



Public risk perceptions and urban greenery: a public participation GIS approach in the petrochemical clusters of Camp de Tarragona

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Abstract Petrochemical clusters are critical industrial zones where crude oil and natural gas compounds and polymers are processed, which pose significant risks to the environment and to public health. As landscapes increasingly combine urban and industrial elements, understanding public perceptions of technological risks in such environments is essential to promote resilient and sustainable urban environments. The study uses the Public Participation Geographic Information System (PPGIS) to assess local perceptions of industrial risks in petrochemical clusters, in particular in the Camp de Tarragona area, and to examine the relationship between these perceptions and the proximity of urban green areas. The findings reveal important differences: almost half of the participant-defined risk points are in line with official risk zones, but many are not, indicating gaps in risk communication and highlighting socio-cultural factors that shape risk perceptions. Although a negative correlation between Distance to Participants' location

and risk perception was found, no significant correlation was found between the presence of green areas as environmental features and risk perception. Despite possible bias in the self-reported data and demographic exclusion, the study highlights the importance of incorporating community input into urban planning and risk-management strategies. By involving public perception in the decision-making process, this participative approach enhances the accuracy of risk assessment and enhances public confidence. The paper advocates inclusive, green infrastructure-based frameworks for urban planning which can reduce industrial risks, improve public health outcomes and promote social cohesion in industrial landscapes.

Keywords PPGIS · Risk perception · Petrochemical clusters · Urban green space

Introduction

Technological development is key to economic growth and to the overall welfare of the population. It is important to recognize that not all countries are experiencing the same level of technological and economic development. Every country must give priority to technological development, as it has a direct impact on economic growth and the well-being of its population. Technological and economic development is unevenly distributed across the country (Pletnev & Barkhatov, 2021). Technology contributes to

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social welfare by raising living standards, enabling economic growth and increasing the level of personal comfort.

At the same time, the production, use, and processing of technologies can potentially affect or harm human health and all parts of the biosphere (Renn & Benighaus, 2013). Furthermore, many technologies, such as nuclear energy, genetic engineering, and nanotechnology, polarize society. People who live near technical installations or are exposed to technology-induced hazards are seriously concerned about potential adverse effects (Bechmann, 1993; Renn & Benighaus, 2013).

The growing concentration of economic resources in urban areas, such as the chemical industry (Fang et al., 2023) has heightened risks related to public safety and natural disasters (Xu et al., 2025). For example, chemical hazards and petrochemical clusters present a range of risks to the environment and to those living in their proximity, both in the short and long term (World Health Organization, 2010). The General Directorate of Civil Protection and Emergencies of the Generalitat de Catalunya (2019) defines chemical risk as whatever is caused by establishments that store, manufacture, and handle large amounts of hazardous substances that can cause severe accidents and that exceed the limits of the chemical facilities themselves and affect the immediate surroundings, the environment and goods (Generalitat de Catalunya, 2019). Chemical accidents near densely populated areas have been shown to cause massive damage, making them potentially catastrophic with a large number of victims (Bustamante Picón et al., 2023). For example, in the year 2020, a chemical accident caused several serious problems and problems, including the tragic loss of life of three people, including two workers and a local resident in Camp de Tarragona. The proximity of the general public to these chemical facilities has been identified as a significant cause of increased human exposure in 43% of the accidents investigated by the United States Chemical Safety Board (CSB) in the world (Tahmid et al., 2020).

Objective risks intersect with perceived risks, as personal knowledge, values, and emotional responses influence people's approach. Unlike physical hazards, which can be seen and measured directly, perceived risk is a psychological construct that reflects the public's perception of potential dangers. According

to Sjöberg et al., (2004), risk perception is an evaluation of a special event that occurred and how individuals are concerned about the consequences of that event. Personal and shared experiences, memories, and cultural context influence how people perceive the seriousness and acceptability of technological risks (Renn & Benighaus, 2013; Slovic, 1992). In the case of chemical facilities, public perception of risk may be particularly heightened by past incidents and media coverage, feeding into a complex cognitive process where the brain organizes this information to form an individual opinion or value judgment (García & Castillo, 2012). For example, the chemical accident in Camp de Tarragona in 2020 has shaken public confidence and raised fear in surrounding communities, prompting calls for stronger regulatory oversight and better emergency response systems. Therefore, understanding risk perception is essential in assessing how communities respond to the risks posed by petrochemical clusters and other high-risk technological infrastructures.

Green space is recognized as a factor influencing public perception of their environment and has benefits for climate change mitigation, public health, economic development, and neighborhood cohesion (Jennings & Bamkole, 2019; Wu et al., 2024). Green space can help improve air quality by absorbing and assimilating air pollutants (Selmi et al., 2016) and mitigating greenhouse gas emissions (Strohbach et al., 2012).

Urban green space refers to open areas and public spaces, and it is understood in terms of how users perceive its quality, significance, and benefits (Cilliers, 2023). In addition, urban green spaces promote physical activity, relaxation, better mental health, and social interaction (Dadvand et al., 2016; Kaczynski et al., 2008; Maas et al., 2009). While it is unclear whether variables such as distance to green space, amount of surrounding greenery, and access to green spaces are associated with better health, especially mental health (Gascon et al., 2015). Urban green spaces can reduce urban risks by reducing environmental hazards such as floods and heat waves, improving air quality, and increasing social resilience (Mukherjee & Takara, 2018).

Geospatial analytical tools have recently advanced risk perception research, with growing interest in the spatial dimension (Balžekienė et al., 2024). A new technique for obtaining spatial data from participants'

perceptions of their environment is the PPGIS (Le et al., 2024). PPGIS is a spatially explicit method and technology that aims to capture and use spatial information in participatory planning processes (Brown & Fagerholm, 2015). PPGIS has been extensively utilized in a broad range of studies, including risk perception studies (Bullen & Miles, 2024; Bustamante Picón et al., 2023; Gheitasi et al., 2024; Johnson et al., 2024; Le et al., 2024) as well as urban greenery and urban green spaces studies (Korpilo et al., 2022, 2023; leBrasseur, 2022; Mansournia et al., 2024; Schrammeijer et al., 2022).

Despite the extensive use of PPGIS/PGIS in natural risks and urban greenery studies such as (Le et al., 2024; Raymond & Brown, 2011; Romelli et al., 2025), there is still a lack of studies in technological risk perception and its relation to urban greenery. Therefore, this research aims to examine (1) the spatial distribution of technological risk sources identified by participants, (2) the difference between

the participants' identified risk sources and the verified government risk sources, and (3) the correlation between individual characteristics and distance to green space areas.

Methodology

Overview of case study

The case study focuses on the Tarragona region on the Spanish Mediterranean coast. The region has a population of over 500,000 inhabitants. Tarragona and Reus are the main settlements, both with populations exceeding 100,000, and a continuous urban fabric stretches along the coast and between main cities (Fig. 1).

In the second half of the twentieth century, government planning and industrial investment transformed the region into an industrial city specializing in the

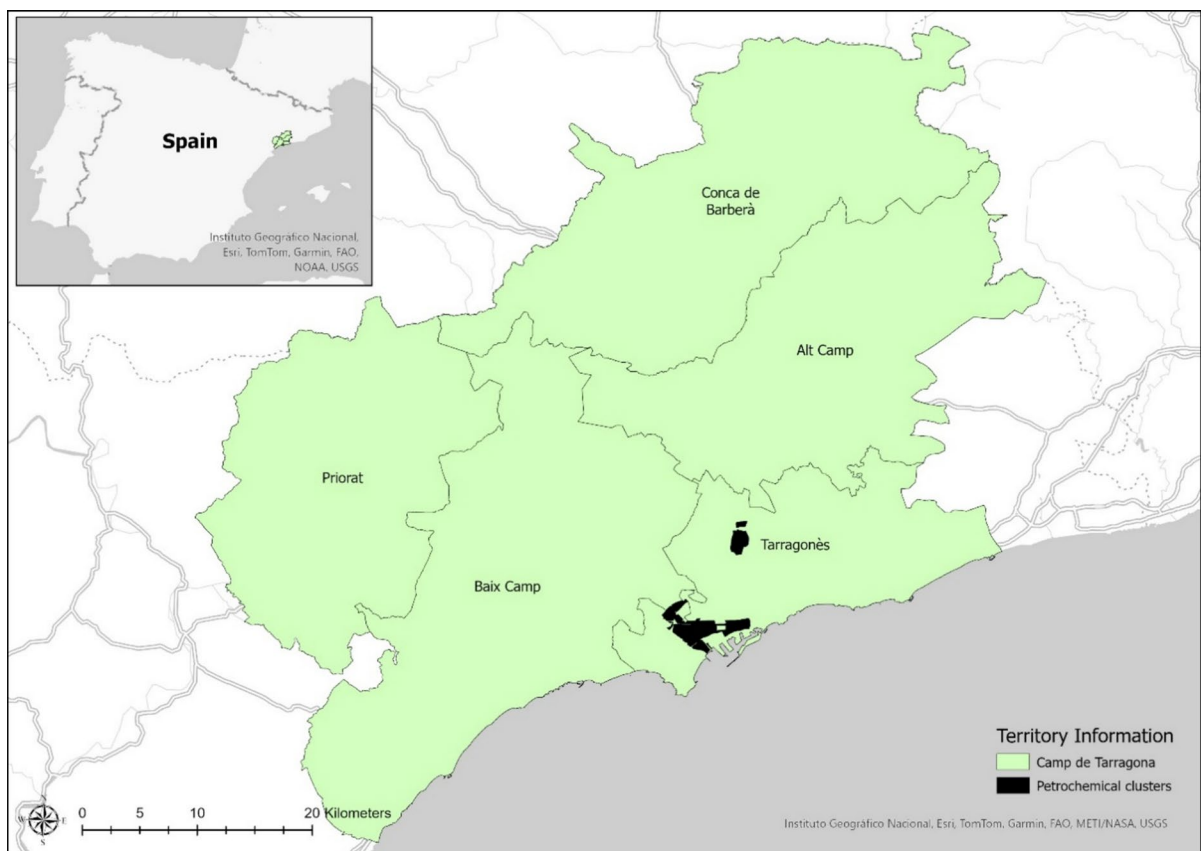


Fig. 1 Case study location

petrochemical sector, leveraging its port and scattered settlement hubs for logistics and workforce distribution. A petroleum refinery and several chemical and petrochemical plants are located in the region (Rovira et al., 2021). The main industrial sites are located on the right bank of the Francolí River, between motorways and the coast, stretching for about four kilometers (Fundació Institut Cerdà, 2024; Oliveras i Samitier, 2012).

Since its inception, there has always been some concern over the possible adverse health effects on the population living in the neighborhood of this industrial complex. The concern notably increased from January 14, 2020, in the wake of the tragedy caused by the explosion in a reactor of the company IQOXE. The incident later extended to a cistern of ethylene oxide, causing three deaths and various injuries, as well as significant material damage. The magnitude of this explosion had a direct impact on people's concern, not only because of the fear of another possible accident, but also for the potential health consequences of living in the vicinity of an industrial complex, where many toxic pollutants are being continuously emitted (Rovira et al., 2021).

Design of the questionnaire

The questionnaire was 8 pages long, written in Catalan and Spanish to encourage participation, and designed to be conducted online via the Porsall platform (<https://porsall.com/>), facilitating efficient, organized data collection. An online version of the questionnaire can be accessed (<https://restaurauv.es/Poll/Show/9910ceb6785c4ae>). The questionnaire was facilitated through various channels, including popular social media platforms such as LinkedIn, WhatsApp groups, and Telegram Channels, to ensure a diverse representation of participants. Additionally, some surveys were filled out in person, so people with problems accessing the Internet were not excluded from the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Committee Concerning Research into People, Society and the Environment of the Universitat Rovira i Virgili (CEIPSA) (CEIPSA-2021-PR-0026, 10 November 2022). Informed consent was obtained from all participants prior to their participation in the study. Participants were asked to confirm that they had read the participant information

sheet and voluntarily agreed to take part in the study. Additionally, they were asked to authorize the use of the data collected through the survey according to the conditions specified in the informed consent form.

The PPGIS Survey included six social-demographic questions, four risk-perception questions, two landscape-perception questions, and five health questions. However, this study focuses on the questions that ask opinions about perceived risk: the location of technological risk sources in the study area, the location of areas affected by technological risk sources, and the level of risk perception (Fig. 2).

Throughout the data collection process, utmost attention was paid to ethical guidelines, ensuring confidentiality and protecting participants' privacy. Clear instructions and explanations were provided to respondents, and any questions or concerns raised by participants were promptly addressed.

Data processing and analysis

The analytical framework for this research consists of several parts (Fig. 3). In the first part, datasets from the data collection were imported into ArcGIS Pro, and shapefiles were created from the coordinates for the points plotted. All data from outside Camp de Tarragona were excluded by using the ArcGIS Pro Clip tool to ensure spatial accuracy. To visualize the spatial distribution of risk sources, simple point maps were used to identify hot-spot locations. In addition, to compare official zones and participants' opinions, all official points for the risk sources were downloaded as SHP files from the Generalitat de Catalunya website (accessible [here](#)). All official points data were imported to ArcGIS Pro, and all data from outside the camp de Tarragona were excluded using the ArcGIS Pro Clip tool.

In the second part, regarding the non-spatial data, all socio-demographic responses from the PPGIS survey were imported into Microsoft Excel and Jamovi 2.6.17. Summary statistics (mean, median, standard deviation, minimum, and maximum) were created using Jamovi 2.6.17. Summary statistics included Gender, Age, Income, level of education, and risk level. In addition, chi-square (χ^2) tests were used to examine associations between individual characteristics variables and respondent groups using descriptive statistics and Chi-square tests in Jamovi 2.6.17.

Part 1: Project Information, Participation Information

Part 2: Spatial Questions

Place the technological risk sources

Place the affected area by technological risk

Place your residential location

Por favor, indique en el mapa, si es el caso, los lugares que cree que podrían verse más afectados por un posible incidente o accidente petroquímico (lugares afectados por los riesgos).

Instrucciones: amplíe el mapa (X) y haga clic en el lugar elegido.

Part 3: Non-Spatial Questions

Health questions:

1. Mental health
2. Self-perceive health

Social-Demographic Questions

1. Age
2. Gender
3. Income
4. Education
5. Birth
6. Postal Code

Risk questions:

1. Level of risk perception

Landscape questions:

1. View to Petrochemical clusters
2. Your feel about walking, sitting, doing activities in certain places

Fig. 2 Overview of the question list in the PPGIS questionnaire

The third part involved calculating the distance between the risk sources selected by participants and nearby urban green areas. Green areas were extracted from the LULC map (Institut Cartogràfic i Geològic de Catalunya) from 2019 to 2022. In order to find the distance between green areas and technological risk sources identified by participants, the Near tool was implemented in ArcGIS Pro. The Near tool calculates the distance between the input features (points) and the closest feature in another layer (green spaces polygons). In addition, this process is used to determine the distance between risk sources identified by participants and their locations.

Therefore, in the final part, to investigate the correlation between variables, the Spearman correlation coefficient was used as a nonparametric measure of the relationship between individual characteristics, distance to green areas, and distance to participants' locations. The coefficient ranges from -1 (strong negative) to $+1$ (strong positive), with 0 indicating no correlation. The statistical significance of these relationships was assessed at the $p < 0.05$ level. Spearman's correlation was chosen in these analyses because it is also suitable for analyzing ordinal and

discrete variables that are not normally distributed (Pietilä & Fagerholm, 2016).

Findings

Individual characteristics

Table 1 presents descriptive statistics for individual characteristics (age, income, education level, and gender) and perceived risk level among the Camp de Tarragona participants. The summary results show the mean, median, standard deviation, and range values. In order to have a numeric value, the level of risk perception (null/very low, low, medium, high, and very high equivalent to 1 to 5 in order), income (no income, less than 1000 euros, between 1000 and 2000 euros, between 2000 and 3000 euros and more than 3000 euros equivalent to 1 to 5 in order), level of education (on education, primary school, secondary school, professional training and university equivalent to 1 to 5 in order) and age remained as a numeric value.

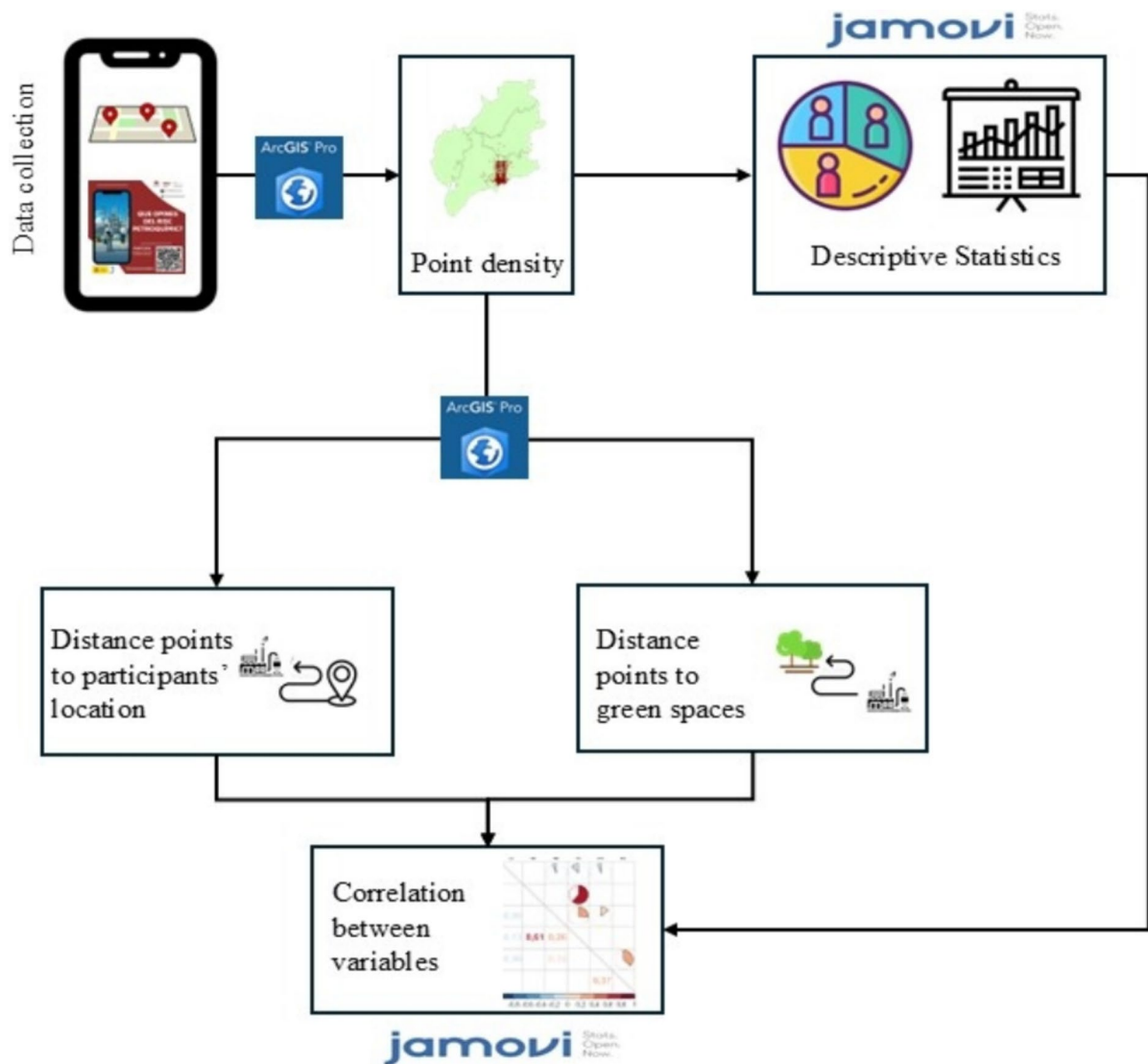


Fig. 3 Analytical framework

Regarding risk perception, the mean was identified as 3.66 for the male group, 3.59 for the female group, and 4 for the others. The median level of risk perception was the same across females, males, and other groups (4.00). The standard deviation was notably higher for the other category (1.41) than for the female and male groups (1.01).

Regarding age, the male group has a mean of 41.6 years, the female group has a mean of 39.6 years, and the “other” group has a mean of 23 years. The median ages are 16 years for both male and female groups, and 1.41 years for the other group.

According to the income data, the mean values are relatively similar across gender groups. In the female group, the mean is 3.03; in the male group, 3.01; and in the other group, 2.50. Also, the standard deviation for the female group is 1.34, for the male group is 1.31, and for the other group is 0.707.

In addition, regarding education level, the highest mean value is in the other group (5.00), while the values for the male and female groups are 4.62 and 4.58, respectively. The median education level is the same across all gender groups at 5.00, indicating that most participants had the highest level on the scale.

Table 1 Summary of statistics for individual characteristics

	Mean	Median	Standard deviation	Min	Max
<i>Risk level</i>					
Female	3.59	4.00	1.01	1.00	5.00
Male	3.66	4.00	1.01	1.00	5.00
Others	4.00	4.00	1.41	3.00	5.00
<i>Age</i>					
Female	39.06	39.00	16.80	0.00	78.00
Male	41.60	42.00	15.90	19.00	86.00
Others	23.00	23.00	1.41	22.00	24.00
<i>Income</i>					
Female	3.03	3.00	1.34	1.00	5.00
Male	3.01	3.00	1.31	1.00	5.00
Others	2.50	2.50	0.71	2.00	3.00
<i>Education</i>					
Female	4.58	5.00	0.84	1.00	5.00
Male	4.62	5.00	0.73	2.00	5.00
Others	5.00	5.00	0.00	5.00	5.00

The results of the chi-square (χ^2) tests (Table 2) show significant differences in the distribution of all individual characteristics ($p < 0.001$ for each). Regarding gender ($\chi^2 = 626$, p value = $< .001$), most participants were female (53.98%), followed by males (45.09%). Income distribution ($\chi^2 = 206$, p value = $< .001$) shows significant variation, with most participants having 1000–1999 euros (33.07%), while 9.27% have less than 1000 euros, and 15.71% have no income. Regarding the educational level ($\chi^2 = 2692$, p value = $< .001$), 77.07% of participants have university degrees. Also, regarding age ($\chi^2 = 26$, p value = $< .001$), the highest proportions are in the 45–54 (23.11%) and 19–24 (21.18%) categories. Regarding risk perception ($\chi^2 = 582$, p value = $< .001$), 41.36% of participants report a high level of risk, and 20.52% report a very high level of risk.

Spatial data

Technological risk sources versus government-verified risk sources

Figure 4 illustrates density clusters representing participant-identified risk sources. Additionally, it displays the official government-verified risk census based on Mapa Protecció Civil (2024). The results

Table 2 Relative shares (%) and statistically significant differences in the individual characteristics of the respondents

<i>Gender</i>	
Female	0.53%
Male	0.45%
Others	0.009%
$\chi^2 = 626$ p value = < 0.001	
<i>Income</i>	
No income	15.71%
Less than 1000 euros	9.27%
Between 1000 and 1999 euros	33.07%
Between 2000 and 2999 euros	23.88%
More than 3000 euros	18.07%
$\chi^2 = 206$ p value = < 0.001	
<i>Education</i>	
Without education	0.23%
Primary school	1.31%
Secondary school	10.14%
Professional training	11.23%
University degrees	77.07%
$\chi^2 = 2692$ p value = < 0.001	
<i>Age</i>	
Under 18 years old	0.53%
Between 19 and 24 years old	21.18%
Between 25 and 34 years old	16.02%
Between 35 and 44 years old	17.02%
Between 45 and 54 years old	23.11%
More than 65	21.14%
$\chi^2 = 26$ p value = < 0.001	
<i>Risk level</i>	
Very low	1.08%
Low	12.19%
Medium	24.85%
High	41.36%
Very high	20.52%
$\chi^2 = 582$ p value = < 0.001	

show that a significant part of the perceived risk areas lie outside the officially recognized zones, around Constanti and La Pobla de Mafumet. These findings show a gap between public perception and official assessments and highlight areas where the authorities may not recognize risks sufficiently. High-density clusters also identify locations perceived by participants as the most dangerous, underscoring the importance of integrating community input into risk management and communication strategies.

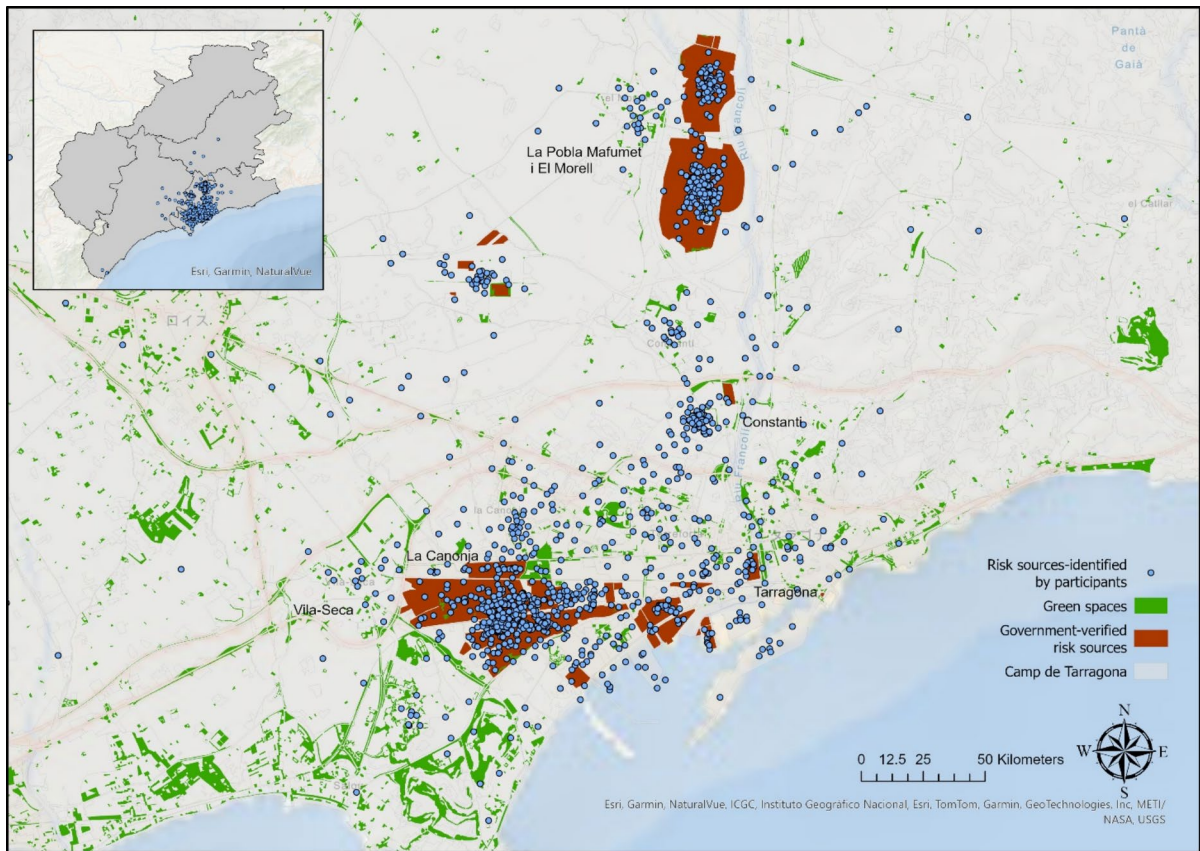


Fig. 4 Spatial distribution of technological risk sources

A total of 47.87% of all selected points overlap government-verified risk sources, indicating that nearly half of the perceived risk locations overlap with officially recognized risk zones. Regarding the total points (47.87%), La Canonja and Vila Seca have 26% of the overlapping points; La Pobla de Mafumet and El Morell have 16.82%; and Tarragona has 26.01% of the overlapping points with government-verified risk sources.

Correlation between variables

Spearman correlation analyses were conducted to explore associations among risk perception, demographic variables, and spatial factors (Table 3). Level of risk was negatively associated with education ($\rho = -0.062$, $p = 0.025$) and income ($\rho = -0.127$, $p < 0.001$), indicating that participants with higher education and income tended to report slightly lower perceived risk.

Age was not significantly correlated with risk perception ($\rho = 0.038$, $p = 0.174$), suggesting no clear association between participant age and perceived risk. Education showed a small but significant positive correlation with distance to participants' location ($\rho = 0.137$, $p < 0.001$), while income was positively correlated with age ($\rho = 0.613$, $p < 0.001$) and education ($\rho = 0.264$, $p < 0.001$), reflecting expected socio-demographic patterns.

Distance to green spaces was significantly associated only with distance to participants' location ($\rho = 0.369$, $p < 0.001$), but showed no significant association with perceived risk, age, education, or income.

Figure 5 shows the correlation matrix, which visualizes the strength and direction of relationships among variables (only significant variables). The color gradient from Orange to Green shows Spearman's rho values ranging from -1 to $+1$.

Table 3 Correlation between individual characteristics and distance to green spaces

		Level of risk	Age	Education	Income	Distance to participants' location	Distance to green spaces
Level of risk	Spearman's Rho	–					
	<i>p</i> value	–					
Age	Spearman's Rho	0.038	–				
	<i>p</i> value	0.174	–				
Education	Spearman's Rho	–0.062*	–0.003	–			
	<i>p</i> value	0.025	0.906	–			
Income	Spearman's Rho	–0.127***	0.613***	0.264***	–		
	<i>p</i> value	<.001	<.001	<.001	–		
Distance to Participants' location	Spearman's Rho	–0.056*	0.004	0.137***	0.042	–	
	<i>p</i> value	0.045	0.886	<.001	0.135	–	
Distance to green spaces	Spearman's Rho	–0.040	–0.004	0.021	0.032	0.369***	–
	<i>p</i> value	0.153	0.874	0.443	0.251	<.001	–

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Fig. 5 Correlation matrix between individual characteristics and distance to green spaces

Discussion

Previous studies, such as (Bastide et al., 1989; Boulding, 1984; Silverman & Kumka, 1987) have variously described women as more nurturing and concerned with health and well-being, interested in the fate of

society, and desiring to limit destructive technologies. However, recent studies such as (Eryılmaz Türkkan & Hırca, 2021) examined that there is no significant relationship between gender and risk perception. The results of this study show a moderate to high level of risk perception across all gender categories.

Regarding age trends, male participants are generally older, which could affect their risk perceptions.

According to Fig. 4, 47.87% of the perceived risk locations overlap with government-verified zones, and a substantial portion (52.13%) falls outside these areas, highlighting a significant divergence that may reflect gaps in public risk communication or overlooked environmental and social factors. The data indicates that industrial hubs like La Canonja, La Pobla de Mafumet, and Tarragona dominate public perceptions of risk, with La Canonja emerging as the most frequently identified high-risk area, accounting for around half of all identified risk points. Interestingly, areas like Constantí have a relatively low risk-perception density, which may indicate successful mitigation efforts, reduced public exposure to perceived hazards, or a lack of awareness among participants. Conversely, areas such as the northwestern part of La Pobla de Mafumet, where the government does not officially recognize perceived risks, underline potential blind spots in government risk assessments. This high number of reports may reflect a combination of factors, including the concentration of petrochemical facilities, a history of past accidents, high population density near industrial sites, and residents' direct experience with industrial hazards. The identified concentration of risk in these areas warrants further investigation to determine whether unassessed environmental risks, socio-cultural factors, or misinterpretations of existing hazards drive these perceptions.

A key finding is the identification of objectively hazardous areas that are not perceived as such by the local population. This mismatch between actual risk and public perception poses serious challenges. For example, if the civil protection issues an alert or evacuation order for such areas, the population may ignore it due to the lack of danger, increased vulnerability, and the possibility of preventable harm in an emergency. These findings emphasize the need for targeted risk communication strategies that address both overestimated risks and underestimated or unknown risks.

Balžekienė et al. (2024) examined the review regarding proximity and risk perception, showing that most empirical studies found a significant positive correlation, meaning that respondents living closer to hazards have higher risk perception. However, our study shows a negative correlation between participants' distance from risk sources and their

risk perception, indicating that those living closer to risk sources have lower risk perception. According to Balžekienė et al., (2024), negative correlations are more common in nuclear risk studies. Our result regarding the negative correlation may reflect a concept of familiarization of risks (Parkhill et al., 2010), meaning that for those who live close to a hazard site, the risk area becomes part of their lives; therefore, perception of risk could decrease (Balžekienė et al., 2024). Regarding the association between risk level and socio-demographic variables, our results show only negative correlations between risk perception and education and between risk perception and income level.

Green spaces and vegetation provide various ecosystem services and health benefits to urban residents and are a major topic of interest in urban health, urban climatology, and climate change mitigation (Lin et al., 2022; Nardone et al., 2021; Yang et al., 2021). According to previous studies (Beyer et al., 2014; Fu et al., 2024; Hart et al., 2022; Hua et al., 2025; Neuner et al., 2025; Park et al., 2010; van den Berg et al., 2010; Vos et al., 2022), greenery and vegetation have several positive health outcomes, such as psychological effects on reducing stress and improving human well-being. Previous studies (Li et al., 2025; Sugg et al., 2025; Wang et al., 2025) examined green spaces and risk perception, indicating a relationship between urban greening and risk areas. However, our study shows that risk perception and distance to green spaces do not correlate. Our results add to the evidence (Cardinali et al., 2024) that proximity to green space does not necessarily correspond to lower perceived risk or better health outcomes, so living in areas with vegetation does not automatically imply a lower risk perception and better health outcomes; however, it might depend on land uses (O'Callaghan-Gordo et al., 2018). Also, even lush green areas might not be perceived as safe if they are located within or near technological risk zones or industrial areas or if they are situated along road infrastructure with poor accessibility, such as parks between highways (Ayala-Azcarraga et al., 2023). In addition, vegetation and green areas in industrial areas are used as green buffers to mitigate air pollution and protect the environment (Haselbach et al., 2024) and may be viewed as artificial buffers in terms of public perception. Existing literature, such as Bakhtsiyarava et al. (2024), Helbich et al. (2019), or Larkin and Hystad (2019),

suggests that green spaces can act as buffers, reducing the perception of risk and promoting psychological well-being in densely built environments. It should be noted that while there is no correlation between green space distance and risk perception in our study, Gheitasi et al. (2024) examined that green landscape significantly mitigates risk perception levels in areas surrounding oil refineries and industrial areas and can significantly improve landscape aesthetics and reduce stress levels, making them critical components of urban and environmental design. This study used manipulated pictures and PPGIS to assess changes in perceptions and emotional responses among the citizens of Tehran, Iran. Key findings showed that there is no significant relationship between technological risk and the perception of landscape value in both the original and the manipulated images. However, considering that in general there is a more significant relationship between manipulated pictures, the design of the landscape could help to mitigate the perception of technological risk.

Regarding social-demographic variables and green spaces, existing studies such as Badakhshan et al. (2025) and Sugg et al. (2025) found that high-income population groups have better access to green spaces at home and along public roadsides, and live closer to public parks. However, unlike previous studies, our results show no association between income level and distance to green spaces. In addition, our findings present no correlation between green spaces and other social-demographic variables such as age and education level.

Conclusion

This study highlights the critical role of PPGIS in understanding technological risk perceptions and their spatial dimensions in industrial areas. The findings reveal significant discrepancies between government-approved risk zones and public perceptions, underscoring the need for more inclusive and participatory risk management and communication approaches. While approximately half of the risk hot-spots identified by participants align with official risk zones, a significant proportion fall outside these zones, indicating gaps in risk communication, unknown risks, or socio-cultural influences on public perception.

This study shows that integrating urban green spaces is an ecological feature that shapes public opinion regarding risk perception. While the literature suggests that green spaces can be vital in reducing perceived risk (He et al., 2025) and affect well-being (Aghabozorgi et al., 2024; Neuner et al., 2025); the results of this study show that green areas do not correlate with risk perceptions in the areas surrounding petrochemical clusters, which suggests that urban green areas do not always shape public opinion and depend on a variety of variables.

This study has several limitations. Our study included 445 participants, representing approximately 0.083 percent of the population in the study area, a low response rate. According to (Brown & Fagerholm, 2015; Loc et al., 2021), the low response rate is explained by: (1) a lack of time and effort to participate; (2) difficulties with technical requirements for online surveys; and (3) a lack of personal interest in the subject matter of the study.

In addition, a significant selection bias was observed in the participatory process, as university-educated individuals were more likely to participate in online surveys. The Chi-square test results (Table 2) showed that the distribution of the respondents across all characteristics examined—gender, income, education, age, and risk perception—is statistically significant, indicating that these variables are not evenly distributed across the sample. This means that some groups, such as highly educated individuals, are overrepresented.

In addition, the involvement of non-specialists with insufficient knowledge of space, geography, and individual features may occasionally compromise the spatial accuracy of PPGIS studies (Le et al., 2024). The use of PPGIS in future research can be optimized for the benefit of society and the environment by addressing these issues.

Overall, this study shows that PPGIS could be a useful tool for integrating public input into risk assessment processes and bridges the gap between expert-based and community-based assessments. While PPGIS provides valuable public input, further integration with environmental monitoring and expert risk assessments is needed to validate perceived risks and correct inaccuracies. The PPGIS approach enhances understanding of perceived and actual risk landscapes and fosters greater public trust and cooperation in managing technological

risks. Also, in this context, PPGIS can contribute to improved community well-being, reduce stress associated with environmental hazards, and reduce anxiety associated with industrial risks.

Future research should explore why people's perceptions of high-risk areas differ from officially designated risk areas, for example, by examining local knowledge, past incidents, and exposure to industrial risks. Policymakers should use this information to implement inclusive engagement strategies, such as community workshops, public consultation, and participatory mapping, to address citizens' concerns and guide interventions that reduce industrial risks and improve public welfare.

Furthermore, future studies should aim to improve the representativeness of PPGIS data by combining online and offline participation methods to reduce socio-demographic bias. It is also recommended to improve spatial accuracy by improving methodology and integrating environmental monitoring data. Finally, further research is needed to better understand the role of urban green spaces in industry, accounting for factors such as availability and perceived quality.

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Data availability The datasets used and/or analyzed in this study can be obtained from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare that they have no competing interests.

Ethics declaration The research was conducted in accordance with the ethical standards of the Declaration of Helsinki. Approval was obtained from the Ethical Committee Concerning Research into People, Society, and the Environment of the Universitat Rovira i Virgili (CEIPSA) (CEIPSA-2021-PR-0026, 10 November 2022). Informed consent was obtained from all participants prior to their involvement in the study, ensuring that they were fully aware of the research objectives, procedures, and their rights, including the right to withdraw at any time. The authors declare no conflicts of interest related to this study.

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