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Designing Context-Sensitive Nudges for Natural Hazard Risk Mitigation: A Participatory Design Thinking Framework

An Experimental Proof-of-Concept Study

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Abstract

This applied research introduces a novel, transdisciplinary methodological framework for co-designing context-sensitive behavioral nudges to mitigate natural hazard risks, based on the IDEAL method. Grounded in design thinking and integrating insights from behavioral economics, policymaking (OECD BASIC), and product design (DECIDE), the framework empowers community experts to collaboratively prototype interventions tailored to territorial specificities. We developed a replicable framework for integrating nudging into disaster risk reduction that bridges theoretical gaps in the application of nudges to natural hazard management. Tested across three workshops (Valli del Verbano, University of Bari, Politecnico di Milano), the method generated actionable nudge prototypes addressing wildfire preparedness, heatwave response, and drought adaptation. Findings demonstrate the framework's capacity to bridge theory-practice gaps, foster social acceptability, and produce ethically grounded, behaviorally informed interventions. This paper documents the method's structure, implementation protocol, observed outcomes, and limitations, offering a replicable model for participatory behavioral design in disaster risk reduction (DRR).

1. Introduction

Natural hazard risk mitigation increasingly demands interventions that address human behavior, not just infrastructure. Yet, standardized 'nudge' toolkits often fail to account for territorial, cultural, and cognitive specificities. This applied research responds by introducing and empirically testing a novel, participatory methodological framework designed to co-create context-sensitive behavioral nudges with community and DRR experts. It presents and tests the IDEAL method, a participatory methodological framework originally conceived for sustainable urban and territorial planning (Ferreira Crispim, 2023) and subsequently adapted for disaster risk reduction (DRR) purposes. Drawing on design thinking, behavioral economics, and policy design, this paper documents the framework's structure, field-testing in three Italian workshops, and observed outcomes, positioning it as a scalable model for human-centered DRR.

The aim of this paper is to present and pilot the IDEAL method for co-designing nudges that can support natural hazard risk mitigation.

The research specifically addresses the following questions:

(1) How can design-thinking methodologies be systematically integrated with behavioral science to enable community experts to co-design effective and context-sensitive nudges for natural hazard risk mitigation?

(2) Can the IDEAL workshop protocol generate feasible, context-sensitive nudge prototypes?

(3) Which nudge typologies recur across diverse contexts?

To answer these questions, the paper is structured to first establish the theoretical background by discussing the behavioral gap in disaster risk reduction and the potential of nudging as a behavioral intervention (Sections 2–3). It then explores the principles of design thinking and its relevance to complex territorial challenges, including disaster management (Section 4). Building on this foundation, the paper introduces the IDEAL framework and situates it within existing nudge design methodologies (Section 5). The empirical application of the IDEAL method is presented through three participatory workshops in Italy, detailing data collection, workshop structure, and observed outcomes (Section 6). The discussion section (Section 7) reflects on the theoretical and practical contributions, limitations, and broader implications of the approach, leading to the final conclusions (Section 8).

2. The Behavioral Gap in Disaster Risk Reduction

Disaster Risk Reduction (DRR), as defined in the *Sendai Framework for Disaster Risk Reduction 2015–2030*, aims to prevent the creation of new risks, reduce existing risks, and manage residual risks, all of which contribute to strengthening resilience and achieving sustainable development (UNDRR, 2017). Unlike traditional emergency management approaches that focus primarily on disaster response and recovery, DRR emphasizes proactive measures to identify, understand, and reduce risk before a disaster occurs. At the core of this approach lies the recognition of the crucial role that human behavior and risk awareness play in shaping both vulnerability and resilience (Van Manen et al., 2023).

Disaster Risk Management (DRM) represents the practical application of DRR principles. While DRR provides the conceptual foundation, DRM is the set of concrete actions taken before, during, and after a disaster to prevent it, reduce its impact, or facilitate recovery (Heazle et al., 2013). DRM typically operates through a cyclical framework comprising four interconnected phases that often overlap and vary in duration depending on the nature and severity of the event (Khan et al., 2008): prevention/mitigation, preparedness, response, and recovery (figure 1) (Basri et al., 2021).

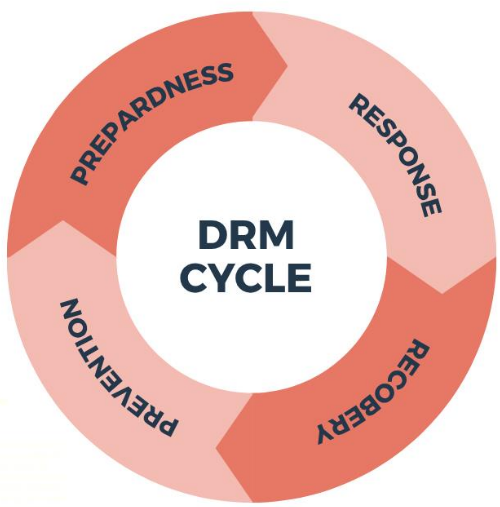

Figure 1 - Disaster Risk Management (DRM) cycle

This shift in perspective from a reactive to a proactive approach has brought increased attention to the prevention and preparedness phases. It also highlights the importance of designing policies and measures that aim to produce behavioral change. In particular, the preparedness phase, which refers to actions taken to reduce the impact of disasters, has increasingly focused on human behavior, encouraging the development of new behavior change strategies to enhance readiness and risk reduction at the individual and community levels (Ejeta et al., 2015).

Nevertheless, despite the growing body of research and policy development in DRR, the field continues to face a range of structural limitations and practical challenges that hinder the effectiveness of its strategies and interventions. One of the most fundamental issues lies in the complexity of disaster risk itself, which constitutes what Rittel and Webber (1973) described as a "wicked problem." Defining risk is inherently difficult, and the ability to fully grasp the relationships between hazards and the other essential elements of disaster risk before an event occurs remains limited (Michellier et al., 2020; Fien, 2023).

Another persistent challenge is the gap between knowledge and action. While our understanding of risk and vulnerability has advanced significantly, there remains a lack of effective implementation strategies and a scarcity of real-world case studies that could inform and guide policy development (Gaillard & Mercer, 2013; Charlesworth & Fien, 2022).

Closely related to this is the continued reliance on top-down, technocratic approaches in many national DRR strategies. These often prioritize scientific and technical knowledge while marginalizing local, indigenous, and experiential knowledge systems. As a result, disaster interventions are frequently standardized, overlooking the context-specific nature of risk and failing to engage meaningfully with the communities most affected (Wisner et al., 2012).

In addition, the field of DRR remains marked by a lack of interdisciplinary collaboration. Research and practice are often siloed within individual disciplines or sectors, with minimal co-design or integration. This fragmentation undermines the development of comprehensive and innovative responses, while the absence of field-based operational insights further limits the capacity to address the systemic and interconnected nature of disaster risk (Charlesworth & Fien, 2022).

A final but crucial limitation is the continued dominance of reductionist and reactive measures. Many DRR strategies focus narrowly on infrastructure, such as building levees or firebreaks, while neglecting the deeper socio-economic and political vulnerabilities that transform natural hazards into disasters. Such approaches often fail to account for the cascading and compounding effects of contemporary extreme events, leaving communities exposed to growing systemic risks (Lee, 2020).

In light of these challenges, it is essential to rethink how we design and implement DRR policies. What is needed is a shift toward system-based thinking, inclusive practices, and context-sensitive strategies that integrate diverse forms of knowledge and foster behavioral change. Without these changes, DRR risks becoming a technocratic exercise, disconnected from the social realities it aims to address, and ultimately ineffective in reducing risk and building long-term resilience.

3. Nudging to Bridge the Behavioral Gap in Disaster Risk Reduction

The integration of nudging into behavioral public policy has gained significant traction since its formalization by Thaler and Sunstein (2008), who defined it as a method of subtly altering the decision-making environment to influence behavior in predictable ways, without restricting freedom of choice or significantly changing economic incentives. Nudges aim to guide individuals toward decisions that are beneficial both personally and socially, while preserving autonomy and avoiding coercion (*ibid*). This approach is embedded within the broader framework of choice architecture, which refers to the design and structuring of decision environments. As Johnson et al. (2012) emphasize, "choice architecture reflects the fact that there are many ways to present a choice to the decision-maker, and that what is chosen often depends upon how the choice is presented."

The theoretical departure from the rational agent model of classical economics, homo economicus, toward a more psychologically realistic understanding of decision-making is central to the nudging paradigm (Thaler and Sunstein, 2008). Behavioral economics acknowledges that individuals often rely on heuristics, emotional cues, and social norms, rather than deliberate reasoning (Baron, 2014). Nudges exploit these intuitive processes to steer behavior in desirable directions, particularly in contexts where cognitive resources are limited or decisions are made under uncertainty (Callaway et al. 2023).

A key cognitive foundation for nudging is dual-process theory, most notably articulated by Kahneman (2011). This framework posits two interacting systems of thought: System 1, which is fast, automatic, and intuitive, and System 2, which is slow, effortful, and analytical. System 1 enables rapid judgments based on learned patterns and heuristics but is prone to systematic biases. System 2, while capable of overriding these impulses, demands greater cognitive effort and is often context dependent. Evans and Stanovich (2013) reinforce this model, arguing that Type 1 processes yield default responses unless actively overridden by Type 2 reasoning, a dynamic that is central to the design of effective nudges.

Building on this foundation, Ly et al. (2013) propose that nudging should not merely exploit cognitive biases but should be strategically aligned with the cognitive architecture of decision-making. Nudges can either support System 1 by simplifying beneficial choices, such as through defaults, framing, or visual cues, or activate System 2 by encouraging reflection, as in educational or informational interventions. This distinction is particularly relevant in the domain of natural hazard risk mitigation, where decisions often occur under stress, time pressure, or limited attention. Thus, to summarize, low-effort nudges (e.g., defaults) align with System 1 and are effective in routine or high-load settings, while high-effort nudges (e.g., deliberative prompts) engage System 2 but may be less effective in time-constrained or emotionally charged situations.

This model has practical implications for designing nudges in complex domains such as environmental conservation and disaster preparedness. For instance, in urban risk contexts, such as flood or earthquake mitigation, nudges that reduce cognitive friction (e.g., simplified emergency procedures, visual hazard cues) can enhance compliance and preparedness. Conversely, interventions that require deliberation (e.g., risk education campaigns) may be more effective when cognitive resources are available and motivation is high.

Importantly, nudges also interact with social norms and institutional standards, which shape perceptions of what is typical or appropriate behavior. As Ferreira Crispim and Cetara (2022, p. 31) note, "nudging is thus a tool to achieve behavioral outcomes by predicting how the human brain perceives its environment and makes decisions." Activating norms through implicit cues or explicit suggestions can foster cooperation and collective action, particularly in community-based risk mitigation efforts.

Ethical considerations remain central to the deployment of nudges. While interventions that minimize cognitive effort often achieve higher compliance, they must be designed transparently and with respect for individual autonomy. As Sunstein (2016) and Schubert (2017) argue, nudges should facilitate better outcomes without manipulation, ensuring that individuals retain the freedom to choose. The balance between effectiveness and ethical integrity is especially critical in public risk contexts, where trust and legitimacy are essential.

In summary, the theoretical foundations of nudging offer a robust framework for developing context-sensitive interventions. In particular, we'll argue later on that when integrated into a participatory design thinking process, these insights enable the co-creation of nudges that are cognitively aligned, ethically sound, and socially embedded. Such an approach is particularly well-suited to the challenges of natural hazard risk mitigation, where behavioral change must be fostered under conditions of uncertainty, urgency, and diverse stakeholder engagement.

3.1 Nudging in Sustainability and Disaster Preparedness: Toward Context-Sensitive Behavioral Design

Building on the cognitive and ethical foundations of nudging discussed above, this section explores its practical applications in sustainability and disaster preparedness and risk reduction. The goal is to extract insights that inform the development of context-sensitive nudges within a participatory design-thinking framework for natural hazards risk mitigation. The table below presents the most relevant papers found within this field. Though the literature review is secondary to the scope of this paper we do still believe that it provides a fair point on the state of the arts on the current use of nudging in the field.

Table 1 Main available literature on the use of Nudging in natural hazards and risk preparedness contexts

Study (Title & Authors)	Domain	Nudge Type(s)	Methodology	Sample Size	Effect Size / Impact	Key Findings	Limitations
Nudging Towards Sustainability: A Comprehensive Review of Behavioral Approaches to Eco-Friendly Choice – Amiri et al. (2024)	Sustainability (Energy, Transport, Food, Waste)	Defaults, Labels, Social Norms, Feedback	Systematic review (2008–2024), thematic & statistical analysis	630 studies	Thematic synthesis; no pooled effect size	Digital nudging and green finance are emerging; decision structure nudges most effective	Lack of longitudinal and cross-cultural studies
The Effectiveness of Nudging: A Meta-Analysis of Choice Architecture Interventions Across Behavioral Domains – Mertens et al. (2021)	General Behavioral Domains	Decision Information, Structure, Assistance	Meta-analysis of 212 studies	2,149,683 participants (summing across all the studies)	Cohen's d = 0.45 (95% CI: 0.39–0.52)	Defaults most effective; food-related nudges strongest; publication bias noted	Declining effect sizes over time; moderate heterogeneity
Nudging Civilian Evacuation During War: Evidence from Ukraine – Martinez et al. (2022)	Disaster Preparedness (Conflict)	Logistical Clarity, Framing	Survey experiment with randomized message framing	2,006 participants	+0.33 to +0.55 (OLS estimates)	Providing evacuation plans significantly increased perceived message effectiveness	Framing alone had no effect; hypothetical scenario
Early Evacuation Promotion Nudges for Heavy Rain Disasters – Ohtake et al. (2020)	Disaster Preparedness (Rainfall)	Loss/Gain Framing, Social Norms	Questionnaire-based field study	~1,000 residents	Significant increase in evacuation intention	Loss-framed altruistic messages most effective	Limited generalizability beyond Japan
The Psychological Impacts of Nudge-Based Evacuation Advisories – Tanaka & Takehashi (2023)	Disaster Preparedness	Gain vs. Loss Framing	3 experimental studies	1,330 participants	Both frames increase intention; loss-frame increase guilt & pressure	Loss-framed nudges evoke extrinsic motivation; gain-framed support intrinsic motivation	Psychological cost of loss-framing

All by Myself? Testing Descriptive Social Norm-Nudges to Increase Flood Preparedness – Mol et al. (2024)	Flood Preparedness	Descriptive Social Norms	Online experiment in NL & Spain	1,805 homeowners	No significant effect	Norm-nudges ineffective for costly or unfamiliar actions	Cultural and individual differences affect outcomes
Setting Descriptive Norm Nudges to Promote Demand for Insurance Against Climate Risk – Robinson et al. (2021)	Insurance Uptake	Descriptive Norms	Online experiment in NL	620 homeowners	No main effect; moderated by trust & prior beliefs	Norms effective only when consistent with beliefs and messenger is trusted	No behavioral outcome measured; hypothetical scenario
Psychological Influences and Implications for Household Disaster Preparedness – Ni et al. (2025)	Disaster Preparedness	Psychological Drivers (Risk Perception, Self-Efficacy, Place Attachment)	Systematic review of 35 studies	35 studies	Qualitative synthesis	Risk perception & self-efficacy promote preparedness; place attachment hinders evacuation	Cultural variation; lack of longitudinal studies
Nudge Theory and Health Risk Control Measures After the Fukushima Disaster – Murakami & Tsubokura (2017)	Health Monitoring	Default Settings	Observational study of WBC test participation	~10,000 residents	Participation: 98% (default) vs. 15% (opt-in)	Default nudges dramatically increased participation in radiation testing	Ethical concerns over involuntary participation

To summarize it, recent research highlights the growing use of nudging as a strategy to promote sustainable and disaster-preparedness behaviors. Broad reviews and meta-analyses (Amiri et al., 2024; Mertens et al., 2021) have categorized nudges into types such as informational cues, structural changes, assistance mechanisms, and social appeals, showing their relevance across domains like energy use, consumption, and waste management. Empirical studies (Wee et al., 2021; Martinez et al., 2022; Ohtake, 2021) emphasize the importance of context-specific design and psychological framing, demonstrating that even simple interventions can lead to meaningful behavioral shifts. However, findings also reveal limitations, particularly in high-risk or unfamiliar scenarios where personal norms and risk perception may outweigh social influence (Mol et al., 2024; Robinson et al., 2021). Recent contributions (Ni et al., 2025) offer psychological frameworks to better understand the drivers of preparedness, while case studies (Murakami & Tsubokura, 2017; Ryu et al., 2025) illustrate how nudges can be ethically and effectively adapted to vulnerable populations. Overall, the literature suggests that while nudging holds promise, its success depends on thoughtful design, demographic targeting, and sensitivity to cognitive and emotional factors.

Taken together, the literature reveals a nuanced and evolving understanding of nudging in natural hazards contexts. While traditional nudges like framing and defaults remain effective, their success depends on contextual sensitivity, demographic targeting, and cognitive alignment; a further description of the different nudges typologies is available in the appendix (9.2). Digital nudging offers scalability but must be designed with attention to user experience and cognitive load. Importantly, studies that challenge assumptions are crucial for refining intervention strategies.

For the purposes of this paper, these insights reinforce the need for a participatory design thinking framework that integrates behavioral science with stakeholder engagement. Nudges must be co-designed with communities, tailored to local risk perceptions, and ethically deployed to respect autonomy while enhancing resilience. As natural hazards risks grow in complexity and urgency, integrating behavioral insights into disaster planning is not merely beneficial but essential for building adaptive, inclusive, and responsive systems of preparedness.

4. Designing Contextual Nudges: A Design Thinking Approach to Disaster Risk Reduction

Despite the growing evidence on their effectiveness, nudges remain underutilized in the field of disaster risk reduction. A key reason lies in the inherent complexity and variability of disaster contexts, which differ greatly across hazards, cultural settings, and population groups. As Schubert (2017) and Banerjee & John (2021) note, behavioral interventions are highly context-dependent, and strategies that prove effective in one domain may not automatically transfer to another. Similarly, Ni et al. (2025) emphasize that psychological drivers of preparedness, such as risk perception or place attachment, vary significantly across communities, complicating the design of universally effective nudges. This underscores the need for systematic approaches that can help policymakers and practitioners adapt behavioral insights to the specificities of each case. To address this challenge, we build upon the design thinking-based methodology introduced by Ferreira Crispim (2023), which combines behavioral science and iterative, user-centered design processes (Brown, 2009; Liedtka, 2018) to guide the creation of context-sensitive nudges. This approach aims to overcome barriers to practical application and offer flexible tools for enhancing resilience across diverse disaster scenarios.

4.1 From Object to Process: Tracing the Transformation of Design into Design Thinking

The increasing complexity of contemporary challenges has fostered the adoption of design thinking as a human-centered approach to innovation and problem-solving. Rooted in the broader field of design, this approach evolved from industrial design, which emerged to create functional and aesthetic artifacts in response to mass production and technological change (Cardoso, 2008). The establishment of the Bauhaus in 1919 further consolidated design as a formal discipline, emphasizing the integration of artistic creativity and technical knowledge (Bomfim, 1995; Cardoso, 2008; Argan, 1992).

From the mid-20th century onward, the notion of industrial design gradually evolved into a broader and more flexible understanding of design, highlighting its adaptability and potential to address not only tangible products but also immaterial and strategic dimensions (Cardoso, 2008; Bonsiepe, 2011). Within the mass consumer culture that characterized the late 20th century, design played a central role in shaping new desires, behaviors, and lifestyles, reflecting the societal shift from "consuming to live" to "living to consume" (Bauman, 1999). As awareness of the social and environmental consequences of consumerism grew, design began to expand its scope beyond the market logic, engaging with issues such as urban planning, environmental protection, and sustainable development, thus consolidating its role as a multidisciplinary and innovative practice.

This expansion marked a fundamental shift: design moved beyond form and function to become a structured approach to address complex challenges. In this paradigm, scholars developed theoretical and methodological frameworks grounded in systems thinking, which laid the foundations of design thinking as a problem-solving methodology (Backman & Barry, 2007; Buchanan, 1992). A key contribution came from Horst Rittel, who introduced the concepts of problem setting, defining the scope and criteria of an issue, and problem solving, integrating these criteria into actionable solutions, particularly in relation to so-called "wicked problems" (Buchanan, 1992).

From this point onward, increasing attention turned to design thinking, recognized as a powerful framework applicable not only to product development but also to complex human and systemic challenges (Buchanan, 1992). This shift sparked renewed efforts to refine design methodologies. Building on Rittel's work, scholars such as Buchanan (1992) and Dorst (2003) introduced a problem finding phase to complement problem setting and problem solving. This triadic model emphasized a collaborative, participatory, and co-productive approach that continues to shape design practice.

Today, despite ongoing debates over its precise definition, design's inherently interdisciplinary nature remains its greatest strength, enabling it to adapt and respond to an ever-changing world. As highlighted by the World Design Organization (WDO), contemporary design is fundamentally a strategic, user-centered process that drives meaningful innovation and contributes to a higher quality of life (WDO, 2021a). Ultimately, design thinking embodies the potential to shape a more sustainable, inclusive, and resilient future by continuously reimagining solutions that place people and the planet at the center.

4.2 The Anatomy of Design Thinking: Human-Centered, Iterative, and Adaptive

At its core, design thinking is solution-oriented, beginning with the identification and reframing of problems. As Ferreira Crispim and Cetara (2022, p. 28) explain, "design thinking is a method for structuring thoughts through a set of principles and phases that can be applied in a range of scenarios where new ideas are synthesized from seemingly discrete fragments, transforming needs into requirements and challenges into opportunities." While many scholars have attempted to define and systematize design thinking into a set methodology with clear stages and objectives, a unified definition remains elusive. This lack of consensus reflects the inherently complex, adaptable, and evolving nature of design thinking itself (*ibid*). Rather than a rigid framework, design thinking is best understood as a flexible approach that transforms depending on the context in which it is applied. It is especially suited to addressing wicked problems, multifaceted issues where problems and solutions co-evolve. As such, design thinking is an effective method for tackling complex situations that resist linear problem-solving strategies. Hereafters are briefly summarized the core elements characterizing the theory of design thinking (table 2).

Table 2 Core elements characterizing the theory of design thinking

Characteristic	Definition	Authors
Systemic practice	Design thinking as system integration, fostering innovation and continuous adaptation.	Buchanan (2001)
Cognitive approach	Design thinking comprises three phases: 1. Exploratory phase: intuition from prior knowledge and context 2. Generative phase: idea generation 3. Representation phase: prototypes/models	Lindberg, Noweski, and Meinel (2010)
Interdisciplinary and multidisciplinary	Design thinking promotes collective learning and co-construction of understanding, addresses knowledge fragmentation and the need for integrated vision.	Lindberg, Noweski, and Meinel (2010); Brown (2008)
Human centered	Design thinking applies the sensibility and methods of designers to align human needs with what is technologically feasible, transforming those needs into meaningful opportunities and values.	Brown (2008)
Iterative, systemic, and non-linear process	Design thinking has three core phases: 1. Inspiration: empathetic observation. 2. Ideation: idea generation 3. Implementation: prototyping and execution Ideas can emerge through emotional, functional, or analytical approaches. The process often moves fluidly between stages, rather than following a fixed path.	Brown (2008)
Interplay between divergent and convergent thinking	Divergent thinking encourages exploration and expands the range of possible solutions, while convergent thinking helps refine and select the most promising ideas.	Brown (2008)
Problem solving methodology	Design thinking is a problem-solving methodology driven by constraints. Far from limiting creativity, constraints stimulate it, prompting designers to treat problems as opportunities for innovation.	Brown (2008)
Abductive reasoning	Designers uses abductive reasoning, a forward-looking form of inference that seeks to imagine what could be, rather than deducing what must be or inducing what probably is.	Martin (2006)
Cognitive attitudinal and interpersonal	The cognitive aspect involves abductive reasoning and the ability to move from abstract visions of what should be to specific, actionable solutions. The attitudinal aspect reflects the designer's constructive and optimistic approach to constraints, treating them as challenges that inspire creativity. The	Martin (2008)

	interpersonal aspect highlights empathy and the ability to engage and collaborate effectively across disciplines and perspectives, an essential trait for navigating today's complex problems.	
Flexible, adaptive approach, grounded in human experience.	Design thinking is fundamentally rooted in observation, collaboration, learning, and analysis, all directed toward understanding and responding to human needs.	Lockwood (2010)

Taken together, these perspectives highlight the multidimensional nature of design thinking, encompassing cognitive, systemic, human-centered, and interdisciplinary dimensions. Its evolving and adaptive character makes it particularly suitable for addressing the complex and layered challenges of contemporary society. By integrating diverse forms of knowledge, embracing uncertainty, and balancing creativity with analytical rigor, design thinking emerges as a flexible framework for innovation and problem-solving in dynamic and unpredictable contexts.

4.3 Design Thinking as a Response to Wicked Problems: From Territorial Innovation to Disaster Risk Reduction

4.3.1 Design for territories

The Design for Territories (D4T) approach originates within the field of design, not as a development of design thinking but as a theoretical and methodological reflection on how design can engage with complex spatial and social systems. As defined by Parente and Sedini (2017), D4T expands the disciplinary boundaries of design by considering the territory itself, understood as a dynamic network of material, social, and symbolic relations, as an object of design intervention. In this sense, D4T seeks to connect the "soft" dimension of design (strategies, services, communication, and experiences that address human behavior and collective identity) with the "hard" dimension of urbanism (infrastructure, urban policy, and planning processes).

While D4T maintains a dialogue with urbanism, it does so from the perspective of design, reinterpreting the means and tools of intervention in urban and territorial contexts. Rather than focusing on morphological or regulatory aspects, D4T emphasizes design's capacity to act as a relational and integrative practice, one that fosters innovation, sustainability, and community engagement across scales. This orientation positions D4T as a framework for understanding how design can contribute to territorial transformation by activating local resources, promoting collaboration among stakeholders, and generating shared visions for the future.

From this perspective, D4T differs conceptually from both 'urban' design thinking and design thinking. The former, discussed by Caliskan (2012) and grounded in the work of Rittel and Webber (1973), belongs to the field of urban design cognition and examines how urban designers reason abductively through iterative cycles of conjecture, modeling, and evaluation. The latter, as theorized by Brown (2008), describes a human-centered and iterative process that combines analytical and creative reasoning to generate innovation. These are distinct genealogies: one rooted in urban design methodology, the other in contemporary design practice.

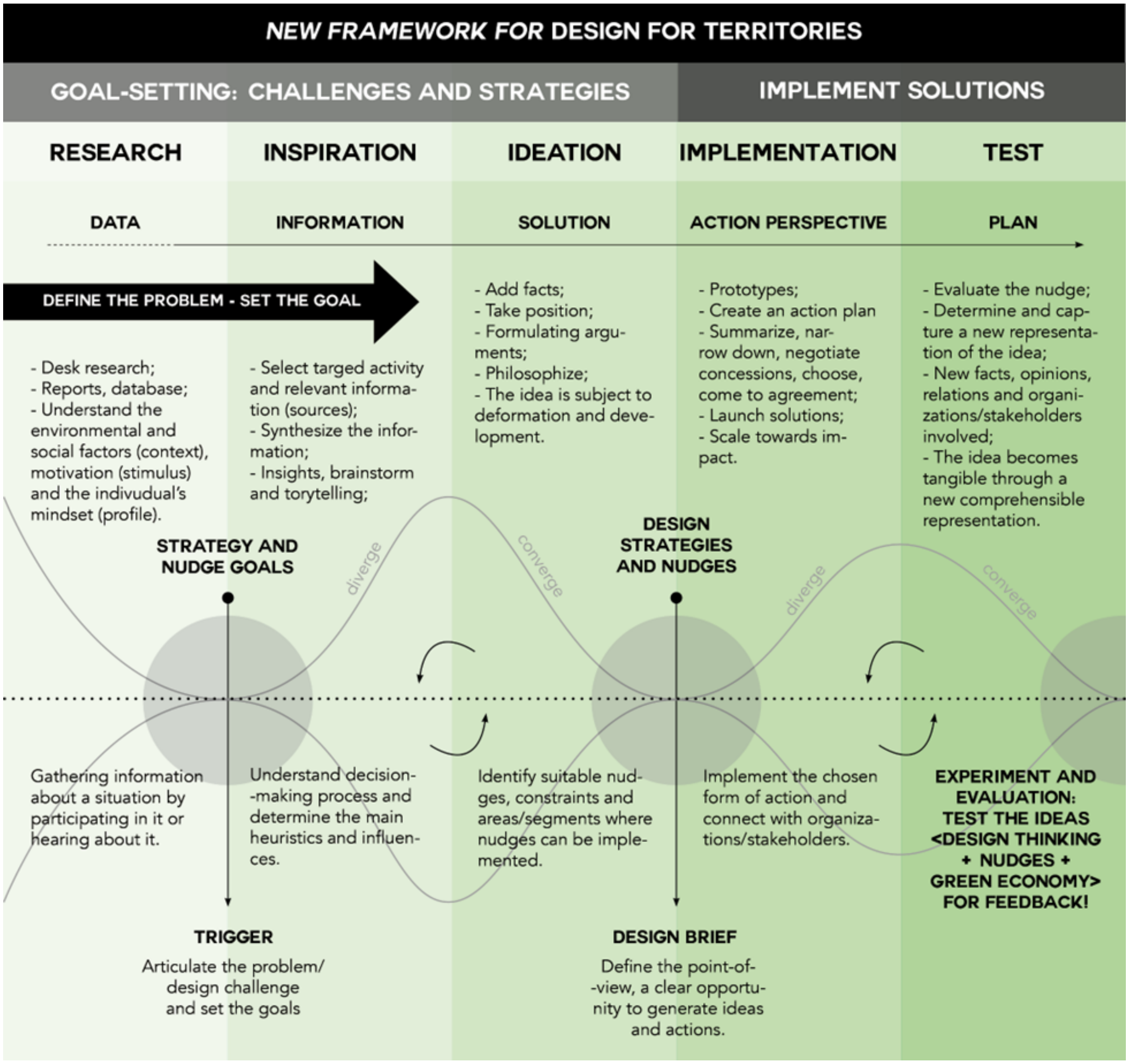

Figure 2. New Framework for Design for Territories. Retrieved from Ferreira Crispim (2023)

This theoretical framework draws on Ferreira Crispim (2023), who expanded the reflection by integrating complementary perspectives into a unified conceptual model, called the New Framework for D4T, which later served as the foundation for the IDEAL method. Through this synthesis, the adaptive and participatory principles of design thinking are reinterpreted within the territorial dimension, enabling design to act as a catalyst for systemic change and community resilience.

4.3.2 Design for disaster management

Despite a growing body of research on urban planning (Caliskan, 2012) and the application of design thinking to risk and climate-change adaptation (e.g., Elliot-Ortega, 2010; Fisher, 2013; Shaw, Rahman, Surjan, & Parvin, 2016; American Society of Landscape Architects, 2020), the integration of design thinking into disaster risk reduction (DRR) and the broader disaster management cycle remains relatively underexplored (Charlesworth & Fien, 2022).

Only in recent years designers begun to engage more directly with the disaster risk management cycle, examining the potential contributions of design thinking to its various phases (e.g., Charlesworth & Fien, 2022; Vigneaux, 2024; Van Manen et al., 2023; Pedgley & Şener, 2024). This is further corroborated by the calls for research proposed by the World Design Organization's "Design in Disaster" initiative (World Design Organization, n.d.).

These developments highlight how design thinking can offer both an innovative framework for understanding the complex interplay between hazard characteristics, exposure, vulnerability, and community capacity (Kelman, 2020), and a conceptual bridge toward building socio-economic and physical resilience in disaster-affected communities (Charlesworth & Fien, 2022).

The integration of disaster risk reduction (DRR) and design thinking presents a promising approach to tackling the complex challenges inherent in disaster management. As Kelman (2020) points out, disasters are not purely natural events; rather, they result from human decisions and actions, in other words, they are designed. This perspective implies that if disasters can be designed, they can also be "un-designed" (Van Manen et al., 2023).

Design plays a meaningful role throughout all phases of the Disaster Risk Management (DRM) cycle. Nelson and Stolterman (2014) observe that emergency managers are constantly engaged in design activities, often without realizing it, as they develop plans, policies, and interventions. For example, during the mitigation phase, design can help create strategies, policies, and tools aimed at reducing hazard threats. These interventions reshape how risks are perceived, communicated, and addressed, embedding hazard awareness into everyday life (Spinosa et al., 1997).

Design thinking offers a hands-on, iterative, and solution-oriented approach that bridges the persistent gap between knowledge and action. According to Vigneaux (2024), the five traditional phases of design, empathize, define, ideate, prototype, and test (Hasso Plattner Institute of Design at Stanford, 2010), align closely with the needs of each stage of the DRM cycle. The strength of this approach lies in its progression from theoretical insight (empathy, problem definition, idea generation) to practical application (prototyping and testing), resulting in more effective and adaptive interventions.

At its core, design thinking refers to Human-Centered Design (HCD), which prioritizes empathy, inclusion, and active participation. Rather than imposing top-down solutions, it fosters co-creation with communities, inviting them to shape the policies, tools, and actions that directly impact their safety and resilience (Van Manen et al., 2023). The designer's role is thus to deeply understand people's realities, not only their needs and challenges but also their values, motivations, and aspirations. This inclusive approach is essential to counter dominant, often technocratic models that exclude community voices from DRR processes (Van Manen et al., 2023).

Moreover, design thinking is inherently interdisciplinary. It encourages the formation of multi-, inter-, and transdisciplinary teams that bring together diverse knowledge forms to define shared problems and pursue collective goals (Pedgley & Şener, 2024). It also enables cross-appropriation, where practices from one field are creatively adapted to address challenges in another, fostering mutual learning and innovation across sectors (Spinosa et al., 1997).

Finally, design thinking promotes a systemic understanding of problems, a critical perspective in DRR where disasters emerge from the complex interplay of social, environmental, political, and economic factors. By emphasizing systemic relationships, design thinking helps frame problems more effectively and generate holistic solutions (Charlesworth & Fien, 2022; Vigneaux, 2024).

In conclusion, design thinking is more than a methodology; it is a philosophy of action. It provides the tools, mindsets, and frameworks necessary to address key gaps in disaster risk management by bridging knowledge and implementation, fostering community participation, encouraging interdisciplinary collaboration, and enabling systemic resilience.

5. Research Design: The Participatory IDEAL Framework for Co-Designing Nudges

This section will present the proposed participatory methodological framework, detailing its phases and explicit **design thinking foundations**.

5.1 Existing Nudge Design Frameworks: DECIDE, BASIC and ABCD

There are several methodological frameworks for developing nudge and behavioral insights interventions. Standard didactic tools used in nudges, behavioral insights, and urbanism include the following options:

- **Case Studies and Empirical Examples**: These illustrate how behavioral interventions have been successfully applied in real-world hazard scenarios, such as flood preparedness, wildfire evacuation, or earthquake drills.
- **Interactive Simulations and Role-Playing**: These tools simulate emergency situations, helping stakeholders understand how behavioral nudges influence decision-making under stress and uncertainty.
- **Guided Learning Materials**: Resources such as *The Little Book of Green Nudges* and *Tools and Ethics for Applied Behavioural Insights: BASIC Toolkit* provide foundational knowledge and practical guidance for applying behavioral science in DRR.
- **Workshops and Training Sessions**: These offer hands-on experience in designing and testing behavioral interventions tailored to specific hazard contexts.
- **Collaborative Design and Planning Exercises**: Interdisciplinary charrettes and co-design sessions foster collective problem-solving and the integration of behavioral insights into emergency planning and community resilience strategies.

To better trace the origin of the development of the IDEAL method it is necessary to present three methodologies widely used for the elaboration of nudging that constitue the basis for the IDEAL method, DECIDE (Wendell, 2021), BASIC (The Organization for Economic Co-operation and Development - OECD, 2019) and ABCD (OECD, 2019).

The effectiveness of these tools depends on the use of appropriate methodologies that account for the complex interplay of environmental, social, and psychological factors influencing behavior in disaster contexts.

5.1.1 DECIDE

In his book, Wendel (2021) introduces the DECIDE method, a six-step design process for developing behavior change interventions. DECIDE stands for:

- **D**efine the Problem

- **E**xplore the Context
- **C**raft the Intervention
- **I**mplement the Solution
- **D**etermine the Impact
- **E**valuate Next Steps

The method accounts for both the decision-making processes of the target audience and the context in which behaviors occur, offering a comprehensive, design-oriented approach. As described by Wendel (2021), the DECIDE method is a six-step design process that helps designers develop interventions aimed at effective behavior change. The method considers both the decision-making processes of the target audience and the context in which behaviors occur, providing a comprehensive and design-oriented framework for behavioral intervention.

Aimed at designers, researchers, and practitioners, it combines an overview of behavior change theory with practical tools for creating products and interventions that encourage positive action. The approach emphasizes context-sensitivity, ethical integrity, and empirical grounding.

5.1.2 BASIC

Another relevant approach is the BASIC framework (OECD, 2019), which provides a broader policy development process for integrating behavioral insights. BASIC stands for:

- **B**ehavior
- **A**nalysis
- **S**trategy
- **I**ntervention
- **C**hange

Unlike DECIDE (Wendel, 2021), which concentrates on the design and evaluation of nudges within products and interventions, BASIC examines behavior across the full cycle of policy design, implementation, and evaluation. In this sense, it aligns with nudge theory (Thaler & Sunstein, 2008), as both emphasize influencing behavior to achieve policy objectives.

5.1.3 ABCD

The OECD's behavioral toolkit (2019) introduces the ABCD model which groups behavioral drivers into four domains:

- **A**ttention
- **B**elief Formation
- **C**hoice
- **D**etermination

It helps identify behavioral bottlenecks and design targeted interventions for risk communication and emergency response.

While the "ABCD of Behavioral Insights in Public Policy" offers a concise overview of how behavioral science can inform policy, including disaster risk reduction (DRR), the "BASIC Toolkit: Tools and Ethics for Applied Behavioural Insights" provides a more detailed, practice-oriented guide. Together with the DECIDE method, these approaches, when integrated with design thinking, enable practitioners in disaster risk management to build a robust, transdisciplinary framework for effective behavioral interventions. This integrated approach enables the development of context-specific, ethically grounded, and empirically validated strategies that enhance public safety, foster community resilience, and support more effective governance in the face of natural hazards.

5.2 Introducing the IDEAL method for Disaster Risk Reduction

5.2.1 Methodological foundation

After a long process of diagnosis, including literature review, analysis, and case studies, followed by development and testing throughout the doctoral studies of Ferreira Crispim (2023), with the supervision of Luca Cetara, the final outcome was the experimental method known as IDEAL:

- **I**dentify
- **D**efine
- **E**laborate
- **A**ct
- **L**aunch

The progressive research process began with the construction of a New Framework for Design for Territories, discussed above (figure2), and evolved through experimental testing in workshop-based formats. The initial framework, conceived as a theoretical and methodological model for integrating design thinking and behavioral insights, was later applied in participatory sessions, allowing the identification of practical dynamics and challenges that informed the final structure of the IDEAL framework (Ferreira Crispim, 2023).

The resulting framework is explicitly transdisciplinary, positioning community experts, rather than external "nudge designers", at the center of intervention design, supported by a tested facilitation process. In its theoretical structure, the IDEAL Method offers a systematic approach to designing behavioral interventions that are context-sensitive and participatory. Conceived originally for complex urban challenges, it proves highly adaptable to natural hazard management, combining design thinking and behavioral economics to address complex, context-specific problems through a user-centered and collaborative perspective.

The IDEAL Method promotes a holistic and inclusive approach to behavioral design. It encourages co-production among researchers, practitioners, policymakers, and affected communities, enhancing the legitimacy and sustainability of interventions. A key feature of the method is its emphasis on the phases of divergence and convergence: divergence expands the solution space by exploring diverse ideas and perspectives, while convergence narrows it by selecting and refining the most viable and impactful interventions. This dual process ensures that solutions are both innovative and strategically aligned with the behavioral goals of the intervention.

By focusing on the behavior of individuals and communities in hazard-prone environments, the IDEAL Method supports the creation of interventions that are not only technically sound but also socially and culturally appropriate.

This study builds upon the original reasoning of a participatory methodological framework, conceived within the context of design thinking, nudge theory, and sustainable urban and territorial planning, adapting the methodology to address behavioral challenges related to natural hazards. This adaptation primarily integrates:

- Design thinking's empathic, abductive, iterative process (Brown, 2008; Martin, 2006)
- Behavioural economics' focus on choice architecture (Thaler & Sunstein, 2008)
- Participatory co-design principles (Van Manen et al., 2023)

The resulting framework is explicitly transdisciplinary, placing community experts instead of external "nudge designers" at the center of intervention design, supported by a tested scheme and facilitation process.

5.2.2 Phases of the IDEAL Method

The IDEAL method consists of five interrelated phases that address specific contextual dimensions and correspond to distinct processes of behavioral change. Building on its original formulation, the present research applies the method to a new domain, natural hazard and disaster risk reduction (DRR), while preserving its core structure and principles (figure 3).

The application of the IDEAL phases is flexible and may vary depending on the available time, the purpose of the activity, and the participants' background. When implemented as a short-term workshop, such as a charrette or pilot session, the method can serve as a beta version to generate preliminary insights, ideas, and collaborative hypotheses that can later be refined and expanded in subsequent design or research phases. As suggested by Ferreira Crispim (2023), in these shorter formats an introductory phase, "Start & Inform", can be incorporated before the first phase of the method (Identify) to provide participants with essential knowledge and contextual grounding. During this preparatory stage, facilitators present the theoretical foundations, behavioral concepts, and case studies relevant to the activity, ensuring that all participants share a common understanding before moving into the core phases of the IDEAL method.

This flexible implementation preserves the methodological coherence of the IDEAL framework while making it more accessible and responsive to different temporal, disciplinary, and social contexts. Ultimately, the method's adaptability allows it to function both as a structured research tool and as an exploratory platform for co-creation and innovation in complex territorial and behavioral scenarios. Following this introductory phase, the IDEAL Method unfolds through five main stages:

Identify, Define, Elaborate, Act, and Launch, adapted here for its application to natural hazard and disaster risk reduction contexts.

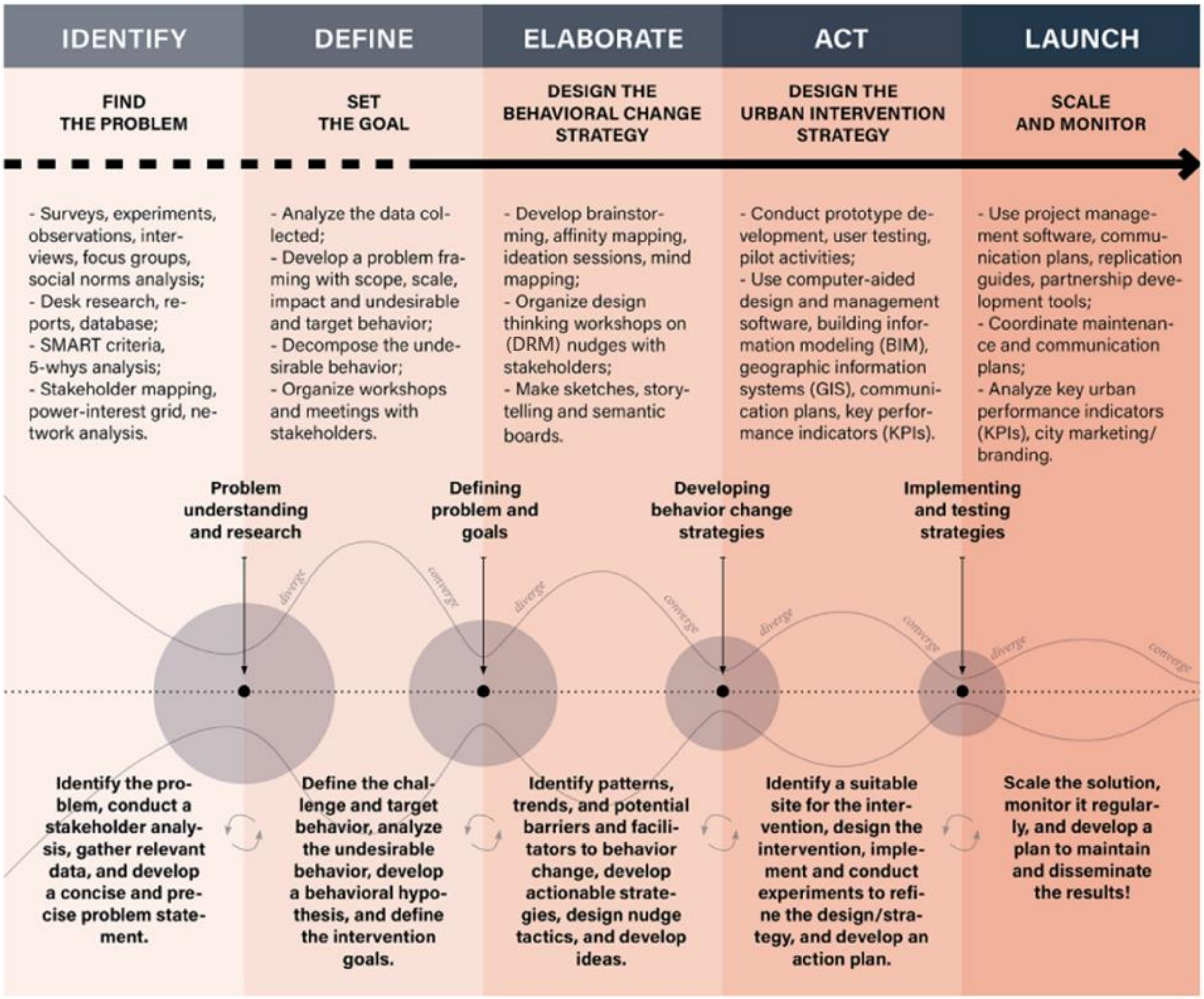

Figure 3 Description of the phases of the IDEAL Method. Adapted from Ferreira Crispim (2023)

Phase 1. Identify: Focus on a comprehensive exploration of the challenge or opportunity at hand. During this stage, participants conduct systematic research and contextual analysis to uncover underlying causes, map the actors involved, and understand the broader conditions shaping the issue. Integrate design thinking's empathy phase by encouraging participants to immerse themselves in the users' experiences and deeply understand the natural hazard challenge and its causes. The key outcome is to select a specific, relevant hazard-related challenge within a designated territory.

Phase 2. Define: Guide participants in delineating the target behavior associated with the chosen challenge (e.g., unsafe practices increasing fire risk). This involves applying design thinking's problem-framing by mapping the current choice architecture and profiling the target population while integrating local territorial, social, and cultural dynamics. This phase ensures a clear problem definition and measurable intervention goals.

Phase 3. Elaborate: This critical phase leverages design thinking's ideation and prototyping strengths. Experts analyze underlying cognitive biases and heuristics influencing the target behavior, then generate tailored nudge solutions through brainstorming and creative exercises (e.g., the "worst possible idea" technique). The phase concludes with the selection of appropriate nudge typologies (e.g., physical environment interventions, social norms, emotional appeals) best suited to the context.

Phase 4. Act: Translate previously elaborated ideas into concrete, implementable nudge interventions. This involves defining modalities, timelines and resources requirements (e.g., personnel, materials, services and costs estimate). Iterative prototyping and testing are emphasized to refine solutions, even low-fidelity ones, to refine the design and anticipate future scenarios. This phase involves visual communication and graphical representation of ideas.

Phase 5. Launch: Establish a plan for monitoring and evaluating the designed nudges, defining metrics for effectiveness and assessing impact on broader sustainability outcomes (e.g., relevant SDGs). This phase highlights the iterative nature of refinement based on real-world feedback, allowing for continuous design improvement and adaptation of interventions.

6. Methodology application & Results

6.1 Data Collection & Observed Outcomes

The framework, developed specifically for DRR and tested in three participatory workshops (Valli del Verbano (Rancio Valcuvia)-Bosco Clima, Bari-UNIBA, Milano-POLIMI) between 2023–2024. Each followed a standardized 2-day protocol that can be summarized as follows:

- Heterogeneous group formation (professionals, students, locals)
- Phased application of IDEAL stages
- Co-creation of nudge prototypes + future scenarios
- Group feedback + visualization

While not a controlled experiment, this applied research design enabled real-world testing of the framework's usability, adaptability, and output quality, considered key criteria for DRR tool evaluation (Charlesworth & Fien, 2022). The workshops demonstrated that the IDEAL method can be used to structure co-design processes and generate feasible nudge prototypes in diverse contexts. Recurring use of salience and default nudges suggests that these mechanisms may be especially relevant in natural hazard risk mitigation

On average, participants generated 4 nudge prototypes per workshop. Table 3 provides an illustrative example of nudges generated, and it summarizes the interventions by context, target group, behavioral mechanism, and applied nudge. Full intervention templates and one example are provided in Appendix A

Table 3 Illustrative example of nudges generated in the workshops

Hazard	Site	Target behaviour	Nudge Type	Behavioural Mechanism
Wildfire	Valli del Verbano	Underestimation of personal risk	Experiential simulation + discount incentive	Anchoring + Optimism Bias
Heatwave	Milano (POLIMI)	Low water intake outdoors	Physical environment (fountain redesign) + social norms	Salience + Norm Activation
Drought	Bari (UNIBA)	Domestic water waste	Default settings + feedback	Status Quo Bias + Monitoring Effect

The method's application produced proposals for behavioral interventions based on mechanisms and typologies (defaults, salience, social norms) suitable to deliver consistent and effective benefits as recalled in recent meta-analyses and reviews (Amiri et al., 2024; Mertens et al., 2021).

By adopting design thinking's abductive and exploratory approach (Brown, 2008; Martin, 2006; Lindberg et al., 2010), it also allowed to produce tailored and creative nudges for natural hazard risk mitigation by responding to the recent calls for more innovative, context-specific behavioral interventions in disaster management (Charlesworth & Fien, 2022; Vigneaux, 2024).

The method's participatory structure addresses the "wicked problem" nature of disaster risk (Rittel & Webber, 1973; Buchanan, 1992) by embedding thematic expertise, local knowledge and stakeholder perspectives, meeting the literature demand for context-sensitive, community-engaged approaches (Wisner et al., 2012; Gaillard & Mercer, 2013). This helps to achieve accuracy in problem framing, overcoming limitations of standardized nudges, and the failure of top-down, standardized interventions aimed at disaster risk reduction.

Co-design and participatory processes rooted in the distinctive design thinking's emphasis on empathy, inclusion, and stakeholder engagement (Brown, 2008; Van Manen et al., 2023) make interventions culturally coherent and socially acceptable, enhancing chances of successful implementation especially in disaster preparedness and lasting behavioral change (Ohtake, 2021; Murakami & Tsubokura, 2017).

Beyond outputs, key process observations emerged:

- **Divergence-Convergence Works:** 'Worst possible idea' exercises (Phase 3) reliably unlocked non-obvious solutions.
- **Territorial Anchoring is Crucial:** Groups struggled until they mapped behaviours onto specific local sites (e.g., 'this square', 'that forest trail').
- **Bias Literacy Enables Design:** Teaching 4 core biases (present, status quo, decoy, von Restorff) empowered non-experts to 'diagnose' behavioural barriers.
- **Ethics Emerged Organically:** Groups self-policed manipulative ideas — e.g., rejecting fear-based messaging for elderly."

A full summary report for each workshop is available in the appendix. In particular, we also provide a list of all the IDEAL phases and each of their components for running a future workshop.

6.2 Theoretical Contribution: Operationalizing Design Thinking for Behavioral DRR

This research demonstrates how design thinking can bridge a persistent theoretical-practical gap in disaster risk reduction, solving the challenge of translating behavioral science into context-sensitive, community-owned interventions. It does so by applying and field- testing the IDEAL framework, rooted in design thinking and behavioral insights, to the domain of disaster risk reduction.

The contribution provided by the paper is mainly theoretical, rooted in the interconnected aspects we examined from a transdisciplinary perspective, and it principally refers to the application suitability of the method we have constructed and tested. We briefly recall the main advancements this paper recognizes concerning the potential benefits of combining theoretical approaches in a single procedure.

First, it operationalizes the ‘wicked problem’ framing (Rittel & Webber, 1973) through a teachable, phase-based protocol. Rather than treating complexity as an obstacle, the IDEAL method turns it into a design parameter, guiding participants to iteratively map local hazard-behavior linkages (e.g., “Why do residents delay evacuation?” or “What makes garden waste burning feel ‘normal’?”) and reframe them as designable choice architectures.

Second, it validates abductive reasoning (Martin, 2006) as a generative engine for behavioral intervention. In workshop settings, participants moved fluidly from observed behaviors (e.g., low water intake during heatwaves) to plausible interventions (e.g., redesigning public fountains for visibility + enjoyment), not through deduction or induction, but through creative leaps grounded in local insight. Outputs like “smoke sausage” devices or incentive-based wildfire simulations exemplify this abductive logic in action.

Third, and most significantly, it demonstrates that ‘choice architecture’ (Thaler & Sunstein, 2008), often perceived as a top-down, expert-driven tool, can be co-designed with non-experts when scaffolded by participatory design methods. Participants with no prior training in behavioral economics successfully diagnosed cognitive biases (e.g., status quo, optimism bias) and mapped them to corresponding nudge types (defaults, framing, salience) proving that behavioral design is not the exclusive domain of policymakers or academics.

Together, these findings reframe design thinking not as a metaphor, but as a concrete methodology for democratizing behavioral DRR, turning community experts into co-designers of their own resilience.

7. Discussion

7.1 Practical Implications: A Field-Tested Protocol for Participatory Nudge Design

For practitioners, the IDEAL framework represents more than a theoretical model. It is an evolving, practice-oriented methodology that is progressively moving toward becoming a field-tested protocol for co-designing behavioral interventions in complex hazard contexts.

Three practical assets emerged from workshop implementation:

1. **A replicable, phase-based workflow:** From “Identify” to “Launch”, the method provided clear guardrails for heterogeneous groups (students, volunteers, professionals) to collaboratively move from abstract risk challenges (e.g., “drought-induced water waste”) to concrete, locally grounded interventions (e.g., default water-saving showerheads in public housing).
2. **A bias-to-nudge translation toolkit:** Simple, visual aids enabled non-experts to diagnose behavioral barriers (e.g., “present bias makes people ignore distant risks”) and select matching nudges (e.g., “immediate feedback via smart meters”). This demystified behavioral science, and turned it into a shared design language.
3. **Built-in ethical co-validation:** Ethical concerns (e.g., stigma, manipulation) were not imposed by facilitators but surfaced organically during group feedback sessions. For instance, fear-based messaging for elderly populations was self-rejected by participants in favor of supportive, dignity-preserving alternatives, demonstrating that participatory design acts as a natural ethical filter.

Critically, all 12 nudge prototypes generated required minimal financial investment, relying instead on behavioral insight, creative repurposing of existing infrastructure, and local knowledge. This outcome reinforces that effective DRR innovation does not depend on high-tech or high-cost solutions.

The IDEAL framework thus proves to be a scalable, low-barrier methodology for human-centered DRR — equally applicable in municipal offices, university labs, or community centers. Supported by visual templates and bias cheat sheets (see appendix), the framework offers a clear roadmap for different stakeholder categories, including municipal officers seeking to co-design DRR preparedness campaigns with local volunteers, university labs training the behavioral DRR designers, civil protection agencies prototyping response nudges with vulnerable communities, and NGOs integrating behavioral insights into regional adaptation programs.

Its strength lies in scalability through simplicity: no specialized software or behavioral economists are required during the nudge-elaboration phase. Instead, the method relies on trained facilitators, diverse participants, and a commitment to human-centered, iterative design.

7.2 Observed Limitations: Boundary Conditions for Application

While empirically validated, this study surfaced four key limitations that define the current boundary conditions of the IDEAL framework:

1. **Short-term observation window:** behavioral outcomes were qualitatively assessed only during workshop prototyping. The longitudinal impact on real-world behavior (e.g., sustained water conservation, actual evacuation compliance) remains unmeasured.
2. **Volunteer participant bias:** workshops primarily attracted motivated, self-selected participants (e.g., students, civil protection volunteers, etc.) potentially overestimating engagement levels and underrepresenting resistant, marginalized, or disengaged groups critical for equitable DRR.
3. **Geographic and cultural specificity:** all workshops occurred in Italy, thus their effectiveness in low-resource, culturally different, or highly institutionalized contexts (e.g., Global South megacities, conflict zones) remains untested.
4. **Facilitator skill dependency:** the output quality varied according to the facilitators' ability to guide abductive reasoning, manage group dynamics, and translate behavioral theory into actionable steps. Although some facilitators participated across the whole set of workshops, introducing a standardized facilitator training module could help ensure a more balanced coordination and results[1].

These limitations do not undermine the framework's validity but, instead, define its current scope of reliable application. The remarks reported above offer clear parameters for responsible deployment and targeted future adaptation of the method.

7.3 Key Contribution: A Structured Protocol for a participatory approach to Behavioral DRR

This research confirms that design thinking offers novel approaches and insights to many different disciplines where it has only occasionally been tested. Particularly, in this case it is qualified as a promising epistemological basis for framing behavioral DRR policies.

By applying the IDEAL method to the DRR domain, this study illustrates how the framework can be effectively applied to a new disciplinary context without altering its core structure or principles. Rather than testing or modifying the method itself, the research explores how the IDEAL framework, grounded in design thinking and nudge theory, can contribute to operationalizing behavioral and

[1] All the facilitators were involved both in the development and test phases of the IDEAL method in its original connotation as well as its adapted version.

participatory approaches within DRR. The method provides a structured, participatory, and replicable phase-based protocol suitable for:

- **Demystifying behavioral science** for non-experts through “bias-to-nudge" mapping and choice architecture visualization.
- **Embedding territorial specificity** by anchoring interventions in real local sites, knowledge, practices, and stakeholder dynamics.
- **Institutionalizing ethical co-validation**, allowing groups to self-correct manipulative or culturally insensitive proposals.
- **Prioritizing low-cost**, high-insight prototyping, proving that impactful behavioral change does not require high-tech or high-budget solutions.

In doing so, it directly addresses three persistent gaps in DRR: the theory-practice divide, the top-down implementation bias, and the neglect of cognitive and cultural context in behavioral interventions.

8.Conclusion

As climate change accelerates the frequency, scale, intensity, and unpredictability of natural hazards, technical and infrastructural solutions alone are insufficient. Human behavior has proven to be a significant determinant of societal and community resilience. This research demonstrates that integrating design thinking with behavioral science enables community experts to co-design context-sensitive nudges for natural hazard risk mitigation.

The IDEAL method, empirically applied and field-tested across three multi-stakeholder workshops in Italy, represents a significant methodological advancement at the intersection of design thinking, behavioral science, and disaster risk reduction (DRR). Building on the boundary conditions identified in Section 7.2, such as the absence of longitudinal data, volunteer bias, geographic specificity, and facilitator dependency, future research should focus on responsible scaling rather than in-depth re-validation. Potential avenues include:

- Co-designed Nudge Impact Evaluation: embedding quasi-experimental designs in real communities to measure sustained behavioral outcomes, moving from nudge prototyping to proof;
- Cross-Cultural Adaptation: piloting the framework in low-resource, non-European, or conflict-affected contexts to test transferability and identify necessary cultural or institutional adaptations;
- Facilitator Certification: developing standardized training modules to reduce output variability and ensure methodological fidelity;
- Ethical Codification: formalizing the “organic ethics” observed in workshops into a DRR Nudge Ethics Checklist to guide interventions in high-stakes, high-vulnerability settings;
- Institutionalization Pathways: exploring how the “design attitude” (abductive, iterative, participatory) for non-structural interventions can be cultivated within traditional DRR organizations, from civil protection agencies to municipal planning departments.

The IDEAL method thus provides a structured yet flexible protocol for participatory behavioral design in DRR. Its empirical application across the Italian workshops, confirms its capacity to generate context-sensitive, ethically grounded, and community-owned interventions. By combining scientifically informed design principles with participatory processes, the framework offers policymakers and practitioners a scalable strategy to foster societal resilience through active participation of local experts and collective learning.

9. Appendix

9.1 Methodology application: Workshops

The IDEAL method has been tested in three workshops to explore its application to the creation of nudges for disaster risk reduction. The workshops were conducted at the University of Bari, Politecnico di Milano, and in the Valli del Verbano area as part of the Bosco Clima project, funded by Fondazione Cariplo. Below a brief

Workshop	**Bosco Clima Workshop (Valli del Verbano)**
Location & date	Rancio Valcuvia (Varese), 11–12 October 2024
Description	The workshop “Nudging for Wildfire Risk” took place over two days with the goal of presenting nudging techniques aimed at encouraging behavioral change in wildfire risk management. Activities were designed to promote collaboration among experts from various fields and to apply theoretical concepts to practical challenges. Participants developed concrete and innovative solutions to address wildfire-related issues, based on the knowledge and experience of local stakeholders, particularly volunteers from the forest fire service (AIB – Antincendio Boschivo).
Participants and background	about 30 (AIB volunteers, civil protection operators, local stakeholders, researchers)

Workshop	**UNIBA**
Location & date	University of Bari, 22-23 April 2024
Description	The workshop “Designing Nudges for Risk Mitigation” was held with the aim of exploring behavioral strategies to reduce risks associated with extreme weather events and climate change impacts. The sessions focused on applying nudging techniques to encourage preventive actions against hazards such as floods, heatwaves, and water scarcity. Participants engaged in collaborative activities combining theoretical frameworks on risk analysis, covering exposure, vulnerability, and adaptive capacity, with practical challenges relevant to urban environments and local communities. The workshop emphasized the role of climate scenarios, risk drivers, and civil protection plans, guiding participants to design innovative, actionable solutions that leverage behavioral change to strengthen resilience and minimize future impacts.

Participants and background	about 15 (researchers, local stakeholders, university students)

Workshop	POLIMI
Location & date	Politecnico di Milano, 11-12 September 2023
Description	The workshop focused on addressing behavioral strategies to reduce climate-related risks, particularly those linked to extreme weather events. The sessions explored practical challenges such as minimizing damage to transportation systems during floods or hailstorms, reducing exposure to heatwaves, and promoting household-level protective measures against severe weather. Another key theme was water scarcity, with discussions on encouraging responsible water use during drought periods. Participants worked collaboratively to design nudging techniques aimed at fostering preventive behaviors, integrating risk analysis concept, such as vulnerability, exposure, and adaptive capacity, with real-world applications. The workshop emphasized innovative, actionable solutions to strengthen resilience and support sustainable development goals, especially in urban contexts vulnerable to climate impacts.
Participants and background	about 20 (master's students, PhD candidates, researchers, and professionals in: architecture, philosophy, economics, engineering, agriculture, psychology, design)

9.1.1 Workshop´s structure

All workshops were conducted over two days, following a structured format. Each phase of the workshop was designed to gradually build a deeper understanding of the nudging approach and to enable participants to work collaboratively in identifying practical, feasible solutions tailored to their local contexts and areas of expertise.

Each workshop adhered to rigorous ethical and procedural standards. Participants were registered in advance and received comprehensive information regarding the objectives, methodologies, and expected outcomes of the activities. Formal authorization was obtained where required, and informed consent was systematically collected from all participants prior to their engagement. The process complied with institutional and legal frameworks governing research ethics and data protection, including GDPR provisions. All data were handled confidentially and exclusively for research purposes.

Data collection followed an exploratory, qualitative approach. Insights were primarily derived from annotations and notes taken during group discussions, which focused on themes such as usability and the perceived quality of proposed prototypes. The aim was to capture emergent ideas and reflections rather than to produce standardized metrics. Consequently, no structured instruments were administered. Instead, observations and informal annotations served as the main source of evidence, consistent with the iterative and participatory nature of the workshops.

Building on these methodological foundations, the workshops were organized into distinct phases, each designed to progressively guide participants from conceptual understanding to practical application. The workshops were structured as follows:

WORKSHOP PHASES	SHORT DESCRIPTION
Launch	Introduction to the workshop: objectives and expected outcomes.
Inform	Overview of behavioral economics, cognitive science, heuristic, bias and main type of nudges.
Group formation	Creation of heterogenous working groups.
Challenge definition	Identification of a behavioral challenge to address by each group.
Target Behavior identification	Definition of target behavior to be changed.
Choice architecture analysis	Study of the architecture of choice behind the target behavior.
Solutions ideation	Elaboration of possible solution, through the use of design thinking techniques such as “the worst possible idea”.
Presentation of nudging best practices	Presentation of real-world nudging interventions, to inspire and refine proposed solutions.
Nudging strategy design	Initial delineation of proposed nudging intervention.
First round of group feedback session	Presentation of the proposals of intervention and sharing of constructive feedback and suggestions.
Final design and visualization	Final definition of interventions and visual representation using diagrams and conceptual maps.
Future scenarios analysis	Creation of both positive and negative scenarios to explore long-term impact, risks, and opportunities.
Final group discussion and evaluation	Final collective discussion, with presentation of proposal of interventions and feedback exchange for further improvement.
Conclusion	Wrap-up by facilitators and coordinators, highlighting key takeaways and next steps.

9.1.2 IDEAL applied to the Workshops

The phases of the IDEAL method (Ferreira Crispim, 2023) were applied and contextually adapted to the workshop setting, which served both as a simulation and as an exercise to assess the feasibility of employing the method for designing nudging interventions in disaster risk reduction.

Phase 1: Identify

The workshop begins with a general presentation of its objectives and structure. To make all participants feel comfortable, some time is dedicated to personal introductions using techniques often employed in design thinking, such as sharing a personal trait, habit, or hobby, or more structured methods like “Two Truths and a Lie.”

To provide participants with the foundational knowledge needed to develop nudging proposals, the facilitators briefly introduce key concepts from behavioral economics and cognitive science, such as heuristics and biases, and then present the concept of nudges and their typologies. The main biases presented include the most common ones:

1. present bias
2. status quo bias
3. decoy effect
4. von Restorff effect.

A limited number of nudges is then presented, along with examples related to the field of hazards and natural risks. The nudges introduced align with consolidated theory, and include:

1. Provision of information
2. Default options
3. Interventions on the physical environment
4. Use of social norms

Following the introductions, participants are divided into relatively heterogenous groups based on their expertise, ensuring a balance of backgrounds and a manageable group size.

Phase 2: Define

In this phase, each group is invited to identify a challenge that is relevant to the local territory and to the interests of its members. The challenge must relate to a specific hazard and its associated natural risks affecting the territory. Furthermore, it must be linked to a behavior, either active or passive, that people adopt or avoid, which contributes to the emergence or worsening of the problem. For example, in the case of Valli del Verbano (Bosco Clima) an inadequate way of dealing with biomass produced by gardens that increases the risk of fires has emerged from the discussion held in the workshop.

After defining the challenge, the group must identify the target behavior they aim to modify through a nudging intervention. This behavioral modification can involve the intensification and diffusion of a socially desirable behavior that mitigates risk, or the reduction and elimination of a socially undesirable behavior that increases risk.

To better analyze and understand the behavior, participants are encouraged to use “choice architecture” to identify the decision-making route that leads a person to enact the behavior and reach either the desired or undesired outcome.

Some practical examples are given to explain how to use the method of choice architecture.

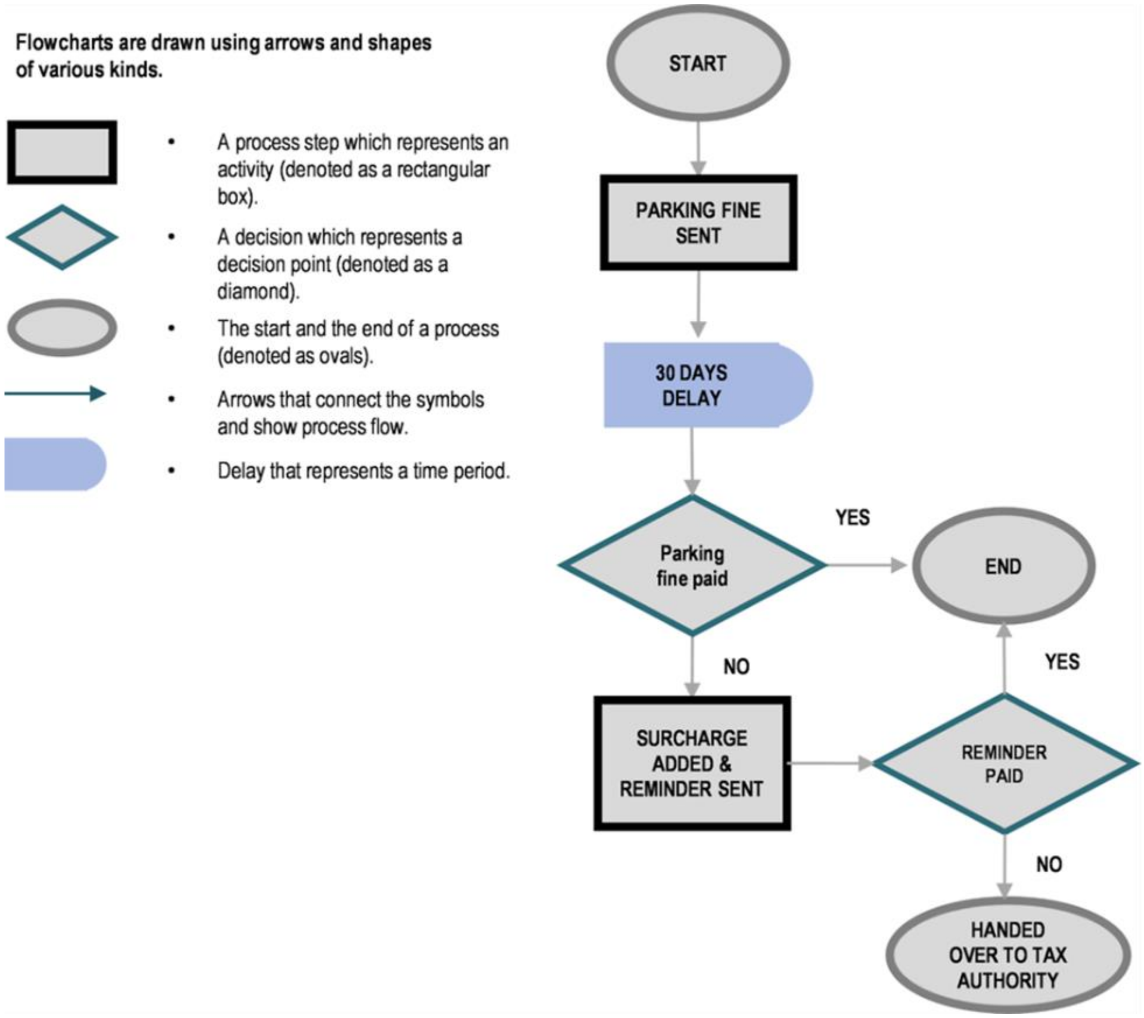

Figure 4 Symbols and an example of a representation of a choice architecture related to a target behavior (from OECD-BASIC).

Participants are asked to represent in detail the decision-making process (including its components and sequential phases) they intend to modify through the nudging intervention. They analyze each phase by constructing a similar scheme to the one presented in Figure 2. In this way, they can identify a possible entry point for the next phase.

Phase 3: Elaborate

In this phase, participants are asked to select a behavioral instrument to intervene and correct the cognitive mistakes that lead, individually or collectively, to either a desirable or undesirable result. To do so, participants are encouraged to interpret the behavior using the heuristics and biases presented at the beginning of the workshop and to consider using one of the nudging typologies presented during the workshop to generate a socially desirable choice.

The main focus of this phase is to identify the prevailing heuristic that determines the target behavior, the bias that manifests and that can be used to modify that behavior, and the type of nudge to propose.

Phase 4: Act

This phase corresponds to the design of the intervention and the elaboration of possible future scenarios to help evaluate outcomes in different contexts.

Once the type of nudge to be applied in the context has been identified, the groups are asked to design the intervention for the specific case and context under analysis.

The design includes the identification of:

1. A detailed description of the intervention
2. The duration of the intervention (e.g., a few days or permanent)
3. The geographical area and specific location of the intervention, identifying where it can be applied (e.g., private homes with gardens, schools, etc.)
4. Public or private stakeholders involved in implementing the intervention (e.g., public institutions, private organizations, citizen groups, NGOs, volunteer associations)
5. The target of the intervention, indicating the primary beneficiaries by using precise categories such as professions, age groups, interests, or competencies (e.g., students, owners of forest areas)
6. Estimated costs and necessary resources, providing an approximate estimate for the realization, implementation, and monitoring of the nudging intervention. If it is not possible to define a precise figure, it is important to indicate at least an order of magnitude (low, medium, high, very high)

The second step is to develop possible future scenarios intended to anticipate how the situation might evolve and to design actions that positively influence the outcome of the intervention.

The future scenarios can be:

- **Independent from the proposed intervention**: scenarios that may occur regardless of the intervention, helping to understand the context more deeply and evaluate risks and opportunities from external influences. For example, an increase in dry days due to climate change could intensify fire risks regardless of the strategies adopted.
- **Dependent on the implemented intervention**: scenarios that assess the impact the designed intervention may have in the future, focusing on how it could actually modify behaviors and reduce risks. For example, introducing visual signs or incentives for keeping wooded areas clean.

Integrating both independent and dependent future scenarios in the planning of nudging interventions helps improve contextual understanding and optimize the actions to be taken. One might start with an independent scenario and then introduce the elements of a dependent one to assess the effectiveness or efficiency of the nudging intervention in light of the broader evolution of the context. Through alternative scenarios, it becomes possible to estimate, at least qualitatively, the relative effectiveness of different interventions either as a whole or in part, based on specific design features.

Phase 5: Launch

The final phase focuses on evaluating the nudging intervention. To evaluate the effectiveness of a nudge, it is necessary to have comparative data and a simple experimental design. Generally, the goal is to create a test that allows for verification of the intervention's effectiveness in terms of its ability to achieve the targeted behavioral change.

In this phase, it is possible to design a test following the steps below:

1. Definition of the objective: clearly identify the behavior to be changed
2. Division of the sample: split the target population into two similar groups based on relevant characteristics for the experiment, a control group (which does not receive the nudge) and an experimental group (which does receive the nudge)
3. Implementation of the nudge: apply the intervention only to the experimental group
4. Measurement of impact: collect data on actual behavior in both groups, typically using simple quantitative indicators (e.g., percentage of adherence, frequency of desired actions)
5. Comparison of results: calculate the impact difference between the two groups. In general, a significant increase in the experimental group compared to the control group suggests the nudge is effective

In cases of limited time, it is possible to estimate the reasons why the intervention might fail and improve the design or conduct a more accurate feasibility analysis.

It is also useful to briefly discuss possible indicators that could be used to evaluate the effectiveness of the nudge and to encourage group discussion among workshop participants.

9.1.3 Workshop results

As an example of the results obtained during the workshops, we provide a summary of the results obtained in the workshop in Valli del Verbano. In particular, for each natural hazards challenge identified we provide a description of the objective, proposed intervention, target group, and more relevant for this study, the behavioral mechanisms, the cognitive biases addressed and most importantly the nudges applied.

Valli del Verbano- Bosco Clima interventions proposed:

Removing False Certainties: Stimulating Common Sense About Wildfire Risk	
Objective	The challenge is to raise citizens' awareness about the risks related to forest fires. The main goal is to eliminate the false sense of certainty that often leads to underestimating the danger.
Intervention	The group proposed organizing experiential events that simulate wildfire situations. The main objective is to give participants firsthand experience of the danger of a real fire. This approach helps to break the illusion of safety and builds understanding of the urgency and dynamics

	of an immediate reaction. Participants realize that the cost of an early intervention is very low, but it increases significantly if the emergency is not addressed in its early stages.
Target group	Frequent forest users: hikers, campers, and regular visitors to green areas.
Behavioral mechanism	To encourage participation, the group suggested offering a 10% discount in outdoor gear and footwear shops to those who attend the event. Additionally, participants would receive free T-shirts and be asked to share a personal reflection at the end of the experience, fostering deeper engagement.
Cognitive biases addressed	1. **Anchoring Bias**: Experiential learning helps participants let go of the "safe forest" mental anchor, revealing the actual risk and promoting a mindset geared toward immediate action. 2. **Optimism Bias**: People tend to overestimate their ability to manage emergencies. The simulated experience provides a more realistic understanding of the actual risks and limitations.
Nudges applied	1. **Framing:** Communication is designed to highlight the low cost of early intervention versus the high cost of delayed action, emphasizing immediate benefits and long-term dangers. 2. **Incentives:** The 10% discount makes the event more attractive and encourages the adoption of safer behaviors.

Safe and Sustainable Behaviors: Reducing the Risk of Open Burning on Farmlands	
Objective	The group focused on the problem of *abbruciamenti* (open burning), a common agricultural technique which, if not properly managed, can become a major cause of forest fires. The goal is to promote composting as a safer and more ecological practice, in order to reduce wildfire risks and improve the management of agricultural waste.
Intervention	The group proposed a communication and information campaign aimed at raising awareness among farmers and landowners about the need to reduce open burning and to adopt composting as a sustainable alternative. Composting not only improves soil quality but also reduces CO_2 emissions. The campaign would involve agricultural cooperatives and suppliers to incentivize composting as a valuable source of fertilizer. Social media and testimonials from local producers who already practice composting would be used to amplify the message.
Target group	Farmers, landowners, agricultural businesses, and all companies involved in gardening and agricultural production.

Behavioral mechanism	The intervention seeks to raise awareness about the risks of open burning through an informational campaign, while also encouraging the adoption of composting through the distribution of free composting kits. By involving the community, the campaign aims to foster a collective behavioral shift.
Cognitive biases addressed	1. **Status quo bias**: People tend to stick with traditional practices, even when safer alternatives exist. The intervention aims to break this bias by presenting composting as a safer and more modern alternative. 2. **Availability bias**: By making composting more visible and accessible through kits and testimonies, it becomes easier to recall and adopt.
Nudges applied	1. **Salience**: The composting alternative is made highly visible and easy to implement, increasing its perceived relevance. 2. **Incentive**: A free composting kit acts as a reward to encourage behavioral change. The immediate gratification increases the likelihood that people will try the new practice.

Responding with Awareness: Appropriate Public Behavior in Case of Wildfire	
Objective	The group focused on the challenge of promoting correct behavior during a wildfire to reduce risks for citizens and facilitate rescue operations.
Intervention	The group proposed a combination of mini-interventions. The main idea involves the distribution of the so called "salsicciotti antifumo", [2]smoke protection devices designed to help people protect themselves from smoke inhalation during evacuation. These would be distributed to households at risk, accompanied by clear instructions on their use. To support this, the group also proposed a communication campaign featuring strong, clear, and emotionally impactful messages. The campaign is designed to be easily understood even in high-stress situations, encouraging immediate and appropriate responses from citizens.
Target group	The main target is the general population exposed to wildfire risk. The intermediate targets include:

[2] The term "salsicciotti antifumo" is a technical expression commonly used by professionals such as firefighters and civil protection teams to refer to cylindrical smoke-filtering devices intended for emergency evacuation.

	• Local media, responsible for spreading accurate information on appropriate behavior during a fire. • Rescue teams, who must be aware of the campaign and its tools to ensure alignment in emergency protocols.
Behavioral mechanism	The intervention focuses on delivering clear, actionable information about appropriate behaviors during wildfires. • Messages are crafted to be understood under stress, using simple, bold language. • The provision of a practical tool (the smoke protection device) helps anchor behavioral guidance in concrete action.
Cognitive biases addressed	**Confirmation Bias**: People tend to seek out information that confirms their pre-existing beliefs. In panic situations, this bias may prevent them from accepting new, safer instructions. The physical presence of the smoke device acts as a tangible reminder that following official guidance (e.g., rescuers' instructions) is the safest and most rational choice.
Nudges applied	1. **Priming**: The distribution of the smoke protection device acts as a visual and tactile prime, promoting a faster, more automatic response and reducing panic-driven behavior. 2. **Framing:** The campaign uses ironic and dramatic framing to convey the urgency of the situation while making the message memorable and emotionally resonant. 3. **Social Norms:** The campaign highlights the collective nature of safe behavior (e.g., widespread use of the devices), encouraging people to conform to responsible community practices.

9.2 Typology of Nudges

The table below summarizes key types of nudges and their definitions. It provides an overview of how different approaches are designed to influence behavior while preserving freedom of choice. This classification helps clarify the mechanisms behind each concept and their role in shaping decision-making across various contexts.

Table 4 Nudges concepts and definition

AUTHORS	CONCEPT	DEFINITION
Nagatsu (2015)	Social nudge	Nudges promoting individual well-being while considering social welfare, aligning with libertarian paternalism and encouraging socially responsible choices.

Hagman et al. (2015)	Pro-self nudge	Nudges aimed at correcting individual irrationalities to improve personal welfare.
Hagman et al. (2015)	Pro-social nudge	Nudges designed to enhance social welfare, even when it may conflict with individual utility.
Weinmann, Schneider & Brocke (2016)	Digital nudge	Use of user interface design elements in digital choice environments to steer decisions.
Sunstein (2016)	Educational nudge	Nudges that foster reflective thinking, increase agency, and improve knowledge through tools like reminders and information framing.
Sunstein (2016)	Non-educational nudge	Nudges that operate through automatic cognitive processes without necessarily improving awareness or control.
Schubert (2017)	Green nudge	Nudges aimed at encouraging voluntary contributions to environmental sustainability and public goods dilemmas.
Schubert (2017)	Paternalistic nudge	Nudges primarily targeting individual well-being.
Schubert (2017)	Non-paternalistic nudge	Nudges promoting broader social welfare beyond individual interests.
Johnson et al. (2012)	Default nudge	Nudges that set a pre-selected option as the default, exploiting status-quo bias to influence decisions without restricting freedom of choice.
Keller et al. (2011)	Salience nudge	Nudges that increase the perceptual prominence of certain options at the decision point, directing attention without adding new information.
Schultz et al. (2007)	Social norm nudge	Nudges that leverage descriptive or injunctive norms to influence behavior by signaling what others do or approve of.

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