

Influence of Information Source and Environmental Cues on Decision-Making During Flood Evacuation

Razan Y. Aldahlawi^{1,3}, Glyn Lawson², Alexandra Lang³ & Vahid Akbari⁴

¹Industrial and Systems Engineering Department, PNU, Saudi Arabia, ²School of Art & Design, Nottingham Trent University, UK, ³Human Factors Research Group, University of Nottingham, UK, ⁴Operations Management and Information Systems Department, University of Nottingham, UK

SUMMARY

This study explored the influence of different information sources and environmental cues on decision-making behaviour at route intersections during flood evacuation. The information sources included traffic police officers, navigation systems, and road signs. The environmental cues involved floodwater on the streets and congestion. The talk-through method developed by Lawson (2011) was employed, in which participants were presented with hypothetical flood scenarios and asked to explain how they would respond. The results showed that receiving routing directions from a traffic police officer to follow the planned route increased the likelihood of complying with the instructions and staying on the planned route the most. In contrast, observing floodwater along the planned route was the strongest factor in decreasing the likelihood of staying on it and switching to an alternative route. Following a within-subject design, these findings were based on nonparametric statistical analysis, in which the Friedman test and the Wilcoxon Signed-Rank test assessed differences in participants' rating scores across conditions. This research makes an important contribution to understanding how information sources and environmental conditions influence decision-making during floods.

KEYWORDS

Human factors, flood evacuation planning, information processing, compliance behaviour

Introduction

Understanding how many drivers choose their routes is a challenge for those responsible for managing and planning large-scale evacuations, yet it can have a notable impact on evacuation outcomes (Lindell et al., 2018; Wang et al., 2021). Route choice decisions occur during two time periods — pre-trip and en route — each influenced by several factors, including diverse information sources (Lindell et al., 2018). However, research is limited on how evacuees perceive information sources and how these sources influence evacuees' compliance when used to communicate routing directions, particularly in the context of flood evacuation.

During an evacuation, although many evacuees may have received instructions via television or other media, those channels are no longer accessible once they are travelling in vehicles. It is therefore important to use communication methods to reach evacuees en route, and emergency personnel must be able to coordinate and communicate with evacuees, whether during transit or upon arrival at reception sites and shelters (Federal Highway Administration, 2007). Transportation information should include evacuation routes and be continually updated and communicated to the public through multiple channels, including road signs and in-vehicle navigation systems (Federal

Highway Administration, 2007). Thus, the information sources used in this study to elicit participants' likely compliance and responses to the hypothetical flood-evacuation scenarios included traffic police officers, navigation systems, and road signs.

Moreover, different types of hazards present distinct environmental cues, enhancing risk recognition and, consequently, the likelihood of evacuation (Perry, 1983; Fujimi & Fujimura, 2020). Similarly, congestion and traffic queues are important cues in emergencies, alerting drivers to the route to take (Lindell et al., 2018). Still, little is known about en route decision-making when environmental cues are noticed during emergency evacuations.

In practice, authorities appear to select larger-capacity roads as evacuation routes; however, many evacuees' route choices are based upon their routine experiences (Lindell et al., 2018). While some adhere to their initially planned route despite traffic conditions, others divert to alternate routes based on experience or instructions from authorities (Lindell et al., 2001). Current research lacks an examination of how likely these instructions are to be followed when they are confirmatory with or contradictory to evacuees' initial plans.

To address these issues, this study was grounded on Lindell and Perry's (2012) Protective Action Decision Model (PADM) to explore drivers' route-choice behaviour during floods under the PADM-derived conditions. PADM is a theory that can serve as a foundation for designing a conceptual model of human behaviour and decision-making in emergencies. It integrates the processing of information derived from social and ecological cues with messages transmitted by social sources to those at risk via communication channels (Lindell & Perry, 2012). According to Lindell et al. (2019), PADM is a suitable framework for studying human behaviour during a flood evacuation. Overall, it is a behavioural theory appropriate for exploring human behaviour during floods, across different information sources and environmental cues conditions.

Thus, the following hypotheses were tested to contribute to developing more efficient routing strategies that promote compliance with instructions in flood evacuation scenarios:

H1 The likelihood of continuing on the planned route differs based on the source of information

H2 Observing environmental cues influences the likelihood of continuing the planned route

H3 The likelihood of continuing on the planned route differs based on whether the routing directions are consistent with or contradictory to evacuees' initial plan

Method

Participants

This study included 20 Saudi citizens (Mean age: 35; range: 20-68) living in areas prone to flooding. Of the total sample, 10 were male, and 10 were female. Participants had 1 or more years of driving experience; 9 had experience driving during a natural disaster evacuation. Participants reported a median awareness level of flood risks and flood-resilience actions in their local areas of 3 (1 = very low, 2 = low, 3 = neutral, 4 = high, 5 = very high).

Materials

This study employed the talk-through, questionnaire-based approach developed by Lawson (2011). The subjective likelihood of continuing the planned route across the conditions was measured using a 0-100 Visual Analogue Scale (VAS), a rating scale often used in human factors investigations (Sharples & Cobb, 2015). Remarkably, the VAS was presented as a 10-cm-long line, and participants' marks were measured with a ruler, yielding scores ranging from 0 to 10 for analysis.

Higher scores indicated a greater likelihood of continuing the planned route rather than switching to the alternative route, as shown in Figure 1.

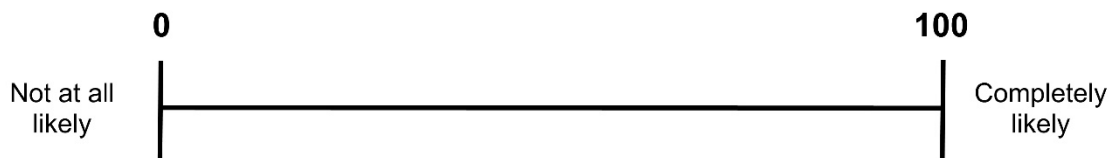


Figure 1 VAS was used for measuring the likelihood of continuing the planned route

The first section of the talk-through questionnaire focused on demographic and socio-economic information. Demographic information, including age, gender, years of driving experience, driving experience during emergency evacuations, and awareness of local flood risks and flood-resilience actions, was collected to characterise the study sample. Likewise, socioeconomic information involving education level, occupational status, marital status, and overall physical/mobility condition was acquired. Subsequently, participants were presented with a written flood-evacuation scenario accompanied by visual vignettes (Figure 2) and then asked several questions.

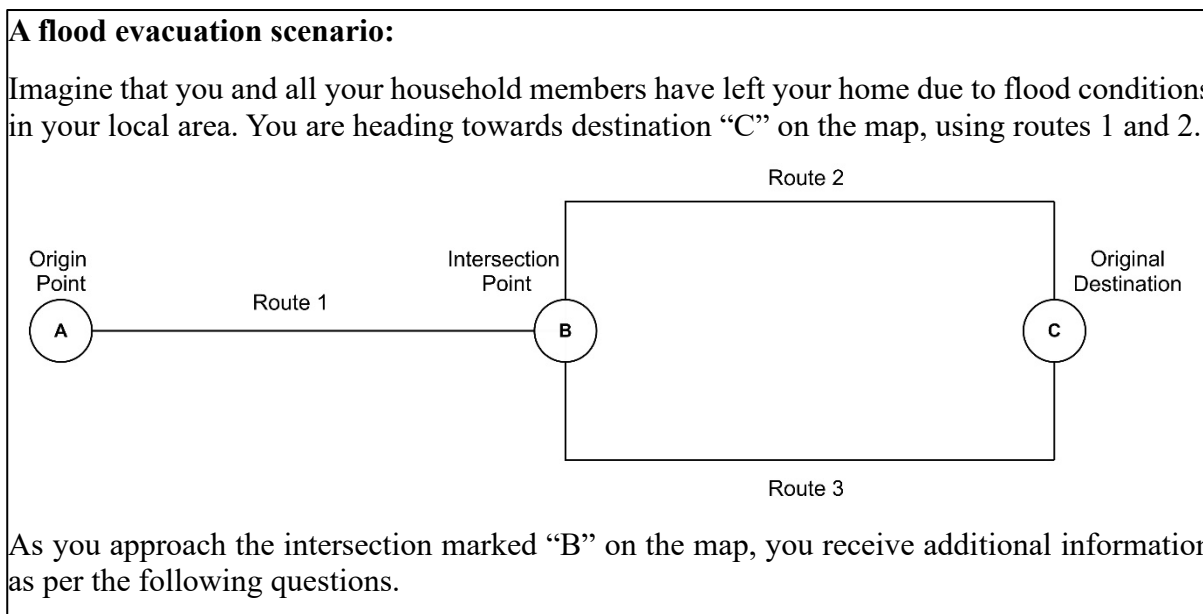


Figure 2 Flood evacuation scenario for the talk-through

The VAS questions asked participants to indicate their likelihood of continuing the planned route under confirmatory or contradictory conditions, and to justify their rating. The confirmatory conditions demonstrated that Route 2 (the planned route) in the hypothetical flood evacuation scenario was confirmed by the information source that delivered the routing instructions. In contrast, the contradictory conditions demonstrated that Route 3 (the alternative route) was confirmed by the information source that delivered the routing instructions. For example, participants were presented with the following statements in the police officer conditions:

- Confirmatory: A traffic police officer directs you towards **Route 2**. Please mark the likelihood of **continuing with Route 2**.
- Contradictory: A traffic police officer directs you towards **Route 3**. Please mark the likelihood of **continuing with Route 2**.

Lastly, they were asked two open-ended questions to elicit insights into the factors influencing compliance while driving. These questions are: “From your perspective, what factors influenced

your compliance with routing instructions the most during the hypothetical flood scenarios?” and “Do you have any suggestions to enhance the efficiency of routing instructions (e.g., how they are delivered, specific information that would encourage compliance, etc)?” This data, along with participants’ explanations for their VAS ratings, were analysed using thematic analysis (Caulfield, 2023). An inductive approach, which allows the data to generate the themes naturally, was used. A semantic approach, which involves analysing the explicit content of the data, was also used. The former concerns theme generation, whereas the latter concerns the analysis technique.

Procedures

The recruitment process included sending an advertisement via social media. People with severe health conditions, mental health issues, traumatic experiences of a flood, or who lost a close friend or relative in a disaster were excluded from this study. The researcher ensured that participants met the criteria and then allocated each a 30-minute appointment. The talk-through sessions were conducted online via Teams or in person, depending on the participant's preference and availability. Each participant was asked to sign a consent form emphasising that they could withdraw from the study at any time if they felt distressed.

During the talk-through session, following a within-subject design, each participant was exposed to the PADM-derived experimental conditions. These conditions involved a control condition, no cues or instructions, and those demonstrated in Table 1.

Table 1 Overview of the Experimental Design

	Information Source (IS)						CC	Environmental Cues (EC)			
	PO-P	PO-A	NS-P	NS-A	RS-P	RS-A		F-P	F-A	C-P	C-A
H₁ (IS)	Influential Information Sources										
H₂ (EC)								Influential Environmental Cues			
H₃	P vs. A		P vs. A		P vs. A			P vs. A		P vs. A	
CC: Control Condition, PO: Police Officer, NS: Navigation Systems, RS: Road Sign, C: Congestion, F: Floodwater, P: Planned Route (Confirmatory), A: Alternative Route (Contradictory)											

Accordingly, the PADM-derived conditions are structured as follows:

Condition 1: Control condition, in which no cues were observed at the route intersection

Condition 2: The traffic police officer directs the planned route

Condition 3: The traffic police officer directs to the alternative route

Condition 4: The navigation system suggests the planned route

Condition 5: The navigation system suggests the alternative route

Condition 6: The road signs direct to the planned route

Condition 7: The road signs direct to the alternative route

Condition 8: Noticing congestion on the planned route

Condition 9: Noticing congestion on the alternative route

Condition 10: Noticing floodwater on the planned route

Condition 11: Noticing floodwater on the alternative route

After each condition, participants rated their perceived level of influence. A partial counterbalancing approach was applied.

Results

Figure 3 shows the median rating scores for participants in each study condition. This indicates a different pattern of results across conditions.

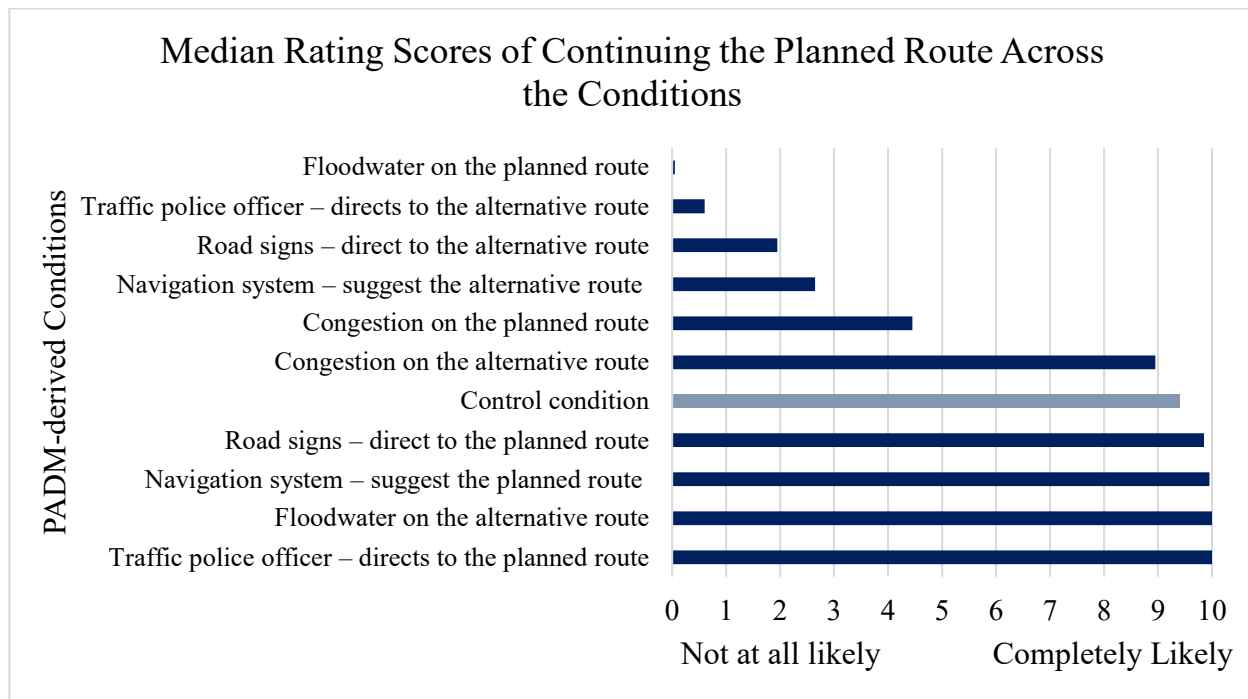


Figure 3 Median Rating Scores of Continuing the Planned Route Across the Conditions

Statistical analyses of these results are presented below.

Influence of Information Sources on Continuing the Planned Route

The Friedman test results indicated a statistically significant difference in rating scores across the conditions [$\chi^2(6) = 86.65, p < .001$]. The Wilcoxon Signed-Rank tests, applying the Bonferroni correction ($\alpha = .0083$), showed that rating scores were significantly lower when directed to the alternative route by police officers (median = 0.60), by road signs (median = 1.95), and by the navigation system (median = 2.65), compared to the control condition (median = 9.4). On the other hand, being directed to the planned route by police officers (median = 10) resulted in a higher rating score than in the control condition.

These findings indicated that when evacuees receive directions from study sources that conflict with their initial plan, they are less likely to continue their planned route. By contrast, receiving consistent directions from police officers would increase the likelihood of continuing on the planned route, whereas no effect was observed for the navigation system or road signs. Table 2 presents the descriptive statistics and the Wilcoxon Signed-Rank test results for comparisons with the control condition.

Table 2 Influence of Information Sources on Continuing the Planned Route

Condition	N	Median	p-Value
Control condition	20	9.4	-
Navigation system – suggest the alternative route	20	2.65	<.001
Navigation system – suggest the planned route	20	9.95	0.187
Traffic police officer – directs to the alternative route	20	0.6	<.001

Traffic police officer – directs to the planned route	20	10	0.005
Road signs – direct to the alternative route	20	1.95	<.001
Road signs – direct to the planned route	20	9.85	0.294

Influence of Environmental Cues on Continuing the Planned Route

The Friedman test results indicated a statistically significant difference in rating scores across the conditions [$\chi^2(4) = 59.263$, $p < .001$]. The Wilcoxon Signed-Rank tests, applying the Bonferroni correction ($\alpha = .0125$), showed that rating scores were significantly lower when noticing floodwater (median = 0.05) or congestion (median = 4.45) on the planned route than in the control condition. In contrast, noticing floodwater on the alternative increased the likelihood of continuing the planned route (median = 10). Table 3 presents the descriptive statistics and the Wilcoxon Signed-Rank test results for comparisons with the control condition.

Table 3 Influence of Environmental Cues on Continuing the Planned Route

Condition	N	Median	p-Value
Congestion on the planned route	20	4.45	<.001
Congestion on the alternative route	20	8.95	0.733
Floodwater on the planned route	20	0.05	<.001
Floodwater on the alternative route	20	10	0.012

Influence of Receiving Directions Consistent vs. Contradictory to Evacuees' Initial Plan

The Friedman test results indicated a statistically significant difference in rating scores across conditions [$\chi^2(9) = 133.561$, $p < .001$]. The Wilcoxon Signed-Rank tests, applying the Bonferroni correction ($\alpha = .01$), showed that all information sources produced significantly lower rating scores when directed to the alternative route than to the initially planned route (all $p < .001$). Regarding environmental cues, observing floodwater along the planned route resulted in a marked reduction in rating score compared with observing it along the alternative route ($p < .001$). In contrast, no significant difference was observed between the congestion conditions.

Thematic Analysis

The analysis was structured into two parts: the open-ended questions and participants' explanations for their VAS ratings. For the former, participants explained that they were more likely to comply with information from sources perceived as authoritative, such as police officers, who were perceived as more credible, knowledgeable, and reassuring. Other drivers of compliance included perceptions of the information as up-to-date and relevant. Regarding determinants of rating scores, participants were more likely to continue their planned route when it was endorsed by credible sources, when they felt safer, and when they were more familiar with the route. In contrast, participants reported being more likely to switch routes when observing a hazard (e.g., floodwater) or a risk of delay (e.g., congestion), or when instructed to do so. This indicates that qualitative results align with the VAS data, providing a robust understanding of en route decision-making during flood evacuation.

Discussion

Among information sources, traffic officers were identified as the most credible and influential in improving driver compliance during flood evacuation. This is similar to Thompson et al.'s (2017) discussion of warning sources, indicating that community officials, such as law enforcement officers, have the greatest credibility and elicit greater evacuation compliance. Moreover, participants often viewed the described officers as reliable and reassuring, as evidenced by the high

compliance rate reflected in the rating scores. This finding is supported by Parr et al. (2016), who found that manual police traffic control effectively manages intersections during evacuations by adapting to changing conditions and reinforcing public confidence. Participants also demonstrated that police officers project an effective, official authority presence during emergencies, a finding similar to that of Lindell et al. (2018), who discussed that manual traffic control is most common at high-volume intersections, particularly those where traffic from one or more routes merges or conflicts with traffic from other routes. This point was also supported by the findings of Parr et al. (2016), that manual control effectively reduced congestion during evacuations.

Nevertheless, according to Lindell et al. (2018), source credibility does not consistently lead to high compliance with evacuation instructions. A meta-analysis by Huang et al. (2016) found that authority messages alone often produced mixed or weak direct effects on evacuation, without concise, explanatory, and prompt information. This aligns with the current study's results and explains why participants perceived officers as most influential, given their ability to communicate instant, relevant, and consistent information. By contrast, non-interactive sources, such as navigation systems and road signs, were perceived as outdated or irrelevant and thus less effective at enhancing compliance than officers.

Considering environmental cues, the study results demonstrated a strong influence of noticing floodwater cues on evacuees' behaviour, consistent with Lindell & Perry (1992), who argue that visible environmental threats strongly prompt protective action. PADM also assumed that environmental cues initiate decision processes independently of social influence (Lindell & Perry, 2012; Lindell et al., 2018), a claim supported by this study, as participants tended to switch routes upon noticing floodwater on the route.

In contrast, noticing congestion had nuanced effects: some participants felt safer among others, whereas others preferred less-congested routes to save time and avoid delays. This duality was similarly observed in Khattak et al.'s (1993) study and discussed by Lindell et al. (2018). Despite this, Khattak et al. (1993) concluded that diversion rates increase with visible congestion on the current route, while Bonsall & Palmer (1999) found that diversion rates decrease with visible congestion on alternative routes. Nonetheless, Knoop et al. (2010) observed that more than half of the affected drivers switched from their original route to an alternate route during a major traffic incident but did not switch for a minor one. The authors concluded that drivers would respond similarly to queues during mass evacuations. Bonsall & Palmer (1999) also found that drivers' likelihood of diverting from a congested route to an alternate route is significantly related to their familiarity with alternate routes. This was also evident in the rating scores, which varied with participants' perceptions of congestion levels.

In both quantitative and qualitative analyses, evacuees preferred familiar routes. Past experience and, thus, route familiarity have been found to influence prior academic work, as many routine commuters are reluctant to switch to an alternative route even when informed that it could yield better outcomes (Khattak et al., 2008). Similarly, Bian et al. (2023) reported that route familiarity greatly influences evacuation decisions. Collectively, the present study's results were supported by previous work, showing that Lawson's (2011) talk-through, questionnaire-based approach could be a useful method for evaluating guidance information for planning emergency response, rather than relying on observational data.

Conclusions

This study identified the likelihood of compliance while driving and route decisions in response to information and environmental cues. Police officers were the most influential source of information for enhancing compliance, compared to road signs and navigation systems. Consistent directions

with evacuees' initial plans also promoted compliance. Both thematic and statistical analyses yielded similar conclusions, providing a robust understanding of route-choice behaviour during floods. Overall, this study may help inform the design of routing strategies for flood evacuation. Among these strategies, a good approach is to allocate police officers to critical route intersections to provide adaptive, immediate route guidance and direct most traffic to more familiar, known routes rather than less-known ones. Future work will explore how the different communication channels and the content of transmitted routing directions influence compliance behaviour.

References

- Bhandari, P., 2023. Within-Subjects Design | Explanation, Approaches, Examples. [Online] Available at: <https://www.scribbr.com/methodology/within-subjects-design/> [Accessed 29 01 2025].
- Bian, R. et al., 2023. Modeling Evacuees' Intended Responses to a Phased Hurricane Evacuation Order. *Applied Sciences*, 13(8), p. 13085194.
- Bonsall, P. & Palmer, I., 1999. Route choice in response to variable message signs—factors affecting compliance. In: R. Emmerink & P. Nijkamp, eds. *Behavioural and Network Impacts of Driver Information Systems*. Aldershot, England: Ashgate, p. 181–214.
- Cova, T. J., Johnson, J. C. & Wolfgang, A. P., 2005. Assessing residential wildfire risk: A case study in the Big Thompson Canyon, Colorado, USA. *Natural Hazards*, 35(2), p. 221–245.
- FHWA—Federal Highway Administration. 2007. *Using Highways During Evacuation Operations for Events with Advance Notice*. United States Department of Transportation, Washington DC.
- Fujimi, T. & Fujimura, K., 2020. Testing public interventions for flash flood evacuation through environmental and social cues: The merit of virtual reality experiments. *International Journal of Disaster Risk Reduction*, Volume 50, p. 101690.
- Huang, S.-K., Lindell, M. & Prater, C., 2016. Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies. *Environment and Behavior*, 48(8), p. 991–1029.
- Khattak, A., Schofer, J. & Koppelman, F., 1993. Commuters' en route diversion and return decisions: analysis and implications for advanced traveler information systems. *Transportation Research— A*, 27(2), p. 101–111.
- Kirschenbaum, A., Cline, T., Hickey, A. & Pressley, R., 2016. Understanding evacuation decisions in wildfires: Findings from interviews with evacuated residents of the 2011 Las Conchas Fire in New Mexico. *International Journal of Disaster Risk Reduction*, Volume 15, pp. 52-61.
- Knoop, V. L., Hoogendoorn, S. P. & van Zuylen, H., 2010. Rerouting behaviour of travellers under exceptional traffic conditions—An empirical analysis of route choice. *Procedia Engineering*, Volume 3, p. 113–128.
- Lam, C. Y. & Cruz, A. M., 2024. An information network analysis approach to assessing the processes of issuing evacuation instructions: A study of evacuation cases in Japan. *Journal of Risk Research*, 27(11), p. 1400–1423.
- Lawson, G., 2011. *Predicting human behaviour in emergencies*, Nottingham: PhD Thesis, University of Nottingham.
- Lindell, M. K., Murray-Tuite, P., Wolshon, B. & Baker, E. J., 2018. *Large-scale evacuation: The analysis, modeling, and management of emergency relocation from hazardous areas*. s.l.:CRC Press.

- Lindell, M. K. & Perry, R. W., 2012. The Protective Action Decision Model: Theoretical Modifications and Additional Evidence. *Risk Analysis*, 32(4).
- Lindell, M. K. et al., 2001. Texas Gulf Coast residents' expectations and intentions regarding hurricane evacuation, s.l.: Hazard Reduction & Recovery Center, Texas A & M University.
- Parr, S., Wolshon, B. & Murray-Tuite, P., 2016. Unconventional intersection control strategies for urban evacuation. *Transportation Research Record* 2599, p. 52–62.
- Perry, R., 1983. Population evacuation in volcanic eruptions, floods and nuclear power plant accidents: some elementary comparisons. *Journal of Community Psychology*, Volume 11, p. 36–47.
- Sharples, S. & Cobb, S., 2015. Methods for Collecting and Observing Participant Responses. In: J. R. Wilson & S. Sharples, eds. *Evaluation of Human Work*. s.l.:Taylor & Francis Group, pp. 83-118.
- Thompson, R., Garfin, D. & Silver, R., 2017. Evacuation from natural disasters: a systematic review of the literature. *Risk Analysis*, 37(4), p. 812–839.
- Wang, Y., Kyriakidis, M. & Dang, V. N., 2021. Incorporating human factors in emergency evacuation – An overview of behavioral factors and models. *International Journal of Disaster Risk Reduction*, Volume 60.