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The invisible risks of the trans-Ecuadorian oil pipeline system: An analysis of social preferences in Quito

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ABSTRACT

Oil infrastructure poses a significant risk to the people living in its vicinity. Despite the numerous studies conducted on the impact of the industry's accidents, research into disaster risk reduction relating to the oil pipelines that pass through urban areas is still limited. This study addresses this gap using the Trans-Ecuadorian Oil Pipeline System in the Metropolitan District of Quito (Ecuador) as a case study. A discrete choice experiment is employed to assess the preferences of the local population concerning risk mitigation measures and the extent of their willingness to pay for their implementation. The results reveal that approximately one third of the respondents were unaware of the risks associated with the pipeline, and only 14% were willing to pay for the introduction of risk mitigation strategies. The paper not only highlights the essential requirements for the development of mitigation policies, including the need to improve public awareness of the unrecognised risks, but also emphasises the importance of considering the population's preferences when designing and implementing measures to mitigate risk.

1. Introduction

Natural and technological disasters have significant and increasing impacts on both the environment and society, including the loss of human life, property damage, and social and economic disruption, with developing countries being particularly vulnerable (UNISDR, 2019). Consequently, disaster risk reduction has become a global objective for governments worldwide, with agendas for action established at the international level. An example is the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015), which provides a political roadmap for governments and citizens to prevent and mitigate the effects of hazards and risks relating to the environment and technology. The goals of reducing risk and increasing resilience mean that a multidimensional understanding of disaster risk is a key priority, requiring information to be generated for the purposes of assessment, prevention, preparedness and mitigation (UNISDR, 2015).

The management of technological risks poses a particular challenge, especially for the hazardous and critical infrastructures located in areas already prone to natural hazards. Conducting a comprehensive risk assessment of infrastructure investment is thus essential to identifying, evaluating and prioritising the hazards potentially posing the most risk and their consequences (Krausmann et al., 2011; Marques and Berg, 2011). This approach helps decision-makers to both design more resilient infrastructure to reduce environmental, operational and financial losses in the event of structural failure (Belluck et al., 2006; Badida et al., 2019), as well as to determine the best infrastructure locations (Kirchhoff and Dobertein, 2006).

In this context, public preferences play a crucial role in decision-making, as projects directly impact the quality of life of the population. The literature on large infrastructure projects employs a diverse range of methodologies, including traditional surveys, interviews, or focus groups (Goodfellow et al., 2014), as well as the stated preference method, which enables more intricate analyses. Specifically, discrete choice experiments, rooted in economic and behavioural theories, provide valuable insights for the decision-making process in investment evaluations. Moreover, DCE analyse the social acceptance of projects and technologies, contributing to maximizing the positive impact of infrastructure investments. This becomes especially important in the

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broader context of infrastructure decision, bridging the gap between risk assessment and public preferences to inform strategic and resilient infrastructure development.

Within the realm of large infrastructure, such as transportation systems or energy initiatives, discrete choice analysis helps identify the factors influencing people's choices, contributing to predicting the potential adoption and acceptance of emerging technologies (e.g., Kim et al., 2014; Brennan and van Rensburg, 2023; Borsje et al., 2023; Lokuge et al., 2023). In the context of the petroleum industry, existing literature on public preferences largely focuses on the valuation of environmental impacts of oil spills. However, applications to pipelines location are limited, mostly focused on the social acceptance of specific installations (Chen et al., 2012; Gravelle and Lachapelle, 2015; McEvoy et al., 2017; Brunner and Axsen, 2020; Bessete et al., 2021). To our knowledge, public preferences concerning alternative locations for existing installations have not yet been investigated.

Our research seeks to fill this gap in the literature by conducting a Discrete Choice Experiment (DCE) using the Trans-Ecuadorian Pipeline System (SOTE) as a case study, as it passes through the urban area of the Metropolitan District of Quito (MDQ), chosen in light to Ecuador's heightened exposure to natural hazards (Poma et al., 2021).

Our primary objectives are twofold: (a) to investigate the demand for and assessment of various alternatives to the current pipeline route, facilitating a comparison between locations and the prioritisation of strategies to mitigate risk, and (b) to analyse the effects of payment periodicity in the design of choice experiments.

Deciding between different alternatives requires the selection of the option that gives the decision-maker the greatest benefit or utility based on the attributes of these alternatives compared at different levels and characteristics (Körding, 2007). A discrete choice experiment was used to assess the preferences of the population regarding eight future scenarios for the SOTE pipeline, described by three non-monetary attributes (landscape, environmental impact, and risk level) and two levels each one. DCEs provide a way to assess each attribute and estimate the willingness to pay to depart from the current situation or status quo. to each one of these future scenarios, i.e., we can obtain a measure of well-being associated to each one of the alternatives, giving to the policymaker new information about the social acceptability of changes from the current infrastructure. In this regard, we propose the following two hypotheses: H_1 - the MDQ population wants mitigation measures; and H_2 - the MDQ population prefers alternatives that would relocate the pipeline away from the city.

While individuals are generally expected to assess programs based on their total cost, some studies have shown that the payment timeframe can affect the choices made, with recurring (e.g., monthly) more acceptable than aggregate (e.g., annual) payments (Soliño et al., 2012; Andersson et al., 2013; Le Tran et al., 2017). Based on this research, this paper aims to analyse whether there are differences when using monthly or annual payments. Accordingly, two hypotheses are proposed: *H3* - status quo alternative is more selected when annual payments are presented; and *H4* - the marginal willingness to pay monthly is higher than that estimated for annual payments.

The results of this study have significant implications for the decision-makers responsible for planning and implementing measures to reduce risk in line with the requirements of the Sendai Framework. Specifically, we highlight the need to improve public awareness of unrecognised risks and, as a primary challenge for large infrastructure projects, emphasise the importance of taking the population's preferences into account.

In the following section, we provide a brief literature review, the description of the study area, the introduction of the DCE, the sample used, and the econometric approach. Finally, we present our empirical results, followed by a discussion of our findings, main conclusions and policy implications.

2. Literature review

In the context of the petroleum industry, the global effects of oil spills are a critical concern (Jernelöv, 2010; Chang et al., 2014; Chilvers et al., 2021). Researchers have employed various scientific approaches to develop effective response strategies and assess the impact on the environment, public health and the economy (Fingas, 2015; Murphy et al., 2016; Michel, 2021). There has been a growing emphasis on the economic valuation of the effects of oil spills, chiefly with the aim of providing compensation for any damage that may be incurred. In particular, individual preferences for environmental goods and services affected by oil industry activities have been analyzed using stated preference methods, including the contingent valuation method (e.g., Carson et al., 2003; Loureiro et al., 2009; León et al., 2014; Whitehead et al., 2023), and choice experiments (e.g., Casey et al., 2008; Liu et al., 2009, 2016; Tuhkanen et al., 2016; Lee et al., 2019; Ukpong et al., 2019).

Choice experiments are a useful valuation method when the program incorporates several non-marketed effects, such as the case of the pipeline, when landscape, environmental and health risk are compromised. Specifically, choice modelling has been used in various countries to assess public attitudes and preferences concerning oil pollution and environmental restoration. Examples include the valuation and assessment of environmental risks and benefits associated with oil transport on the Amazon (Casey et al., 2008), marine environmental quality in Estonia (Tuhkanen et al., 2016) and the oil and gas industry in Nigeria (Ukpong et al., 2019). Other studies have been conducted to evaluate choices between mitigation strategies in coastal areas, including the use of different remediation measures in South Korea (Lee et al., 2019) and China (Liu et al., 2016), and the prevention of pollution in Germany (Liu et al., 2009). However, there has been little focus on the public's preferences concerning the measures available to reduce the risks associated with hazardous oil infrastructures in urban areas, particularly with regards to those that are primarily subterranean. This is especially the case for oil pipelines, about which little is typically known by the individuals exposed to the risks they pose (Slovic, 1987), which often go unnoticed until an accident occurs, or a new project is proposed (Hansen et al., 2006; McAdam et al., 2010; Chien and Chang, 2021). Moreover, a literature search for the use of discrete choice methods in public preferences on oil pipelines alternative routes yields no results to our knowledge.

Finally, one of the main issues in stated preference research is related to the hypothetical nature, and the validity and reliability of results. The reliability refers to the degree of reproducibility of the results and can be analyzed by testing small changes in the definition of attributes (Rakotonarivo et al., 2016). In this regard, several authors have analyzed the consistency of DCE results among different treatments related to the payment attribute (Soliño et al., 2012; Meginnis et al., 2020; Cunha-e-Sá et al., 2023). In the line of Soliño et al. (2012), this study delves into a fundamental aspect of valuation, the analysis of the effects of payment periodicity in the design of choice experiments. The wording of the monetary attribute (Rowen et al., 2018), the payment timeframe or the temporal aggregation of payments (McGowan et al., 2023) may impact on the results of estimates. We examine the impact of the issue of the payment timeframe on evaluations of the marginal willingness to pay and the consistency of the decisions made relating to such payments.

3. Material and methods

3.1. Study area

The state-owned SOTE, which accounts for 84% of the oil transported (EP Petroecuador, 2019), is a crucial component of the Ecuadorian pipeline system, along with the Heavy Crude Oil Pipeline (OCP) and the San Miguel-Lago Agrio Pipeline (OSLA). At a length of 520 km, it transports oil from the production fields in the Amazon, through the

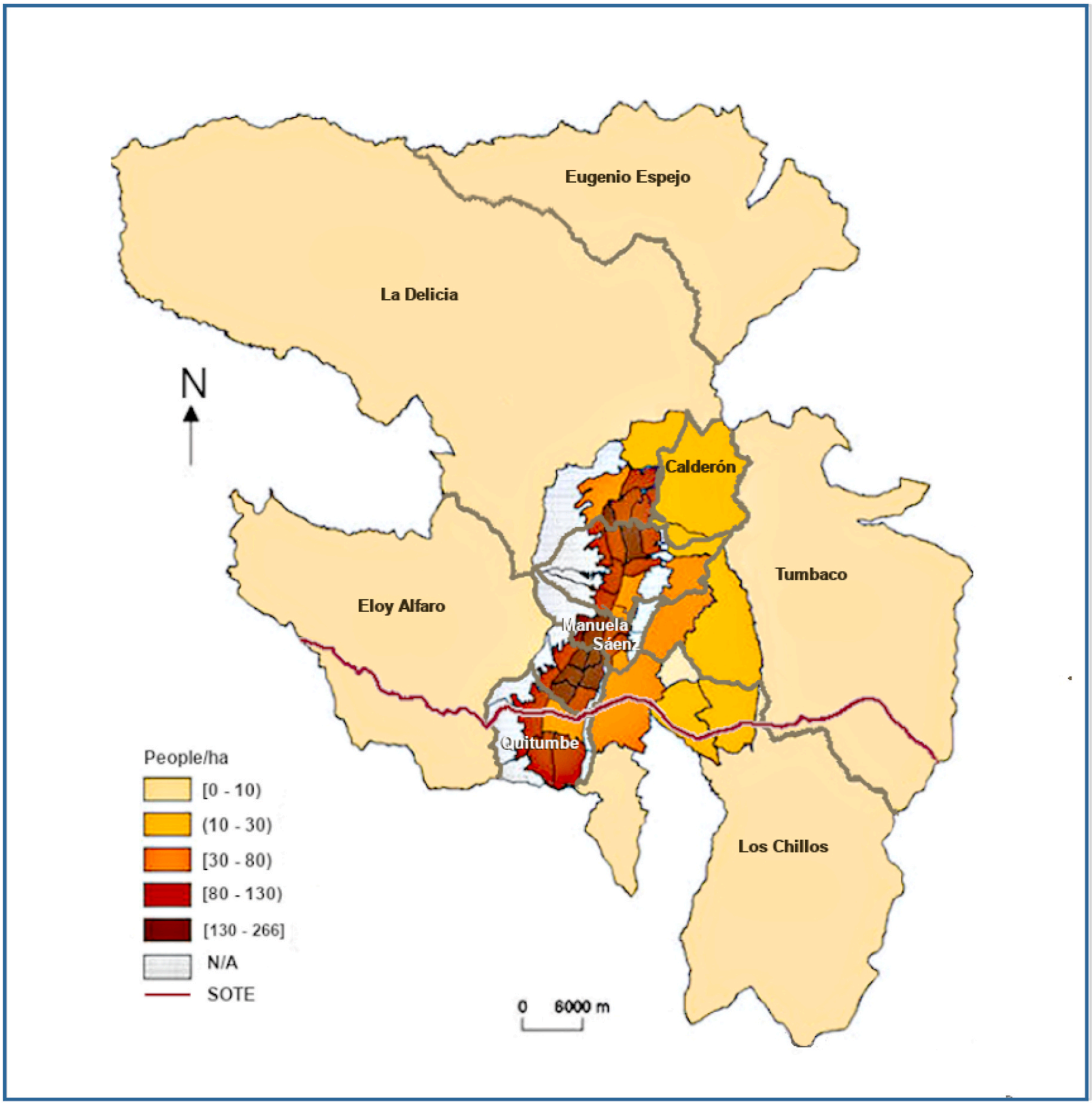

Fig. 1. Population densities in 2021 and SOTE route in the administrative zones of the MDQ.

Andes mountains, to the coastal region to either be processed in the Esmeraldas Refinery or commercialised and shipped from the Pacific coast. The pipeline runs through areas of high volcanic and seismic threat, with a maximum level of vulnerability at any point along its route (EP Petroecuador, 2011). This is aggravated by the facts that it is currently operating at its installed capacity limit (98.9%) (BCE, 2017) and has exceeded its life-cycle by 25 years (Albán Soria, 2009). Moreover, the pipeline passes through highly sensitive and complex ecosystems that have suffered from frequent oil spills, persistent leaks and wastewater dumping, mainly in the Amazon. Oil contamination poses significant risks to human health and the ways of life of indigenous communities (e.g., San Sebastián et al., 2001; Widener, 2011). Furthermore, the SOTE traverses densely populated urban areas with high population growth. An example is the MDQ (Fig. 1), where the number of inhabitants has increased five-fold since the pipeline's inauguration in 1972. This rapid growth has resulted in a dynamic expansion towards the south of the district, with a proliferation of informal settlements (UN-Habitat, 2003) that haphazardly occupy the territory in areas crossed by the SOTE, even encroaching into the pipeline's safety zone (EP Petroecuador, 2019). The risk to the population is compounded by the coexistence of an operational pipeline in a city that is highly exposed to various threats and natural hazards (Toulkeridis et al., 2015).

3.2. Discrete choice experiment

A discrete choice experiment is a stated preferences method that asks respondents to express their preferences from a set of alternatives (Louviere et al., 2000). Each alternative is described with various characteristics (known as attributes) that have different levels. The individual's choice represents their preference for one alternative over another, as well as over the status quo (i.e., without implementing any change and not involving any payment). This enables researchers to assess the impact of changes made to the attributes that define an environmental program, as well as the willingness to pay for each attribute. Specifically, individual i will choose an alternative k, $\forall k \in J$ with J being the choice set, if (and only if) the utility of the choice U_{ik} is greater than the utility of the alternatives, $U_{ik} > U_{ij}$, $\forall k \neq j$. The probability of an individual choosing an alternative depends on its levels, including the cost. The choice is determined by an aversion to lose and a

Table 1
Attributes and levels used in the choice experiment.

Attributes	Levels
Landscape	Garden: Linear garden crossing the city Out: Outside the city
Environmental impact	Negative: if the policy causes environmental damage in the urban area of the MDQ. Positive: if the policy does not cause any environmental damage in the urban area of the MDQ.
Risk level	High: there is a significant risk of harm to the population of the MDQ. Low: there is no significant risk of harm to the population of the MDQ.
Monthly/annual payment	$8 monthly/$96 annual $18 monthly/$216 annual $28 monthly/$336 annual $38 monthly/$456 annual

desire to win, with the status quo being a reference point. Consequently, the magnitude of the gain or loss is a function of how far removed the decision made is from the status quo (Kahneman and Tversky, 1979; Pearce et al., 2002).

In this work, a DCE was used to evaluate different alternatives for mitigating the risks to the MDQ population posed by the presence of the SOTE. In the first stage of the research, alternative pipeline routes were defined in relation to the status quo using studies concerning pipelines and the risks associated with their construction and operation (Kutukov et al., 2001; Goodland, 2005; Van Hinte et al., 2007; Casey et al., 2008; Mendoza-Cantú et al., 2011; Su, 2014; DHNY, 2014; Davis et al., 2015; Zhao et al., 2015; Tian and Chen, 2016).

A collaboration of eight experts was asked to prioritise alternatives that would reduce the risks associated with the SOTE's presence in the urban MDQ, and to determine the variables (attributes and levels) that would enable the prioritised alternatives to be distinguished. The selection of these experts was based on their experience and academic qualifications in fields such as risk and safety, the environment, infrastructure, and the oil industry. Initially, they designed eight attributes with intermediate levels, but the results of the pretest showed that the participants were not able to manage more than four attributes and had difficulty in understanding the intermediate levels. As a result, only the extreme levels were able to be assessed with a reasonable cognitive effort. Moreover, a pilot test was conducted with 10% of the sample to obtain the priors for an efficient experimental design. Four final attributes were included in the experiment (Table 1): 1) landscape, which represented the appearance of the SOTE route after intervention in the area where the policy would be executed; 2) the environmental impact of executing the program; 3) the level of risk to the urban population in the event of leaks, spills, explosions and/or fires caused by the pipeline; and 4) the monthly or annual payment required from residents' households, whether owners or renters, in the form of an increase in the urban property tax to be paid for a period of five years. We assume that consumers could bear the entire cost directly if all people should pay the higher bid level. Another approach could be assessing the willingness of consumers to contribute smaller amounts, encouraging community engagement and gauging the inhabitants' financial capacity. Our approach raises essential questions about how people would perceive strategies of cost sharing and cost sprawling, or about the extent to which the government or private companies would need to supplement the total cost. Moreover, considering a tiered payment system based on property tax could make the project financially feasible for a wider segment of the population, ensuring a more equitable distribution of the burden and leading to a more sustainable funding model. Incorporating alternative payment strategies opens avenues for practical implementation, ensuring the infrastructure project's success while minimizing the economic strain on individual consumers. There was no specification of whether the payment would be made at the beginning or end of the month/year, and it was not considered a discount rate because of the short duration of the payment period.

Similarly, the levels of each attribute were predetermined to ensure the information presented to the respondents was pertinent and explicit (Table 1). We verified that the choice cards were significant without presenting dominance, ensuring the respondents were required to make trade-offs between the attribute combinations they were asked to consider. There were two levels for the landscape attribute: 1) a linear garden crossing the city within the SOTE's exclusive use area, which is a right-of-way delimited by 15 m on each side. This option would mean clearing the SOTE area via expropriation and the demolition of certain structures in specific locations; and 2) moving the SOTE's route from the MDQ's urban area and using the Heavy Crude Pipeline's route outside the city instead. There were also two levels for the environmental impact attribute: 1) negative impact and 2) positive impact, depending on whether or not the proposed alternative would cause environmental damage in the urban part of the MDQ. Finally, high and low levels were defined for the risk level attribute, whether or not the proposed alternative posed a significant risk of harm to the MDQ's urban area.

Moreover, an undefined opt-out alternative was included in the experiment as a way to present choice scenarios that mirrored real life. The individual could choose to continue as before, without any alteration in the SOTE, but the levels of environmental impact and risk associated with such alternative were not presented. In terms of the current circumstances concerning the pipeline, the respondents were asked about their perceptions of the consequences of non-intervention, both in relation to the SOTE's environmental impact (positive/negative) and the risks it posed (high/low). These two variables enabled us to incorporate the individual's perceptions into the preference modelling. Our analysis builds on the work of Domínguez-Torreiro and Soliño (2011) and Marsh et al. (2011), who demonstrated that consideration of the perceived status quo improves preference estimates. The design of the experiment had an unspecified opt-out, meaning that the respondents were not a priori anchored to any particular value and were able to spontaneously express their views about the status quo. We initially started the experiment with a model that did not consider perceptions about the status quo, but the results were worse in terms of the statistical significance of the attributes.

Consequently, our econometric approach included the landscape associated with the SOTE, i.e., a linear garden both crossing the city (GARDEN) and outside it (OUT). However, we did not directly introduce the original attributes of environmental impact and level of risk into the model, instead recoding them as "winning" variables in terms of the environmental impact (W-ENV) and the risk level (W-RISK). As a result, when a respondent is presented with an alternative that encompasses positive (negative) effects and he/she has the perception that the status quo has the same positive (negative) effects, the proposed intervention will not have an impact. In other words, the effect of the program will be null, and the individual respondent will neither win nor lose. Nevertheless, when an alternative dealing with negative (positive) effects is proposed, the individual will lose (gain) due to his/her positive (negative) perceptions of the environmental impact and/or risk.

Two versions of the survey were used for the monetary attribute (COST), distinguished per the payment timeframe: monthly (M) and annual (A). This enabled us to analyse whether the timing of when payment was required affected the choices made by the respondents. Four price levels were established based on the costs of implementing the proposed alternatives. The total cost was calculated according to the criteria determined by the experts we had consulted. This involved the application of the highest market prices to ensure full financing, taking into account the total number of registered households in the MDQ, i.e., 549,472 (INEC, 2017). In USD, a minimum monthly payment of $8 and a maximum of $38 were estimated, with the remaining payments being $18 and $28. In relation to the annual case, the payments were set at $96, $216, $336 and $456, giving us equivalent total payments for both versions of the questionnaire (Table 1).

The Ngene® software was used to create the choice cards

Attribute	Program A	Program B	Status Quo
Landscape	Linear garden crossing the city	Outside the city	Empty lots and some buildings in the city
Environmental impact	Negative	Positive	
Risk level for urban population	High	Low	
Monthly urban property tax for 5 years	$38	$8	$0
CHOICE (mark with an X your preferred alternative)	[ ]	[ ]	[ ]

Fig. 2. Example of choice card for monthly payment.

(Choicemetrics, 2018) and the D-efficiency was employed as the statistical criterion for the experimental design (0.087437 for the final design). There were 12 choice cards in the DCE, with each one presenting two scenarios and the status quo based on the attributes and levels described earlier. Fig. 2 contains an example of a choice card used in the monthly payment version of the questionnaire.

As a preamble to the choice experiment, the respondents were told that:

> “The SOTE, with more than 44 years of operation, is the oldest oil pipeline in Ecuador. The SOTE crosses rural and urban areas, as well as Quito from west to east, through the urban parishes of Quitumbe and Chillogallo located in the south of the city. Please choose the alternative you prefer with respect to the presence of the SOTE”.

During the fieldwork, the interviewers provided the respondents with a detailed explanation of the attributes, including information about the potential consequences of a disaster or accident caused by the pipeline. They were also shown maps of its current course and the proposed alternatives, which enabled them to visualise their place of residence in relation to its route. The respondents were also reminded of the budget restrictions, with a clear explanation provided to them that any new program would affect their personal and/or family budgets. In addition, a real commitment to implementing the alternative chosen was conveyed to generate payment incentives and increase the credibility of the proposals (Kling et al., 2012).

Table 2
Descriptive of survey samples for annual and monthly payment timeframe versus urban Ecuadorian population statistics.

<table>
<tr><th></th><th>Annual payment</th><th>Monthly payment</th><th>Population</th></tr>
<tr><td>Administrative zone (%)</td><td></td><td></td><td></td></tr>
<tr><td>Quitumbe</td><td colspan="2">14.0</td><td>13.9</td></tr>
<tr><td>Eloy Alfaro</td><td colspan="2">19.3</td><td>20.4</td></tr>
<tr><td>Manuela Sáenz</td><td colspan="2">10.5</td><td>10.5</td></tr>
<tr><td>Eugenio Espejo</td><td colspan="2">21.0</td><td>20.2</td></tr>
<tr><td>La Delicia</td><td colspan="2">15.8</td><td>16.1</td></tr>
<tr><td>Calderón</td><td colspan="2">7.8</td><td>7.4</td></tr>
<tr><td>Tumbaco</td><td colspan="2">4.0</td><td>3.8</td></tr>
<tr><td>Los Chillos</td><td colspan="2">7.8</td><td>7.8</td></tr>
<tr><td>Gender (%)</td><td></td><td></td><td></td></tr>
<tr><td>Female</td><td>51.2</td><td>50.5</td><td>51.5</td></tr>
<tr><td>Male</td><td>48.8</td><td>49.5</td><td>48.5</td></tr>
<tr><td>Age (%)</td><td></td><td></td><td></td></tr>
<tr><td>19–35</td><td>47.2</td><td>46,2</td><td>46.0</td></tr>
<tr><td>36–64</td><td>46.0</td><td>43.5</td><td>44.1</td></tr>
<tr><td>65+</td><td>6.8</td><td>10.3</td><td>9.9</td></tr>
<tr><td>Average number of years of education</td><td>13.3</td><td>13.4</td><td>12.4</td></tr>
<tr><td>Monthly urban household income (%)</td><td></td><td></td><td></td></tr>
<tr><td>< $450</td><td>30.8</td><td>25.8</td><td>35.2</td></tr>
<tr><td>$450 - $900</td><td>38.5</td><td>50.2</td><td>35.0</td></tr>
<tr><td>$901 - $1350</td><td>24.3</td><td>21.3</td><td>15.3</td></tr>
<tr><td>$1351-$1800</td><td>5.8</td><td>2.5</td><td>6.5</td></tr>
<tr><td>> $1800</td><td>0.8</td><td>0.3</td><td>8.0</td></tr>
<tr><td>Mean monthly household income ($)</td><td>718</td><td>685</td><td>841</td></tr>
</table>

3.3. Sample

We employed a stratified random sampling method with proportional allocation to select households located in the MDQ based on the eight administrative zones, gender and age. Adults over 19 years old were interviewed face-to-face at the participants’ home by trained personnel during the period February to March 2017. A total of 800 households were selected, with independent split samples of 400 in size for each payment timeframe (annual and monthly) to prevent individual survey anchoring effects on the time preferences. Table 2 shows the characteristics of the respondents from each sample and compares them to Ecuadorian official data (INEC, 2013, 2017, 2020), revealing that our samples are closely representative of the MDQ population by administrative zone and socio-demographics, including gender, and age. In regard to urban household income, our sample is not representative of the overall population. Questions about personal income are always complicated and generate mistrust, potentially resulting in strategic responses. In our study, we note that the mean monthly urban household income in 2012 (INEC, 2013) exceeds the median value stated by the interviewees, which may make us suspect that they have responded downwards about their household income. home, the participants exhibited a higher education level in both samples compared to the population average of 12.4 years in Quito (INEC, 2017). A total of 880 people were contacted, 80 of whom refused to participate in the survey, mainly due to time constraints. Each of these non-respondents was replaced with a reserve randomly pre-selected from the same stratum. The interviewees were informed about the voluntary nature of their involvement and the strict confidentiality and anonymity of their responses. They were also explicitly informed of their right to end the interview at any time.

3.4. Econometric approach

We worked with a panel data whereby the respondents were assigned to one of the two versions of the questionnaire ($i_{ANNUAL} = 1, 2, \ldots, 400$; $i_{MONTHLY} = 1, 2, \ldots, 400$) and asked to select an alternative from a set of choices set out in t cards ($t = 1, 2, \ldots, 12$). The utility obtained by individual i from alternative j in the choice situation t can be expressed as:

$$U_{ijt} = \beta_i\, x_{ijt} + \delta_i\, w_{ijt} + \gamma_i\, c_{ijt} + \varepsilon_i \tag{1}$$

where:

x_{ijt} is the vector of the landscape attributes (GARDEN and OUT) for each alternative j,

w_{ijt} is the vector of the recoded "winning" attributes (W-ENV and W-RISK) for each alternative j, defining w_{ijt} as the difference between the level presented and that perceived by individual i in the absence of a program,

c_{ijt} is the monetary attribute (COST)

β_i, δ_i and γ_i are vectors of the estimated coefficients, and ε_i is the error term.

As with other stated preference methods, a discrete choice experiment may see the registration of protest responses by the participants. This occurs when respondents reject any of the key elements of a valuation scenario, even though they may be willing to pay for the implementation of an alternative that minimises risk (Bateman et al., 1995; Carson, 1999; Vollmer et al., 2016). There is much discussion about how to treat protest responses, although those that refer to budget restrictions are usually taken to be true zeros (Soliño et al., 2010). Our modelling excluded protest responses, with a lower number registered in the sample participating in the monthly version of the questionnaire (10%) than in the annual version (30%). Protest responses were classified as those where the respondent repeatedly chose the status quo because of views like disagreeing with the tax increase (more than 60% of the motivations in both versions) or not trusting that the payment sought would be used appropriately, i.e., motivations unrelated to the budget restriction (4% in the monthly version and 11% in the annual version).

The data panel for the monthly payment group consisted of 359 households and 12 choice sets, giving us a total of 4308 observations; meanwhile, there were 279 households and 12 choice sets in the annual payment group, which produced 3348 observations. A latent class model (LCM) was used to analyse the choice data (Vermunt and Magidson, 2016). In this framework, the indirect utility function of individual i (V_i) can be represented as:

$$V_{ij} = \alpha_j + \overline{\beta}' S_{ij} + \theta_i' S_{ij} + \varepsilon_{ij} \tag{2}$$

where α_j is a constant for each alternative ($j = 1, 2, \ldots, J$); S_{ij} is the attribute vector; $\overline{\beta}$ is the vector of the population's mean preference values; θ_i denotes deviations in individual preferences; and ε_{ij} is an *i.i.d.* type I extreme-value random utility component. Several econometric approaches are available to analyse discrete choice data, as a random parameters logit, willingness to pay in space models, or latent class models, among others. We have estimated several models (see the Appendix for results from a RPL model and a WTP-in space model), but in this paper we focus on the results from a Latent Class Model (LCM) with random parameters to better catch the unobserved heterogeneity of the choice data. In our model, the distribution, f(β), is discrete, encompassing a finite number of classes, 1, 2, …, k (in our case, three, based on the Akaike Information Criterion - AIC). Consequently, β_{ik} follows a distribution with a density f(β) for each class k. We treated random behaviours as inter classes (θ_i) for all the attributes, i.e., $\beta_{ik} = \overline{\beta}_k + \theta_i$. Denoting $F_{i,k}$ as the probability that $\beta_i = \beta_k$, the probability of the individual sequence of choices [$y_1, y_2, \ldots, Y_T$] is an integral, as follows:

$$P_i\left[y_1, y_2, ..y_j, .., y_T\right] = \sum_{k=1}^{K} F_{i,k} \frac{1}{R} \sum_{r=1}^{R} \left[\prod_{t=1}^{T} \frac{e^{\mu\left(\alpha_j + \beta_{ik}'^{r} S_{ijt}\right)}}{\sum_{h=1}^{J} e^{\mu\left(\alpha_h + \beta_{ik}'^{r} S_{iht}\right)}} \right] \tag{3}$$

Each latent class matches a segment of the interviewees allocating the same importance to the attributes of the SOTE pipeline, i.e., the sample is divided into different classes of people acting in a similar way (intra-class behaviour), but quite different to other individuals in another classes (inter-classes behaviour). In this way, unobserved heterogeneity can be explained via latent classes.

Our LCM with random parameters was estimated via simulation using the Latent Gold® software. After estimating the model parameters, the marginal willingness to pay (WTP) was calculated to quantify the marginal utility assigned by the respondents to each attribute in monetary terms. The WTP for attribute k was computed as the negative ratio between the parameter of attribute k (β_k) and the cost parameter (β_{Cost}), i.e., $WTP_k = -(\beta_k/\beta_{Cost})$. This value provided decision-makers with relevant information about the welfare to households when implementing the proposed alternatives.

4. Results

This section presents the results obtained from our two independent samples of MDQ households using different payment timeframes, monthly (M) and annual (A). These findings indicate that the respondents held relatively favourable perception on the status quo and associated it with a positive environmental impact; for 46% and 50.75% of those in the monthly and annual payment groups, respectively. Likewise, a high number of respondents thought the status quo presented a low risk: 32.75% and 45% in the monthly and annual payment groups, respectively. These results suggest that, despite the provision of detailed information about the SOTE pipeline, including its route and potential impact in the event of an accident, a considerable number of the respondents had a positive perception of the status quo, with more favourable perceptions held by those in the group assigned to consider the annual payment method. In fact, 27.48% and 44.21% of the respondents in the monthly and annual payment groups, respectively, preferred the status quo to any of the other alternatives. This difference can also be attributed to an income effect in relation to the proposed timeframe, which appears to be lower in the version of the questionnaire referencing monthly payments.

The LCM results for the annual and monthly payment groups are presented in Table 3 and Table 4, respectively. The analysis identified three latent classes according to the AIC values obtained for the different modelling specifications. For version A (annual), those in Class 1, which comprised 71.74% of the households in the sample, valued landscape changes as positive, but did not take into account the monetary attribute or the gains in terms of the environmental conditions and risk. Those in Class 2, comprising 15.39% of the sample, valued landscape changes as very positive, assigning a similar positive weight to the option of creating a linear garden and moving the SOTE pipeline outside the city. Finally, Class 3 was composed of households (12.88% of the sample) who valued the proposed landscape changes negatively. Gains in terms of environmental conditions and risk did not affect the utility of the households in any of the three classes. The random parameters, meanwhile, were statistically significant for all the attributes except W-RISK.

In version M (monthly), those in Class 1, which comprised 61.12% of the households in the sample, did not consider the monetary attribute when making their decisions about the alternatives presented to them. However, households in this class assigned a negative value to environmental improvements, which can be explained by their strong perception that the status quo already has a positive environmental impact. Class 2, comprising 25.41% of the sample, valued the same attributes as those in Class 1, but with greater intensity. The significant and positive aspect of the COST coefficient may indicate the existence of some complacency or 'yea-saying' bias among these respondents. Environmental gains did not affect the utility of those in this class. Finally, Class 3, representing 13.47% of the surveyed households, showed positive preferences for both landscape changes, especially the option of creating a linear garden, and environmental gains, with a

Table 3
Results of the LCM for the Annual version (A).

	Class1		Class2		Class3		Rdm.Param.	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
COST	<0.001	<0.001	−0.008***	0.001	0.011	0.008	0.001**	<0.001
W-ENV	0.005	0.047	−0.200	0.156	0.106	1.002	0.137**	0.066
W-RISK	−0.053	0.046	−0.157	0.142	0.770	1.131	0.033	0.056
OUT	1.076***	0.125	10.638***	3.408	−11.039***	3.688	0.812***	0.172
GARDEN	1.057***	0.123	10.097***	3.405	−9.826***	3.118	0.931***	0.162
Intercept	1.086***	0.101	−0.454***	0.139	−0.632***	0.127		
R^2	0.0525		0.5092		0.0843		Overall:	0.3071
Class Size (%)	71.74		15.39		12.88			

***p < 0.01 **p < 0.05.

Table 4
Results of the LCM for the Monthly version (M).

	Class1		Class2		Class3		Rdm.Param.	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
COST	−0.001	0.003	0.052***	0.006	−0.045***	0.009	0.004	0.003
W-ENV	−0.396***	0.057	−0.114	0.081	0.836***	0.154	−0.050	0.052
W-RISK	0.095**	0.048	0.649***	0.098	0.192	0.113	0.006	0.047
OUT	2.570***	0.334	6.430***	0.904	7.626***	0.895	5.337***	0.589
GARDEN	2.366***	0.333	6.745***	0.899	8.346***	0.896	5.254***	0.590
Intercept	0.797***	0.122	−0.081	0.131	−0.716***	0.147		
R^2	0.2412		0.2986		0.3276		Overall:	0.3067
Class Size (%)	61.12		25.41		13.47			

***p < 0.01 **p < 0.05.

negative COST coefficient indicating an income effect. Random parameters were only statistically significant for the landscape attributes.

These results demonstrate that H_1 should not be rejected, since MDQ respondents demanded some mitigation measures with respect to the status quo. However, H_2 must be rejected since the respondents were either indifferent to or had more favourable views on the option of creating a linear garden. Finally, H_3 should not be rejected, since 44% of the respondents in the annual payment prefers the status quo, compared to 27% of those considering the monthly payment.

In relation to the economic contributions required of households to fund an alternative to the status quo, the coefficient was positive for Class 2 in the monthly payment group. This is contrary to expectations and suggests that those faced with more frequent payment were less aware of the total cost of the program than those facing annual payments. Consequently, H_4 should not be rejected, since the estimated mean WTP was higher among the monthly payment group than in the group facing annual payment. In order to verify this, we calculated the WTP for the significant variables in the classes where the COST coefficient was negative and statistically significant, i.e., Class 2 in the annual payment group and Class 3 among the monthly payers.

The WTP for W-RISK was never statistically significant and W-ENV was only so for the monthly payment group, where the WTP for W-ENV was set at $224. The equivalent annual WTP for OUT ranged from $1382 for the respondents facing annual payments to $2047 for their counterparts considering the monthly payment. Meanwhile, the equivalent annual MWTP for the GARDEN alternative ranged from $1311 in the annual version to $2241 for the group facing monthly payments. These findings suggest that the MWTP for the OUT and GARDEN alternatives was quite similar among households in the same group, but the average WTP of the monthly payers was between 1.48 and 1.70 times higher (expressed in annual terms) than that of their annual payer counterparts.

5. Discussion

The results for the landscape attribute, which was measured using the variables OUT and GARDEN, suggest that respondents' preferences were similar for the two options, albeit with slightly higher values for GARDEN. This suggests that creating a linear garden along the SOTE route was perceived as a slightly better alternative. The minor differences observed between the two alternatives could be attributed to a perception that the pipeline's current route is not a cause of concern. Moreover, the low significance of the coefficients of the W-ENV and W-RISK attributes indicates that, compared to the status quo, the respondents did not generally associate improvements to the environment or a reduced level of risk with the alternatives under consideration. In fact, they regarded the risks posed by the SOTE as low or negligible which may be because this infrastructure has become an integral part of the urban landscape and there have been no major accidents in the MDQ. Furthermore, the risk arising from living close to the pipeline may be perceived as low when compared to that posed by other natural hazards like earthquakes, volcanic eruptions, or landslides, which present a more immediate and tangible threat to safety and well-being (Zevallos, 1996).

The results concerning the economic contribution attribute were puzzling. The cost coefficients were not statistically significant for Class 1 and Class 3 of the annual payment group, and Class 1 of the monthly payers. This suggests a null marginal utility of income. However, the significant positive coefficient obtained for Class 2 of the monthly payment group is inconsistent with the rational economic behaviour inherent in the theory of random utility maximisation (Hoyos, 2010). This indicates that the respondents in this class regarded the proposed contributions as low, suggesting a negative marginal utility of money before the disbursement they had to make. In this sense, the presence of attributes that the respondents deemed to be similar to the status quo may have biased the estimates of the cost coefficient (Hess et al., 2005), even though the interviewers had provided detailed information about the SOTE and the potential consequences of an accident.

The difference in the WTP between the monthly and annual payment groups highlights the relevance of the periodicity of the proposed payment. More frequent payments were linked with a higher WTP. Accounting for the size of each class, and extrapolation to the wider population suggests that, if faced with making annual or monthly payments, 15.39% and 13.47% of households, respectively, would be willing to pay for mitigation measures. The proposal put to the respondents involved an increase in the urban property tax for a period of 5 years. We did not, however, consider the use of a discounted rate due to the short duration of the payment timeframe. This may be a limitation of the study, especially during inflationary periods. Therefore, discount rate analysis may thus be an interesting avenue for future research.

In addition, the average annual urban household income in urban areas of Ecuador ($10,092 in 2012) means that the unexpectedly high WTP for the landscape attributes raises some concern about the reliability of our estimates. Although the reasons for these high values are uncertain, it is possible that the respondents also took into account other subjective perceptions related to the landscape attributes not embedded into the SOTE program. Differences between stated and actual behaviour are not, however, only a problem in stated preference methods (Soliño et al., 2020). Nevertheless, the estimates produced can be unreliable, and the external validity of the study's results may have been affected by well-documented biases, including hypothetical bias (Loomis, 2011; Fifer et al., 2014). Although our case study included reminders about budgetary restrictions, we did not employ mitigation techniques like cheap talk (Ladenburg and Olsen, 2014; Varela et al., 2014) or certainty scales (Ready et al., 2010) to control for hypothetical bias. In addition, the application of DCE in low-income and lower-middle-income countries (LICs) may encounter further challenges to validity and reliability (Rakotonarivo et al., 2016). Issues such as low literacy rates, language barriers, difficulties in explaining hypothetical scenarios, and relatively low respondent exposure to surveys may be more prominent (Bennett and Birol, 2010; Christie et al., 2012). Therefore, we have specifically identified and highlighted evidence from, and implications for, DCEs conducted in LICs. This limitation of the study requires consideration in future research on preferences concerning energy infrastructures.

Despite the limitations of our study, it nevertheless provides valuable insights into the complex dynamics of public perceptions and preferences regarding risk reduction measures associated with oil infrastructures in urban areas. In contrast to the typical public perception of oil pipeline projects, which often face strong opposition (e.g., McAdam et al., 2010; Ternes et al., 2020), a significant proportion of our respondents did not perceive any risk in relation to the well-established infrastructure of the SOTE. Nonetheless, the use of advanced modelling techniques and latent class models capable of capturing heterogeneous behaviours, enabled us to identify a small segment of the population that would, in fact, benefit from safety improvements if mitigation measures were introduced.

5. Conclusions and policy implications

This study contains a unique assessment of the local population's preferences concerning alternative routes for the SOTE pipeline that crosses the MDQ in Ecuador. The use of the stated preference methods provides valuable insights into the demand for risk mitigation measures in relation to oil industry infrastructures. The results showed that approximately one third of the respondents did not associate the SOTE with any significant risk, as it has been a part of their daily life for decades. This suggests that the urban inhabitants of the MDQ do not hold negative views towards the status quo. Their lack of awareness of the pipeline's underground route and the dangers it poses to the urban environment where they live and work has led to a very low, or almost non-existent, perception of the risks they face. The study shows that the best a priori attribute levels do not represent a marginal utility for the MDQ's inhabitants, meaning that the proposed alternatives to the pipeline's current route do not lead to any increase in their welfare. Consequently, most of those in our population are generally content with the status quo, and this satisfaction is thus not substantially improved by alternatives that would require them to make a financial contribution. This means that they are unwilling to pay for something they believe they already possess. There is thus an asymmetric information problem, which may require multidimensional assessments of the public's perceptions of technological risks (Renn and Benighaus, 2013).

Nevertheless, this research found that some respondents regarded the proposed mitigation measures positively and were willing to pay for programs that would make changes to the status quo. In fact, the study provides empirical evidence that approximately 14% of the MDQ's households are willing to pay for measures to mitigate the risks posed to them by the pipeline. Consequently, we recommend the design of policies at the national and local level that contribute to informing the population in the MDQ's urban area about the risks posed by the presence of the SOTE and the measures required to mitigate them. The design of these policies must involve all risk-management stakeholders, as well as the population-at-large more broadly. This participation must be based on the provision of access to relevant information on the risks posed by the pipeline, duly updated and validated. In addition, these policies must comply with the relevant standards and institutional framework established for risk management, with suitable communication and information channels developed to consolidate the population's knowledge of the dangers they face and how they are managed. It is therefore important to implement response plans for catastrophes and accidents that may be caused by the pipeline and to allocate the funds required to mitigate the consequences, even though the local population does not currently have any great awareness of the risks they face.

CRediT authorship contribution statement

Alfredo-Geovanny Salazar-Baño: Conceptualization, Data curation, Methodology, Writing – original draft. **María-Luisa Chas-Amil:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Mario Soliño:** Conceptualization, Methodology, Software, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

APPENDIX

Table A.1
RPL results

	Monthly				Annual			
	Coeff.	Std.Err.	WTP (Annual transformation)	Std.Err.	Coeff.	Std.Err.	WTP	Std.Err.
OUT	1.01244***	0.13141	106.596*** (1279.152)	27.10173	0.98676***	0.13046	843.285***	134.6121
GARDEN	0.99701***	0.12587	104.971*** (1259.652)	26.07001	0.90191***	0.12866	770.78***	131.3161
ENV	−0.19256***	0.03686	−20.2737*** (−243.284)	5.09098	0.00057	0.04333	0.48729	37.02163
RISK	0.22155***	0.03680	23.3262*** (279.914)	5.91237	−0.03851	0.04332	−32.9076	37.65299
COST	0.00950***	0.00173			−0.00117***	0.00017		
Nº observations			4308				3348	
Nº individuals			359				279	
Log likelihood			−4175.54				−3344.50	
Pseudo ρ^2			0.1177				0.0907	

***$p < 0.01$ **$p < 0.05$.

Table A.2
WTP in space model results

	Monthly		Annual	
	Coeff. (Annual transformation)	Std.Err.	Coeff.	Std.Err.
OUT	377.707*** (4532.48)	60.8706	2041.03***	442.0864
GARDEN	379.856*** (4558.27)	60.7350	1993.71***	441.6010
ENV	−9.38728*** (−112.647)	2.8377	15.6836	25.7371
RISK	15.8552*** (190.262)	3.2183	−11.8840	23.23334
Nº observations	4308		3348	
Nº individuals	359		279	
Log likelihood	−3678.19		−2971.23	
Pseudo ρ^2	0.2228		0.1922	

***$p < 0.01$ **$p < 0.05$.

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