suggested by Baker (2009), namely that even if people are aware of the risks of a disaster occurring, they are otherwise unprepared for natural hazards. Thus, aside from residents not having had previous experience in disasters or accidents related to oil pipelines in operation, as has been detected in the case of the SOTE, this result suggests that adequate information on this type of risk would positively influence their preparedness to deal with it. Knowledge also positively influences preparedness indirectly through risk perception and intention to prepare. The partial mediation of risk perception indicates that the positive effect of knowledge on preparedness could be further enhanced if the public' perception of risk increased. However, no indirect relationship between knowledge and preparedness through trust has been found.

Contrary to our hypothesis, the non-significant relationship found between trust and intention to prepare to face a disaster or accident caused by the SOTE is possibly since trust in authorities may lead the population to be less concerned about taking measures to prepare to deal with a risk. This result is consistent with the findings of Wachinger et al. (2013), although contrary to Terpstra (2011), who found a weak but direct relationship between the variables trust and preparedness to handle a risk. However, in contrast to other authors (e.g., Liu et al. 2020), our results show that risk perception acts as a negative full mediator in the relationship between trust and preparedness, solely or with intention to prepare. Therefore, it seems necessary for households to reach an adequate level of risk perception so that authorities and institutions can influence their intention to be prepared to deal with a risk.

Our study has several limitations that present opportunities for further research. Due to the cross-sectional nature of our data, a causal relationship between the variables considered cannot be definitively established. However, a longitudinal design was not considered feasible because variations in the population's perception of risk in relation to the SOTE would only potentially be observed in the event of an accident in the studied period. In addition, the selected sample does not include households of some irregular urban settlements that do not maintain minimum conditions from a sanitary or safety perspective. Future research should carry out the analysis of the data collected according to the characteristics of the population, such as gender, age, educational level, etc., as well as the influence of household's distance from the SOTE to capture its effect in the results.

6. Conclusions

This research provides information on the factors contributing to risk perception and influencing preparedness for response and recovery from technological disasters. A sequential mediation model has been developed that shows that knowledge, trust in authorities, and risk perception display a relationship with the population's preparedness to deal with the risk posed by an oil pipeline in operation in the MDQ. The results obtained shown the key role of risk perception as a mediating variable, meaning that knowledge and trust in authorities affects preparedness through their influence on risk perception.

In a city where the residents, livelihoods, and housing are exposed to multiple natural hazards, the problem is exacerbated by the coexistence of an operational oil pipeline with a highly vulnerable population. This situation is aggravated by the fact that the population is largely unaware of the presence of the SOTE because most of its route is underground, and, for many years, the pipeline has been part of the landscape to which the urban community of the MDQ has become accustomed. This has caused the public's perception of risk with respect to the SOTE to be very low, which could lead to complacency and insufficient preparedness to address the risk. This means that the significant hazard of living near an operational oil pipeline may be perceived as lower risk compared to other existing natural hazards, such as earthquakes. However, this does not imply that the risk does not exist, or cannot impact peoples welfare or cause serious damage to them or their property. Instead, it tends to go unnoticed over time and is forgotten.

The results of the empirical study indicate that knowledge enhances the publics risk perception and preparedness to manage potential disasters. Therefore, disaster risk reduction has been proposed to develop educational, and information dissemination campaigns on potential technological hazards faced by MDQ residents, particularly those belonging to vulnerable communities, to strengthen their preparedness. Improving the oil pipeline signage for different underground zones according to the risk level, as well as public dissemination of risks associated with irregular settlements in the pipelines safety zone, can increase the population's awareness of the risk and willingness to prepare.

Furthermore, given the negative relationship found between trust in authorities and risk perception, and indirectly, with preparedness, it is recommended to involve the population be in risk management and policy design, making them co-participants and co-responsible for the application of measures. This approach would prevent placing all responsibility for risk prevention and management on third parties. Additionally, providing public financial support for self-protection plans would strengthen the relationship between willingness to prepare and effective preparedness.

CRediT authorship contribution statement

Alfredo-Geovanny Salazar-Baño: Conceptualization, Data curation, Methodology. **María-Luisa Chas-Amil:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Emilio Ruzo-Sanmartín:** Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Emilio Nogueira-Moure:** Visualization, Writing – original draft, Writing – review & editing.

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