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Original Research Article

Modeling of Factors Influencing the Improvement of Flood Risk Perception Through the Analysis of the Perceptual Factors of the Urban Environment
(Case Study: Zibadasht Neighborhood, Tehran)*

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Abstract

Problem statement: Considering the river channelization and the establishment of flood control structures, individuals' perceptions of river ecological processes and environmental safety have been disrupted. A lack of proper understanding of flood risk leads to decreased adaptability in communities and increased damage and casualties during floods. Therefore, nowadays, flood risk management, in addition to structural solutions, has incorporated non-structural measures, such as flood risk perception. In this regard, it is essential to determine the role of related disciplines in non-structural approaches.

Research objective: This research aims to explain the role of urban design in non-structural measures of flood mitigation by modeling the factors influencing flood risk perception and flood-adaptive behaviors. It assesses the impact of perceptual factors of the urban environment (perceived qualities, sense of place, and vision of nature) in the context of Iran.

Research method: The overall approach of the study is quantitative and is categorized as cross-sectional survey research. It began with deductive reasoning based on the theoretical foundations. Following an analysis of the theoretical literature, the impact of perceptual factors of the environment on flood risk perception was identified, and a conceptual model was developed. To assess the research model within the context of Iran, 221 questionnaires were completed in the Zibadasht neighborhood around the Kan River. Data were analyzed using Smart PLS software and structural equation modeling methods.

Conclusion: According to the results obtained in the Zibadasht neighborhood, urban design can play a significant role in improving flood risk perception by adjusting the perceived qualities of the environment and enhancing individuals' place attachment to the Kan River. In addition, strengthening the place identity of individuals in relation to the Kan River is one of the factors influencing flood-adaptive behaviors in this area.

Keywords: *Integrated Flood Management, Flood Risk, Environmental Perception, Structural Equation Modeling (SEM), Kan River.*

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Introduction and Problem Statement

In recent decades, following the channelization and covering of urban rivers, these ecological elements have been removed from the city image of residents, and flood control structures such as dams and channels have been constructed on the riverbeds. These entirely structural and engineering solutions to flood risk, by limiting seasonal flood flows, reduce people's perception of the ecological processes of rivers. Additionally, the presence of flood control infrastructure in the environment sometimes creates a false sense of environmental safety. These structural measures disrupt people's flood risk perception in the long term, subsequently leading to a significant decrease in the adaptive capacity (resilience) of communities to flooding. The lack of adaptive capacity around rivers and flood-prone areas exposes communities to much greater damage and casualties during severe flood events. Therefore, in recent years, flood risk management has shifted from an exclusive focus on structural measures to integrated solutions (both structural and non-structural measures). The emphasis on non-structural approaches in the integrated flood risk management process opens opportunities for the participation of related disciplines. Meanwhile, flood risk perception is considered a focal point of non-structural solutions, playing a significant role in advancing preventive approaches and reducing flood damage. Urban design is among the disciplines related to environmental perception. Despite its impact on individuals' perceptual experience of the environment, the role and function of this discipline in flood risk perception remain undefined. Clarifying how urban design integrates with flood risk perception defines the role of this discipline in non-structural measures of flood risk management.

In this regard, the first step involved conducting an interdisciplinary systematic review to define how urban design integrates with flood risk perception (Toossi Ardekani et al., 2023). Based on the results of this review, urban design can influence individuals' perceptual experience of rivers, and subsequently their perception of flood risk, through perceptual factors of the environment (perceived qualities, sense of place, and vision of nature). Furthermore, the impact of these perceptual factors on flood risk perception depends on the study context, and based on the social, cultural, and geographical environment, conflicting results are possible. Therefore, to investigate this relationship within the context of Iran, this study aims to assess the impact of these perceptual factors within the Zibadasht neighborhood around the Kan River.

In this study, the first step involved modeling the factors influencing flood risk perception following a review of theoretical foundations. In the second step, the research methodology was developed, and data gathered from a survey of 221 participants were analyzed using Structural Equation Modeling (SEM). In the third step, based on the gathered data, the validity, reliability, and quality of the questionnaire were examined, and the results were explained. Then, the results were discussed by comparing them with the findings of other studies. In the final step, the role of urban design in the context of Iran was clarified in the conclusion.

Research Questions and Hypotheses

The main hypothesis of the study is based on the idea that urban design, by influencing certain perceptual factors of the urban environment, can improve flood risk perception and promote flood-adaptive behaviors in flood-prone areas. Therefore, this study assesses the impact of three perceptual factors (perceived qualities, sense of place, and vision of nature) on flood risk perception and flood-adaptive behaviors. Based on the conceptual model (Fig. 1), the study's sub-hypotheses have been formulated, as shown in Table 4. To clarify the role of urban design in the context of Iran, investigating the following questions in the research process is essential:

Which perceptual factors of the environment in the Zibadasht neighborhood can impact the "affective dimension of flood risk perception"?

Which perceptual factors of the environment in the

Zibadasht neighborhood can impact the "cognitive dimension of flood risk perception"?
Which perceptual factors of the environment in the Zibadasht neighborhood can impact "flood-adaptive behaviors"?

Research Background

In the research background on flood risk perception, the factors influencing this concept have been recognized from different perspectives. Cognitive approaches consider intrapersonal processes as the most significant determinants of this concept, and identify factors such as cognitive errors and negative emotions as influential on risk perception (Slovic & Peters, 2006; Tversky & Kahneman, 1974). Socio-cultural approaches describe risk perception as a social construct, considering cultural norms and social identity as influential factors (Kahan et al., 2007). In geographical approaches, characteristics of the built and natural environment, such as openness of the area and the distance to a hazard source, are taken into consideration (Botzen et al., 2009; O'Neil et al., 2016). To date, in addition to individual factors (cognitive approaches), the impact of environmental factors (socio-cultural and geographical approaches) on flood risk perception has been investigated. However, in examining the role of environmental factors, the impact of urban design and its perceptual factors on flood risk perception has not yet been studied. On the other hand, in Persian articles over the past decade, the emphasis has shifted from engineering approaches to resilience thinking as a new approach for addressing floods (Bahrami et al., 2019; Hataminejad & Sadeghi, 2023). Given the inability of humans to accurately predict natural disasters, environmental adaptation to these disasters has been highlighted (Hemmati, 2015). However, flood risk perception, as an essential prerequisite for community adaptation to floods, has been neglected, and the role of environmental design disciplines (urban design, landscape design, etc.) in this field has remained unclear. Therefore, this study can address the existing gap in this field and provide an initial step in explaining the role of urban design in non-structural measures of flood mitigation.

Theoretical Foundations

Earlier flood management approaches predominantly sought to reduce the probability of flood occurrence. However, with a shift towards minimizing the probability of flood damage, the focus of flood risk management has transitioned from engineering solutions to more integrated solutions. In other words, modern approaches prioritize resilience over flood resistance. In recent decades, there has been an increasing emphasis on the adaptive capacity of communities. How people perceive flood risk plays a critical role in their preparedness, response, and behavior toward flood (Liao, 2012; O'Neil et al., 2016).

The public's flood risk perception is measured using different subjective criteria. In general terms, individuals perceive and behave according to risk through two different approaches. In the intuitive approach (risk as feeling), individuals display an emotional response, while in the rational approach (risk as analysis), decisions are made logically and purposefully (O'Neil et al., 2016). Miceli et al. (2008) consider flood risk perception as a complex construct comprising cognitive and affective dimensions. The cognitive dimension focuses on individuals' perception of the probability of hazard occurrence and its potential consequences, while the affective dimension encompasses the level of fear and concern. Although some studies in the field of flood risk perception have focused exclusively on one of the two dimensions, this study, like other comprehensive studies conducted in this area (Miceli et al., 2008; Terpstra, 2011; Wilson et al., 2018), assesses both the cognitive dimension (perceived probability – perceived consequences) and the affective dimension (affect) of flood risk perception within the conceptual model of the study (Fig. 1).

The primary reason for the focus on risk perception is that if the public perceives the risk of a disaster, they are more likely to take protective behaviors. Therefore, in the field of disasters, the role of risk perception in driving protective behaviors must be examined (Weinstein et al., 1998). Some studies have reported the impact of flood risk perception on flood-adaptive behaviors (Grothmann & Reusswig 2006; Miceli et al., 2008; Terpstra, 2011; Zaalberg et al., 2009), while others have found no significant relationship between these two concepts (Siegrist & Gutscher 2006; Thieken et al., 2007; Zaleskiewicz et al., 2002). Considering the significance of this subject, the relationship between flood risk perception and flood-adaptive behaviors is examined within the conceptual model of the study (Fig. 1).

To assess how urban design integrates with flood risk perception, an interdisciplinary systematic review was first conducted in six steps (defining the research question, applying keywords in the area of flood risk perception, applying inclusion criteria for the research, applying keywords in the field of urban design, applying eligibility criteria, and conducting qualitative content analysis of selected studies) in the Scopus database (Toossi Ardekani et al., 2023). According to the results of this interdisciplinary systematic review, urban design can influence flood risk perception through certain perceptual factors (perceived qualities, sense of place, and vision of nature). Therefore, this relationship has been incorporated into the conceptual model (Fig. 1) for assessment in the context of Iran:

- **Perceived qualities**

while individuals' perception of river environments is based on aesthetic qualities, most river restoration projects emphasize ecological qualities. Additionally, despite the emphasis on reducing flood risk in these projects, flood risk perception and water safety from the perspective of non-experts are often overlooked. Therefore, urban design must adjust the perceived qualities of the environment to interact and synergize with ecological qualities, thereby improving flood risk perception (Buijs, 2009; Junker et al., 2007; Seidl & Stauffacher, 2013). In the conceptual model, the impact of perceived qualities (naturalness, maintenance, diversity, coherence, absence of environmental disturbances, and spaciousness) on flood risk perception and flood-adaptive behaviors is assessed (Fig. 1).

- **Sense of place**

the meaning that individuals attach to a place affects the perception of river landscapes and the adoption of protective behaviors. Furthermore, depending on the research context and the severity and probability of the hazard, the sense of place can have either a positive or negative impact on flood risk perception. Therefore, by considering the social, cultural, and geographical context of the environment, as well as the severity and probability of the hazard, urban design can adjust individuals' emotional connection to a place to effectively affect flood risk perception (Bernardo, 2013; Bonaiuto et al., 2016; Verbrugge & van den Born, 2018). In the conceptual model, the impact of sense of place components (place attachment, place identity, and place dependence) on flood risk perception and flood-adaptive behaviors is examined (Fig. 1).

- **Vision of nature**

individuals' vision of nature has a substantial impact on their perception of nature (such as flood risk perception). As individuals' visions shift from "master over nature" (supporting engineering solutions) to "participant in nature" (supporting nature-based solutions), the emphasis on the intrinsic values of nature and mutual interaction with it increases (De Groot & De Groot, 2009; De Groot & van den Born, 2003). Furthermore, Individuals' understanding of the adopted solutions is influenced not only by their vision of nature but also by the level of perceived risk in the environment, the effectiveness of these solutions against floods, and their benefits (ecosystem services) (Santoro et al., 2019). In this context, environmental design can play a significant role in individuals' vision of nature by creating a balance between the benefits of green solutions and the effectiveness of grey solutions. In the conceptual model of the study, the impact of the components of the vision of nature (master over nature, steward of nature, and participant in nature) on flood risk perception and flood-adaptive behaviors is assessed (Fig. 1).

Research Method

The research approach was quantitative, supported by a post-positivist philosophy. This study began with deductive reasoning based on theoretical foundations. Following the analysis of the theoretical literature, the conceptual model and research hypotheses were constructed. Finally, through collecting and analyzing the data, these hypotheses were either confirmed or rejected. The research strategy was a non-experimental (descriptive) quantitative design, describing the relationships between the perceptual factors of the environment (independent variables) and the flood risk perception and flood-adaptive behaviors (dependent variables). Additionally, considering the method of participant selection and the intervals of data collection, this study was classified as cross-sectional survey research (Creswell & Creswell, 2017).

The data were collected through face-to-face interviews and analyzed using structural equation modeling (SEM). SEM combines factor analysis and path analysis methods, incorporating both measurement and structural models research (Hair et al., 2016). The analysis was conducted using variance-based SEM with SmartPLS version 4.

The study population consisted of residents aged 18 and older living in the Zibadasht neighborhood, located in District 22 of Tehran, around the Kan River. A stratified random sampling method was employed. Cohen's formula was used to calculate the sample size, with a significance level of 0.01, a Cohen's effect size of 0.3, and a power of 0. 8 (Cohen, 2013). Given the prevalence of structural equation modeling (SEM) in statistical analysis, the model's complexity could be incorporated into Cohen's formula. Online software (Free Statistics Calculators-version 4) calculated a minimum sample size of 148 participants, considering the model's complexity. Increasing this to 171 participants ensured the detection of even the smallest effect size. A total of 221 questionnaires were completed for this study.

- **Study site**

The Kan River, Tehran's most significant river with a perennial flow, possesses the largest watershed among the city's rivers (Water Research Institute, 2011). Comprehensive plans implemented in 1968 and 1991 in the Kan River basin led to the construction of channels for flood control (Alehashemi et al., 2015). These unidimensional flood control approaches have not only failed to mitigate floods but have also degraded the river's structure and ecosystem (Bahrami et al., 2019). On the vulnerability map of Tehran, this basin is identified with the highest risk (Ghahroudi Tali et al., 2016). The occurrence of multiple floods in April and November 2012, July 2015, April 2019, and August 2022 confirms this high vulnerability. The river originates from the northwestern highlands of Tehran and flows

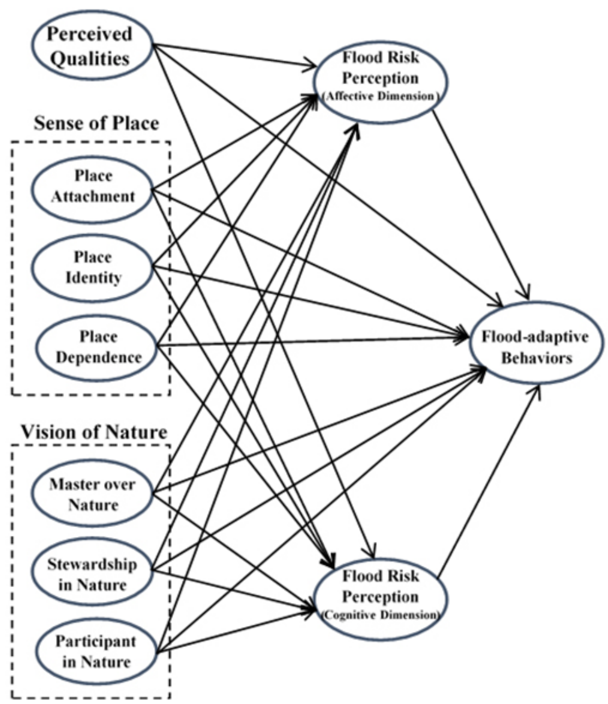

Fig. 1. Conceptual model. Source: Authors.

southward through the western neighborhoods of the city. Although the Kan River traverses a relatively long path in Tehran and passes through various neighborhoods, the potential for floods and debris flows remains high in the northern areas. Furthermore, because the river is not covered in the northern area, residents can observe the Kan River and consequently perceive the flood risk. Therefore, based on field observations, the Zibadasht neighborhood in the northern area of the Kan River was selected as the study site. Direct access for residents to the Kan River from the eastern side, along with the organization and landscaping of the river around the neighborhood (Javanmardan Park), provides a suitable context for assessing the relationship between perceptual factors of the environment and flood risk perception (Fig. 2).

Research Instrument

To achieve practical indicators for measuring the study's latent variables, a preliminary questionnaire was designed using theoretical foundations and existing questionnaires from related fields. Next, to align the questionnaire with the study site, targeted interviews were conducted with a group of experts in relevant disciplines. Following this, through three pilot tests with potential participants, necessary revisions were made to the questionnaire. Ultimately, the research questionnaire was designed

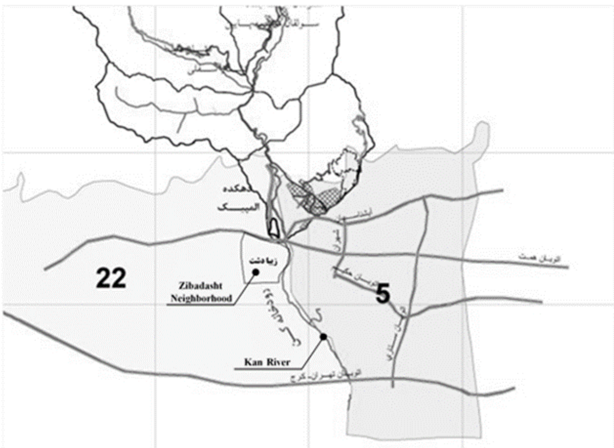

Fig. 2. Location of Zibadasht neighborhood within the Kan River basin and the municipal districts 5 and 22. Source: Water Research Institute, 2011.

in six sections (flood risk perception, flood-adaptive behaviors, vision of nature, sense of place, perceived qualities, and demographic information) using a Likert scale (Table 1).

Results

In the Zibadasht neighborhood, a total of 221 questionnaires were completed by residents over 18 years old from late September to mid-February 2023-2024. Six questionnaires were excluded from the dataset due to outlier data, and eleven questionnaires were removed due to missing data, resulting in a total of 204 questionnaires used for analysis. Before starting the data analysis process, the adequacy of the sample size and the sphericity of the relationships were assessed using the KMO and Bartlett's tests. Given the obtained KMO value (KMO = 0.953 > 0.7), the number of observations was sufficient for factor analysis. Additionally, the sphericity of the relationships among the indicators was confirmed by the statistical significance of Bartlett's test (sig = p-value = 0.000 < 0.05), which is the main condition for factor analysis (Sarstedt & Mooi, 2018).

- **Validity, reliability, and quality of the questionnaire**

Before examining the validity and reliability of the measurement model (questionnaire), the homogeneity of the reflective indicators must be assessed. In this regard, the factor loadings of the reflective indicators must be greater than 0.7, and their statistical significance (p-value < 0.05, T-value > 1.96) must be confirmed (Hair et al., 2010). These points were evidenced in the reflective indicators (Table 2).To calculate the reliability of the questionnaire, the internal consistency of the latent variables was examined using coefficients such as Cronbach's alpha, McDonald's Omega, and Composite Reliability (CR); these coefficients must be greater than 0. 7 (Hair et al., 2017). According to the obtained values, the reliability of the questionnaire was confirmed (Table 2).To assess the convergent validity of the questionnaire, the Average

Table 1. Measurement model (indicators measuring latent variables). Source: Authors.

Latent variables			Observed variables(indicators)	Type of indicator	Reference
Endogenous latent variables (dependent variables)	Flood Risk Perception	Affective Dimension	- The extent to which individuals feel fearful when thinking about the risk of flooding - The extent to which individuals feel concerned when thinking about the risk of flooding - The extent to which individuals feel anxious when thinking about the risk of flooding	Reflective	(Terpstra, 2011)
		Cognitive Dimension	- Individuals' assessment of the probability of flooding occurrence in their area within the next 5 years - Individuals' assessment of the severity of flooding consequences in their area within the next 5 years - Individuals' assessment of the probability of becoming a victim (damage to possessions/wounded) in case of flood in their area - Individuals' assessment of the probability of fatal consequences in case of flooding in their area	Reflective	
	Flood-adaptive Behaviors (Protective Behaviors)		- The extent to which individuals are interested in flood preparedness - The extent to which individuals are interested in searching for information about flood preparedness - The extent to which individuals avoid areas around rivers during flood warnings	Reflective	
Exogenous latent variables (independent variables)	Vision of Nature	Master over Nature (Structural Solutions)	- Human beings have the right to radically alter and use nature to control flooding. - Although nature has value for itself, humans stand above it. - In facing a flood, entirely structural solutions are sufficient.	Reflective	(de Groot & van den Born, 2003)
		Steward of Nature (Hybrid Solutions)	- It is because we treat nature poorly that there are more and more flood disasters. - Human beings have an obligation to protect nature. - In facing a flood, a combination of green and structural solutions is necessary.		
		Participant in Nature (Nature-based Solutions)	- The spiritual aspect of nature is very important - Human beings are subordinate to nature. - In facing a flood, entirely green solutions are sufficient, and using structural solutions is a form of damage to nature.		
	Sense of Place	Place Attachment	- I have a strong attachment (emotional bond) to this "place" - I feel a strong sense of belonging to this "place" - This "place" means a lot to me.	Reflective	(Jorgensen & Stedman, 2006)
		Place Identity	- I identify strongly with this "place" - I feel that this "place" is part of me and my identity. - Visiting this "place" reflects the type of person I am		
		Place Dependence	- I can't imagine a place other than this "place" for what I like to do. - This "place" is the best place for doing the activities I enjoy most. - I enjoy visiting this "place" more than any other place.		
	Perceived Qualities		- Diversity (collative factor) - Coherence (organizing factor) - Spaciousness (spatial factor) - Naturalness (content-ecological factor) - Maintenance (content-ecological factor) - Disturbance (content-ecological factor)	Formative	(Buijs, 2009)

Table 2. Reliability, convergent validity, and quality of the questionnaire. Source: Authors.

Latent variables		Indicators	Factor loadings/ weights	Statistical significance Factor loadings/) (weights P-value	T-value	Cronbach's alpha	McDonald's Omega	Composite Reliability	Average Variance Extracted	Variance Inflation Factor	Q²
Flood Risk Perception	Affective Dimension	FRPa1	0.885	0.000	75.853	0.889	0.887	0.931	0.819	-	0.539
		FRPa2	0.896	0.000	69.989						0.462
		FRPa3	0.933	0.000	101.884						0.517
	Cognitive Dimension	FRPc1	0.832	0.000	35.680	0.868	0.866	0.909	0.715	-	0.511
		FRPc2	0.888	0.000	61.291						0.551
		FRPc3	0.847	0.000	40.999						0.339
		FRPc4	0.814	0.000	32.174						0.326
Flood-adaptive Behaviors (protective behaviors)		FAB1	0.896	0.000	78.444	0.798	0.791	0.881	0.713	-	0.622
		FAB2	0.751	0.000	22.362					-	0.284
		FAB3	0.878	0.000	53.484						0.550
Vision of Nature	Master over Nature	MON1	0.889	0.000	67.166	0.820	0.819	0.893	0.736	-	-
		MON2	0.903	0.000	73.511						
		MON3	0.776	0.000	23.086						
	Steward of Nature	SON1	0.817	0.000	28.667	0.734	0.756	0.850	0.654	-	-
		SON2	0.741	0.000	16.319						
		SON3	0.864	0.000	45.885						
	Participant in Nature	PIN1	0.888	0.000	61.959	0.788	0.789	0.875	0.700	-	-
		PIN2	0.850	0.000	42.868						
		PIN3	0.768	0.000	24.235						
Sense of Place	Place Attachment	PA1	0.886	0.000	69.428	0.844	0.844	0.905	0.762	-	-
		PA2	0.885	0.000	52.132						
		PA3	0.846	0.000	39.227						
	Place Identity	PI1	0.854	0.000	45.613	0.830	0.834	0.898	0.746	-	-
		PI2	0.886	0.000	59.022						
		PI3	0.852	0.000	44.494						
	Place Dependence	PD1	0.861	0.000	52.375	0.823	0.824	0.894	0.738	-	-
		PD2	0.842	0.000	40.278						
		PD3	0.875	0.000	39.389						
Perceived Qualities		VA	0.084	0.433	0.784	-	-	-	-	1.305	-
		CO	0.206	0.001	3.217					1.903	
		SP	0.268	0.000	4.362					1.867	
		NA	0.273	0.000	3.846					2.657	
		MA	0.272	0.000	4.681					2.072	
		DI	0.201	0.001	3.377					1.474	

Variance Extracted (AVE) was used; this coefficient for each latent variable must be greater than 0. 5 and less than the corresponding Composite Reliability (rho_c) coefficient (Hair & Alamer, 2022). Based on the obtained values, the convergent validity of the questionnaire was confirmed (Table 2). The discriminant validity of the questionnaire was assessed using the Heterotrait-Monotrait (HTMT) ratio, and all the obtained values in this matrix must be less than 0. 9 (Henseler et al., 2015). Given that 95% of the HTMT values met this criterion, the discriminant validity of the questionnaire was confirmed (Table 3). The assessment of formative indicators (for the perceived qualities variable) involves evaluating the statistical significance of indicators' weights. Generally, the weights of formative indicators are expected to be lower than the factor loadings of reflective indicators (Hair & Alamer, 2022). Except for the perceived quality of "diversity", other formative indicators achieved acceptable statistical significance (p-value < 0.05, T-value > 1.96). Furthermore, unlike reflective indicators, high correlations between formative indicators should not be reported. Therefore, the Variance Inflation Factor (VIF) was used to assess collinearity, which must be less than 5 (Diamantopoulos et al., 2008). According to the obtained values, the formative indicators met standards (Table 2). Regarding quality assessment, the questionnaire demonstrated "very strong" predictive power for endogenous latent variables (Q^2 > 0.35), with only three indicators showing "strong" predictive power (0. 15 < Q^2 < 0.35) (Table 2).

- **Structural model**

The structural model consists of three endogenous latent variables and seven exogenous latent variables. The relationships between these variables were tested through 23 hypotheses in the Zibadasht neighborhood (Fig. 1). According to the results, 10 hypotheses were statistically significant. The impact of perceptual factors of the environment on three endogenous latent variables was examined in detail (Table 4).

- Flood risk perception-affective dimension (FRPad)

According to the statistical significance (P-value<0.01), the impact of "perceived qualities," "place identity", and "place dependence" on FRPad in the Zibadasht neighborhood is confirmed at the 99% confidence level. Based on the effect size for perceived qualities (F^2 = 0.157), this variable's proportion to the explained variance is considered strong (0. 15 < F^2 < 0.35). The effect sizes for place identity (F^2 = 0.034) and place dependence (F^2 = 0.088) indicate a moderate proportion to the explained variance (0. 02 < F^2< 0.15). According to the coefficient of determination (R^2 = 0.693), the predictive power of the seven exogenous latent variables on FRPad is considered moderate (R^2 < 0.75) (Hair et al., 2019).

- Flood risk perception-cognitive dimension (FRPcd)

The impact of "perceived qualities", "master over nature vision", and "place attachment" on FRPcd in the Zibadasht neighborhood is statistically significant (P-value<0.01), confirming their influence at the 99% confidence level. The impact of "place dependence" on this variable is also confirmed at the 95% confidence level (P-value<0.05). Based on effect sizes, the proportions of perceived qualities (F^2=0.078) and place attachment (F^2=0.160) to the explained variance are moderate (0.02<F^2<0.15) and strong (0.15<F^2<0.35), respectively. The negative path coefficients for place dependence and master over nature vision indicate that stronger place dependence or master over nature vision is associated with a decrease in FRPcd. Furthermore, the effect sizes for place dependence (f F^2=0.017) and master over nature vision (F^2=0.033) suggest weak (F^2<0.02) and moderate (0.02<F^2<0.15) proportions to the explained variance, respectively. The coefficient of determination (R^2=0.676) indicates that the seven exogenous latent variables exhibit moderate predictive power regarding FRPcd (R2<0.75) (ibid.).

- Flood adaptive behavior (FAB)

Based on the statistical significance (P-value<0.01), the impact of "master over nature vision" and FRPcd on FAB in the Zibadasht neighborhood is confirmed at the 99% confidence level. Additionally, the impact of "place identity" on this variable is statistically significant at the 95% confidence level (P-value<0.05). Based on effect sizes, place identity (F^2=0.021), master over nature vision (F^2=0.083), and FRPcd (F^2=0.103) demonstrate moderate proportions (0.02<F^2<0.15) to the explained

Table 3. Discriminant validity of the questionnaire (HTMT ratio). Source: Authors.

Latent variables	Flood-adaptive Behaviors	Flood Risk Perception (Affective Dimension)	Flood Risk Perception (Cognitive Dimension)	Master over Nature	Steward of Nature	Participant in Nature	Place Attachment	Place Identity	Place Dependence
Flood-adaptive Behaviors		-	-	-	-	-	-	-	-
Flood Risk Perception (Affective Dimension)	0.796		-	-	-	-	-	-	-
Flood Risk Perception (Cognitive Dimension)	0.891	0.695		-	-	-	-	-	-
Master over Nature	0.986	0.790	0.870		-	-	-	-	-
Steward of Nature	0.878	0.751	0.721	0.929		-	-	-	-
Participant in Nature	0.776	0.740	0.623	0.780	0.861		-	-	-
Place Attachment	0.804	0.666	0.863	0.883	0.685	0.653		-	-
Place Identity	0.870	0.784	0.738	0.895	0.819	0.690	0.717		-
Place Dependence	0.692	0.792	0.511	0.681	0.704	0.753	0.511	0.620	

variance. The negative path coefficient for master over nature vision indicates that a stronger master over nature vision is associated with a decrease in FAB. Given the coefficient of determination (R^2=0.747), the predictive power of the nine exogenous latent variables in predicting FAB is considered moderate (R^2<0.75) (ibid.).

- **Mediation analysis**

The conceptual model displays the affective (FRPad) and cognitive (FRPcd) dimensions of flood risk perception as mediator variables between the endogenous latent variable (FAB) and the exogenous latent variables (Fig. 1). Bootstrapping was used for mediation analysis, requiring assessment of the statistical significance of both direct and indirect effects. In this method, a non-significant indirect effect indicates no mediation effect, and further mediation analysis and Variance Accounting for (VAF) calculations are unnecessary (Cheung & Lau, 2008). Hypothesis testing (Table 4) reveals a non-significant effect of FRPad on FAB (P-value=0.872); therefore, this variable was excluded from further mediation analysis. Analysis of FRPcd as a mediator indicates significant direct and indirect effects only with three exogenous latent variables (perceived qualities, place attachment, and master over nature vision). Calculating VAF for these variables reveals that, in the Zibadasht neighborhood, FRPcd acts as a partial mediator only between the exogenous latent variables "perceived qualities" and "place attachment", and the endogenous latent variable (FAB) (Table 5).

Discussion

Based on the results from the Zibadasht neighborhood, the impact of perceptual factors of the environment on flood risk perception and flood-adaptive behaviors varies across hypotheses, showing positive, negative, and non-significant relationships. Considering the study's main objective to identify the role of urban design in non-structural measures of flood mitigation, the impact of perceptual factors in the Zibadasht neighborhood will be discussed separately:

- **Perceived qualities**

In the Zibadasht neighborhood, these qualities

Table 4. Hypothesis testing. Source: Authors.

Hypothesis	Path coefficient	Statistical significance (P-value)	Effect size (F^2)		Result	Coefficient of determination (R^2)
Perceived Qualities -> Flood Risk Perception (Affective Dimension)	0.486	0.000	0.157	Strong	Sig.	0.693 The predictive power of the model on the “affective dimension of flood risk perception” (FRPad) is considered moderate.
Master over Nature -> Flood Risk Perception (Affective Dimension)	0.008	0.931	0.000	Weak	n.s.	
Steward of Nature -> Flood Risk Perception (Affective Dimension)	0.011	0.877	0.000	Weak	n.s.	
Participant in Nature -> Flood Risk Perception (Affective Dimension)	0.027	0.687	0.001	Weak	n.s.	
Place Attachment -> Flood Risk Perception (Affective Dimension)	0.021	0.702	0.001	Weak	n.s.	
Place Identity -> Flood Risk Perception (Affective Dimension)	0.164	0.009	0.034	Moderate	Sig.	
Place Dependence -> Flood Risk Perception (Affective Dimension)	0.235	0.000	0.088	Moderate	Sig.	
Perceived Qualities -> Flood Risk Perception (Cognitive Dimension)	0.353	0.000	0.078	Moderate	Sig.	0.676 The predictive power of the model on the “cognitive dimension of flood risk perception” (FRPcd) is considered moderate.
Master over Nature -> Flood Risk Perception (Cognitive Dimension)	-0.214	0.006	0.033	Moderate	Sig.	
Steward of Nature -> Flood Risk Perception (Cognitive Dimension)	0.044	0.535	0.002	Weak	n.s.	
Participant in Nature -> Flood Risk Perception (Cognitive Dimension)	-0.036	0.548	0.002	Weak	n.s.	
Place Attachment -> Flood Risk Perception (Cognitive Dimension)	0.352	0.000	0.160	Strong	Sig.	
Place Identity -> Flood Risk Perception (Cognitive Dimension)	0.048	0.455	0.003	Weak	n.s.	
Place Dependence -> Flood Risk Perception (Cognitive Dimension)	-0.107	0.041	0.017	Weak	Sig.	
Perceived Qualities -> Flood-adaptive Behaviors	0.092	0.411	0.006	Weak	n.s.	0.747 The predictive power of the model on “flood-adaptive behaviors” (FAB) is considered moderate.
Master over Nature -> Flood-adaptive Behaviors	-0.305	0.000	0.083	Moderate	Sig.	
Steward of Nature -> Flood-adaptive Behaviors	0.078	0.187	0.009	Weak	n.s.	
Participant in Nature -> Flood-adaptive Behaviors	0.053	0.342	0.005	Weak	n.s.	
Place Attachment -> Flood-adaptive Behaviors	-0.004	0.940	0.000	Weak	n.s.	
Place Identity -> Flood-adaptive Behaviors	0.121	0.029	0.021	Moderate	Sig.	
Place Dependence -> Flood-adaptive Behaviors	0.060	0.276	0.006	Weak	n.s.	
Flood Risk Perception (Affective Dimension) -> Flood-adaptive Behaviors	0.014	0.872	0.000	Weak	n.s.	
Flood Risk Perception (Cognitive Dimension) -> Flood-adaptive Behaviors	0.284	0.000	0.103	Moderate	Sig.	

have an impact on both the affective and cognitive dimensions of flood risk perception. All qualities except for “diversity” show a positive impact. The lack of impact from “diversity” is attributed to the absence of diverse flora and fauna around the Kan River in Zibadasht. Most studies in this field have supported the effectiveness of these qualities on individuals’ flood risk perception

Table 5. Mediation analysis (cognitive dimension of flood risk perception). Source: Authors.

perceptual factor	Direct effect (c)		Indirect effect (a, b)				Indirect effect (a*b)	Total effect (a*b)+c	Variance Accounting for (VAF)	Result
	Path coefficient	P-value	Path coefficient	P-value	Path coefficient	P-value				
Perceived Qualities	Perceived Qualities -> Flood-adaptive Behaviors		Perceived Qualities -> Flood Risk Perception (Cognitive Dimension)		Flood Risk Perception (Cognitive Dimension) -> Flood-adaptive Behaviors		0.1002	0.2992	0.3348 (0.2<VAF<0.8)	Partial mediation effect
	0.199	0.026	0.353	0.000	0.284	0.000				
Place Attachment	Place Attachment -> Flood-adaptive Behaviors		Place Attachment -> Flood Risk Perception (Cognitive Dimension)		Flood Risk Perception (Cognitive Dimension) -> Flood-adaptive Behaviors		0.0999	0.1989	0.5022 (0.2<VAF<0.8)	Partial mediation effect
	0.099	0.082	0.352	0.000	0.284	0.000				
Master over Nature	Master over Nature-> Flood-adaptive Behaviors		Master over Nature-> Flood Risk Perception (Cognitive Dimension)		Flood Risk Perception (Cognitive Dimension) -> Flood-adaptive Behaviors		-0.0607	-0.4227	0.1436 (VAF<0.2)	No mediation effect
	-0.362	0.000	-0.214	0.006	0.284	0.000				

(Litton, 1977; Nillesen, 2019). Conversely, Buijs (2009) reports that perceived qualities are not associated with risk perception. Furthermore, perceived qualities are not associated with the adoption of flood-adaptive behaviors in Zibadasht. A systematic review in this field identifies a wide range of factors (previous experience, demographic characteristics, fear and anxiety, level of awareness, etc.) influencing flood mitigation behaviors (Bubeck et al., 2012). However, none of these studies investigates the impact of perceived qualities as an influencing factor. It can be concluded that studies in this area are limited and require more investigation.

- **Sense of place**

The impact of different components of the sense of place varies in the Zibadasht neighborhood. Increased place attachment and place identity to the Kan River are associated with stronger cognitive and affective dimensions of flood risk perception, respectively. However, increased place dependence on the Kan River environment is associated with a weaker cognitive dimension of flood risk perception but a stronger affective dimension. Conversely, some studies have suggested that strong place attachment enhances perceived security, thereby reducing flood risk perception (Armas & Avram, 2009; Domingues et al., 2021). Other studies have examined this relationship, considering the severity and probability of the hazard (Bernardo, 2013; Bonaiuto et al., 2011).Van Heel and Van den Born (2020) conducted a comprehensive study demonstrating that, among sense of place components (place identity, place dependence, nature bonding, and social bonding), only nature bonding significantly has impact on flood risk perception. In the Zibadasht neighborhood, among the sense of place components, only place identity significantly has impact on flood-adaptive behaviors. Specifically, individuals who strongly identify with the Kan River exhibit a higher likelihood of adopting protective behaviors. This result is consistent with some studies indicating a positive association between sense of place and the adoption of protective behaviors and flood preparedness (Anacio et al., 2016; Tierney et al., 2002). However, Holley et al. (2022) emphasize the importance of differentiating between relocation from flood-prone areas and other protective behaviors. Individuals with high levels of sense of place are less likely to evacuate but more likely to engage in other flood mitigation behaviors.

- **Vision of nature**

Based on the results from Zibadasht neighborhood, individuals prioritizing master over nature vision exhibit a weaker cognitive dimension of flood risk perception and a lower likelihood of adopting flood-adaptive behaviors. Additionally, No significant relationship has been found between the other two visions (steward of nature - participant in nature) and flood risk perception or flood-adaptive behaviors in this study. In this regard, some studies have suggested that the human-nature relationship (vision of nature) has impact on perceptions of environmental hazards (Sipos et al., 2022; Verbrugge et al., 2013). Conversely, Han et al. (2023) found no significant relationship between flood risk perception and support for nature-based solutions (participant in nature vision). Furthermore, regarding flood-adaptive behaviors, some studies have reported no significant relationship between vision of nature and environmental behaviors (Raymond et al., 2013). In contrast, Braito et al. (2017) found a significant relationship, indicating that master over nature vision reduces the likelihood of adopting pro-environmental behaviors. Additionally, Van Riper et al. (2019) indicated that individuals with participant in nature vision demonstrate a stronger likelihood of adopting pro-environmental behaviors.

Conclusion

Regarding the transition in flood risk management from structural to integrated approaches, the role of relevant disciplines in non-structural approaches must be defined. Flood risk perception is a key factor in non-structural approaches for risk reduction and improving the adaptive capacity of communities to floods. Urban design, by intervening in the perceptual factors of the environment, can influence individuals' perceptual experience of rivers and their flood risk perception. Therefore, to define the role of urban design in non-structural measures of flood mitigation, this study, by modeling the factors influencing flood risk perception, examines the impact of perceptual factors of the environment in the context of Iran (Zibadasht neighborhood-Kan River).

Among the perceptual factors examined in the Zibadasht neighborhood, perceived qualities have the most significant impact on residents' flood risk perception and can play a key role in improving both dimensions of flood risk perception. Although these qualities do not directly influence flood-adaptive behaviors, given the mediating effect of flood risk perception (cognitive dimension) in the relationship between perceived qualities and flood-adaptive behaviors, urban design, by intervening in perceived qualities, can indirectly influence flood-adaptive behaviors. Furthermore, while urban design can influence (positively or negatively) flood risk perception in Zibadasht through all components of the sense of place, the most influential component is place attachment. Place attachment and the emotional bond between residents and the Kan River increase the cognitive dimension of flood risk perception, leading to greater awareness and more accurate estimations of future floods. Regarding the impact of a sense of place on flood-adaptive behaviors, the likelihood of adopting these behaviors increases only when individuals define their identity and personality in relation to the Kan River. Furthermore, urban design, through the perceptual factor of vision of nature, can provide appropriate responses to floods by adjusting ecosystem services according to the area's risk level and individual preferences. However, in the context of this study (Iran-Kan River), it is likely that due to the residents' environmental awareness level, individuals do not exhibit a clear orientation toward a vision of participation or stewardship in nature. Consequently, these visions do not act as predictors of environmental perceptions and behavior; only the master over-nature vision serves as a predictor variable.

Therefore, based on the study context, urban design can play a significant role in improving flood risk perception by adjusting the perceived qualities of the environment and enhancing individuals' place attachment to the Kan River. In addition, strengthening the place identity of individuals in relation to the Kan River is one of the factors influencing flood-adaptive behaviors in this area. On the other hand, given the negative impact of the master over nature vision on flood risk perception and the adoption of flood-adaptive behaviors, improving residents' environmental awareness is essential to promote the acceptance of greener and more sustainable solutions in this neighborhood.

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