Product Design of Water Safety Warning Products in the Context of Resilient Cities

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Abstract. As the frequency of extreme weather disasters impacting water safety continues to rise, it becomes increasingly important to study methods for safeguarding water resources and establishing a comprehensive water safety pre-warning system within the framework of resilient cities. This paper delves into the design of water safety warning products (WSWP). We propose the design of a water safety warning device that can be employed throughout the disaster management process, offering key functionalities such as pre-warning, first aid, public education, and power outage management. This design aims to contribute to the construction of a more robust safety warning system.

Key words. resilient city, water safety, pre-warning system,

1 Introduction

This paper focuses on the design of the safety warning products of urban water safety warning system and its application in changing climate and urban environment, and puts forward the design and application of the water safety warning products with pre-warning, first aid, science popularization and power outage as the main improvement direction.

2 Urban water resilience needs to be improved to cope with extreme weather

2.1 Extreme weather

In the context of global climate change and rapid urbanization, the characteristics of the urban water cycle have changed markedly, resulting in a significant increase in the frequency of extreme weather events such as extreme rainfall, thunderstorms and floods in urban areas. In a short period of time, it triggers heavy rainfall and exceeds the capacity of natural water bodies and drainage systems to handle it, triggering an outbreak of internal waterlogging.

The rapid urbanization process makes the "heat-island effect" and "rain-island effect" more obvious, in the form of warmer temperatures and more concentrated rainfall in urban areas. These elements interact to increase the frequency of urban storm events and amplify flooding[1]. It caused serious damage and adversely affected the sustainable economic and social development of cities[2], such as severe floods in Beijing on July 21, 2012, Xi'an on July

ADDT 2023, September 15-17, Xian, People's Republic of China

DOI 10.4108/eai.15-9-2023.2340899

24, 2016, Guangzhou on May 25, 2020, Zhengzhou City in Henan province on July 20, 2021, Suizhou City in Hubei province on August 11, 2021[3]. These trends highlight the seriousness of the problem of urban waterlogging and the need for richer responses to address this challenge.

2.2 Severe urban waterlogging

In response to urban storm disasters, expert Liu Jiahong [4]has proposed three critical stages for urban response: "no standing water," "no waterlogging," and "maintaining vigilance." The "no loss" phase represents the maximum amount of rainfall that urban drainage systems and emergency facilities can effectively manage. This phase serves as the last line of defense for cities grappling with floods. An investigation into the "7-20" extreme rainstorm in Zhengzhou, Henan province, highlights the significance of this phase. During this incident, the water level in the north tunnel of the Jingguang Expressway increased from approximately 30cm to 60cm in just 12 minutes, leading to the shutdown of the emergency services drainage pumping station in a mere six minutes. Tragically, six lives were lost due to this minor lapse alone.

While the state of the urban drainage system plays a crucial supporting role in urban waterlogging, multiple factors contribute to this issue, including urban surface hardening and low-lying terrain. As urban surfaces become more impermeable due to hardening, rainwater finds it increasingly challenging to infiltrate. Consequently, when rainwater runoff intensifies, impervious surfaces hinder water seepage[5], causing peak water levels to occur earlier. Low-lying areas within cities are particularly susceptible to waterlogging, and the interplay of these factors compounds the vulnerability of cities to waterlogging during extreme rainfall events.

The aforementioned highlights the ongoing challenge faced by cities when dealing with ceilings and limitations, even with functional drainage systems and emergency facilities in place. Consequently, it is imperative for cities to comprehensively upgrade their disaster warning systems [6]and response strategies to address the deficiencies in the existing system.

3 Application Environmental Analysis of Water Safety Warning Products

A comprehensive understanding of the application environment is critical when designing a water safety warning devices. This analysis involves evaluating various scenarios and identifying factors closely associated with security warnings, such as power source, lighting, security markers, visibility, communication functions, and rescue potential (Table 1).

Table 1. Application environmental analysis of water safety warning products

Scenario	Power source	Lighting source	Security markers	Visibility	Communicatio n function	Rescue potential
The road	Power distributi on network	Streetlight	Orientation	Open and unobstructed environment	Yes	No

Waterside	Power distribution network	well lit	Safety, orientation	Open and unobstructed environment	No	Yes
Tunnel entrance	Power distribution network	well lit	Safety, orientation	easily obscured and difficult to judge	No	No
Emergency shelters	Power distribution network	emergency lighting	Safety, orientation	environment is open and unobstructed	Yes, site communication	Yes
Subway	Power distribution network	emergency lighting	Safety, orientation	easily obscured	Yes, site communication	Yes

Based on the key factors identified, we have selected city streetlights as the foundational nodes for our design. Streetlights offer several advantages, including power supply, illumination, safety guidance, and board visibility, allowing us to leverage the existing urban infrastructure effectively.

1.Power and lighting reliability: Streetlights are equipped with distribution boxes, ensuring a consistent and reliable source of electricity for lighting.

2.Safety signage: Streetlights incorporate signposts to provide essential safety information and help with orientation, enhancing the safety aspect of the design.

3.Visibility and accessibility: Streetlights are strategically positioned at a moderate height, ensuring unobstructed visibility and making them easily noticeable.

4.Smart infrastructure: The prevalence of smart streetlight has enabled the comprehensive enhancement of streetlight functionalities. They can collect data, including safety precautions and traffic flow, thanks to their accurate positioning and grid layout.

Given these advantages, streetlights serve as ideal comprehensive nodes for housing water safety warning products in prominent locations. By utilizing their complete power and lighting capabilities, we can significantly enhance the pre-warning effectiveness of these products. The grid distribution pattern of streetlights also aligns with the overall coverage requirements of the security warning system, establishing a broad coverage and high-precision security warning system.

4 Implementation of WSWP Design

Innovations in WSWPs should be grounded in the utilization of existing urban infrastructure, focusing on pre-warning, first aid, power outage management, and public education. The proposed design aims to establish a more comprehensive safety warning system that operates before, during, and after disasters, enhancing the overall protection.

4.1 Functional Properties of WSWP

4.1.1 pre-warning function

The proposed WSWP are pivotal for ensuring safe evacuations. They continuously monitor rapid changes in meteorological disasters and employ sound and light alarms to quickly grab public attention. These alarms convey crucial disaster information and evacuation instructions, including message timing, disaster onset and conclusion predictions, and real-time updates. This provides the public with a response time frame. These products also indicate the warning severity, enabling a rapid threat assessment. Clear guidance on necessary actions helps residents in affected areas prepare while defining the disaster's extent.

4.1.2 First aid function

In once-in-twenty-years heavy rainfall scenarios, it's crucial to safeguard both adults and children, as highlighted by Song Ying-hua's research[7]. Adults face up to 65 minutes of vulnerability, while children are at risk for 72 minutes, typically occurring 45 to 110 minutes after rainfall onset . Moving during these vulnerable periods increases the risk of falls and water-related accidents significantly. Thus, adapting self-rescue behaviors to each stage is essential. When instability is likely, stabilizing and awaiting assistance is the wisest choice. This underscores the need for security products with features like leverage, warning signals, and location tracking.

4.1.3 Science Education Function

Popular scientific education on disaster prevention and mitigation is notably lacking among the general population. Only a tiny fraction, between 1% to 3%[8], has received self-rescue and medical first aid training. More than half of crisis-related negative outcomes result from a lack of awareness about waterlogging risks and safety concerns[9]. Security warning products should be effective not just during disasters but also in everyday life. Strengthening residents' self-assurance and their understanding of waterlogging disaster responses during non-emergencies is vital. This proactive approach better equips individuals to handle disasters when they occur.

4.1.4 Power outage features

During urban waterlogging, water threatens power lines and equipment, elevating the risk of electrocution and short-circuits. A magnetic induction nut detects water levels and physically cuts off power to prevent accidents and electrical leaks.

To ensure reliable performance in pre-warning, first aid, education, and power outage functions, WSWPs adhere to national standards, employ core technologies, and standardize usage processes. This approach guarantees stable protection for residents in diverse conditions.

4.2 Design and Material Standards

For its design, the product takes the form of a "life preserver" with an eye-catching orange color and reflective strips, boosting visual recognition and enhancing its overall effectiveness. The inclusion of foam fastening bands with "nodes" within the packaging layer ensures a secure grip and ease of handling during use. National Standard Reference are detailed in **Fig. 2**. Material choices are detailed in **Table 2**.

Table 2. Materials for WSWP

Name of components	Materials	Characteristics
Stuffing	Ethylene acetate copolymer	Good water resistance, corrosion resistance, buoyancy,
Parcel layer	Polyester Oxford	Thick and wearable
Fixed-tape	Ethylene acetate copolymer	Thick and wearable
Warning slips	Reflective fabrics	High reflectivity and visibility

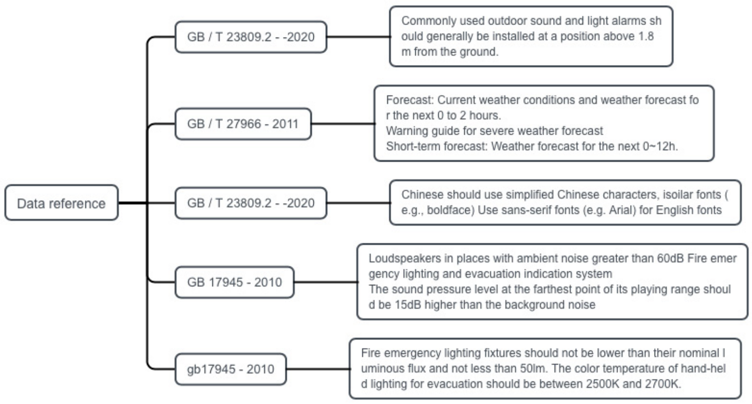


Fig. 1. National Standard Reference for WSWP design

4.3 Core Technologies

The technical module orchestrates a seamless disaster management service encompassing pre, during, and post-disaster phases through collaborative integration. This collective effort results in the development of a comprehensive water safety pre-warning system.

4.3.1 Water level prediction technology

Leveraging cameras for road image capture and employing image processing algorithms, water level detection models, trained using open-source machine learning frameworks like TensorFlow or PyTorch, accurately gauge water depth.

4.3.2 Alarm trigger

Utilizing C code, an alarm system, comprising both sound and light components, is activated when water levels surpass predetermined thresholds. GPIO controllers facilitate connections to sound-and-light alarms.

4.3.3 Power outage function technology

A preset water level threshold in a C-language program is used to control relays or switches via general purpose input/output (GPIO). When the water level exceeds this defined value, the power is cut.

4.3.4 Promotion and educational technology

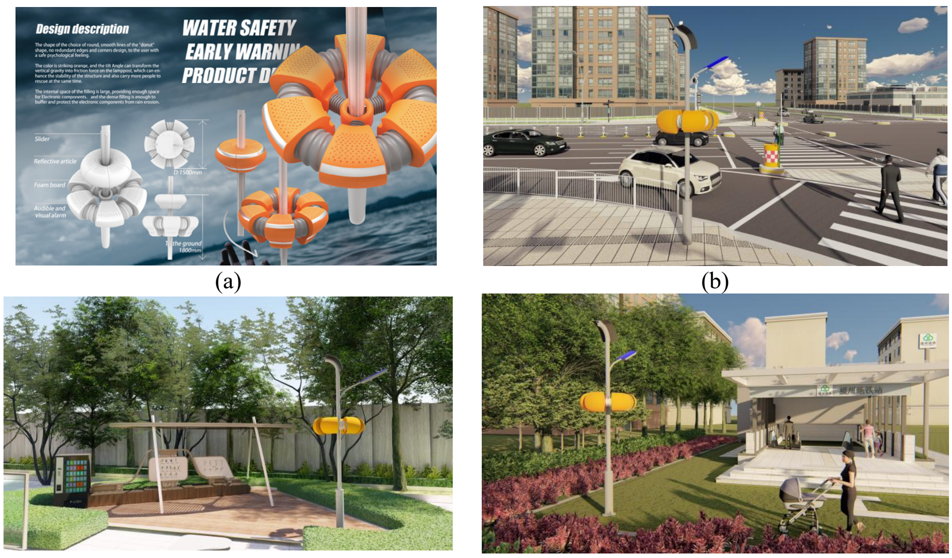
Incorporating 5V LED flexible displays or promotional columns, Python, and open-source graphic libraries, this technology conveys disaster prevention and mitigation knowledge using text, images, and animations. Additionally, open-source application programming interfaces (APIs) enable knowledge sharing and content promotion via QR code scanning.

4.4 Use process

To ensure timely and effective warnings and safety during floods and similar emergencies, we established a structured process: When water levels rise to the threshold, alarms activate, and power is cut off. Pre-warnings prompt evacuation, provide disaster information, and safety instructions. When currents indicate instability risk, the device deploys lifebuoys, warning the public and guiding them to life support equipment. It ensures steady protection and sends location-based distress signals, providing time for emergency services to respond.

4.5 Real-life simulation

Real-life simulations offer crucial reference data for testing and optimization, enhancing our comprehension of the performance of WSWP across diverse scenarios. This comprehensive understanding allows us to identify potential issues and provides robust support for subsequent optimization and marketing efforts, as illustrated in **Fig. 2**.



(a) (b) (c) (d)

Fig. 2. Illustration of WSWP demo (a) and its application in varied scenarios (b, c and d).

4.6 Market expectations

The marketization of our products will progress through distinct phases: Initially, we will conduct small-scale promotional and experiential trials. Feedback from users will be collected through online questionnaires and offline feedback sessions within pilot communities. As our products gain traction, we will promote them through multi-platform interactions, including public interest lectures and water safety literacy campaigns. The product's recognition, exemplified by winning the second prize in the 2023 Young Creators Competition's Beijing division and participation in the 2023 China Manufacturing Design Conference, will further bolster our marketing efforts. In the final stage, we will shift our focus towards product updates and maintenance, ensuring long-term sustainability within urban communities.

5 Conclusions

The evolving climate demands fresh approaches to safety warning products. These products, crucial in our safety systems, should extend their impact from disaster response to daily life. This means enhancing dimensions like pre-warnings, first aid, power management, and public education. We must also embed disaster preparedness and response into community culture and urban life to achieve a synergistic effect greater than the sum of its parts.

These considerations drive ongoing product updates and set new directions for the WSWP market, aiming to build a future city that's water-secure, sustainable, and resilient.

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