

Risk Reduction in Emergency Evacuation Through Innovative Mobile Applications: A Study on User Trust and Behavior

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Abstract. The article explores emergency management strategies in densely populated urban areas, with a particular focus on the use of existing warning technologies to facilitate the safe evacuation of the population. It examines the warning systems currently in place in various countries, including the USA, Canada, Japan, Mexico, Australia and Italy, highlighting their features and limitations. The article then presents an innovative research project called RISK, funded by the Italian government, which aims to develop a platform integrating Artificial Intelligence with the Internet of Things to provide detailed information and personalized evacuation routes during emergencies.

To demonstrate the validity and effectiveness of these technologies, an experiment was conducted in the industrial area of Rende, adjacent to the University of Calabria. The results show that over 90% of respondents would follow the instructions received on their smartphones if properly informed.

This study underscores the importance of training and trust in technology during emergencies to enhance public safety and reduce the risks associated with catastrophic events.

Keywords: Emergency Management · Warning Systems · Risk Reduction

1 Introduction

Since the Industrial Revolution, people's social lives have developed around large urban centers. In 2024, the world's population reached 8 billion, and according to the United Nations (UN), it is expected to reach 10 billion by 2050. The most populous cities range between 15 and 30 million inhabitants, while some urban areas reach up to 38 million. Given such significant numbers, in recent years, authorities have dedicated considerable effort to organizing effective plans for managing populations during emergencies. This has become especially crucial as adverse weather events and disasters have increased due to climate change, making it essential to manage the orderly evacuation of people seeking safe locations. Naturally, ensuring the safety of millions of people is a particularly challenging task. This has led to the need for a reliable way to communicate emergency-related information to the population, whether about an imminent threat or an

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ongoing crisis. The most immediate and effective means of delivering such information is undoubtedly smartphones, a tool that virtually everyone now possesses.

In 2023, the Italian government launched a research project called RISK (Recovery Increasing by Social Knowledge) to study safe evacuation methodologies aimed at reducing the risks associated with panic during emergencies. The research project seeks to integrate the use of IoT and AI to design a platform capable of providing detailed information about ongoing or anticipated emergencies and suggesting safe evacuation routes to users. The goal is to manage crowd flows effectively, preventing bottlenecks or situations where people attempt to take roads that are blocked due to the emergency. This procedure, known as "risk reduction," aims to minimize people's exposure to the danger at hand.

This article is structured as follows: Section 2 analyses the risk exposure reduction strategies, with a focus on the main alert systems adopted at international level and on the technologies currently employed. It also describes the innovative contribution proposed by the RISK project, based on the integration between Artificial Intelligence and Internet of Things for the generation of personalized evacuation routes. Section 3 is dedicated to the experimentation conducted in the industrial area of Rende, illustrating the operational context, the adopted methodology and the results obtained through a survey conducted on workers. Finally, Section 4 presents the conclusions, discussing the main results and outlining possible future developments in the research.

2 Exposure Reduction

When an emergency occurs, it generates a risk. According to Russo, Chillà, and Comì, risk is determined by the product of three components: occurrence, vulnerability, and exposure. Occurrence refers to the probability or frequency of an emergency happening. Vulnerability is the likelihood that a system can withstand the effects of the event. Exposure represents the number of people affected by the event [1, 2]. When trying to mitigate the damage caused by an emergency, it is impossible to intervene in occurrence. However, efforts can be made to reduce vulnerability by strengthening infrastructure so that it can withstand the effects of floods, earthquakes, or other sudden events as much as possible. Addressing exposure, however, is more complex. For years, efforts have been made to develop strategies to reach as many people as possible, including through drills and training exercises.

2.1 Existing Warning Technology

While a system based on training people for evacuation is well-tested in enclosed environments and has proven to be highly effective, it is not always possible to apply it in every situation. When an exceptional event occurs, leading to an emergency situation, even though scientific research is making significant progress in predicting such events [3], especially thanks to the ability to collect vast amount of data from IoT systems distributed through our cities [4], However, it is not guaranteed that all involved individuals have been trained in evacuation procedures, nor that it is possible to follow the evacuation plan outlined in the training. For this reason, it was necessary to find a methodology

that would allow communication of emergency information and a safe evacuation route to tourists or occasional visitors, thereby excluding any roads affected by the ongoing danger.

Currently, various technologies and applications exist worldwide that are capable of communicating the necessary information to the population. A certainly useful system is to communicate emergencies through television or radio messages. However, in almost all countries, these systems are supplemented by sending information directly to users' smartphones. In the last decade, smartphones have become a tool available to the majority of the population: about 60% of the world's population owns a smartphone, and those who do not, such as the elderly or children, are often assisted by those who do [5]. Therefore, practically every country has its own Governmental Population Warning System that operates by sending notifications to citizens' smartphones. However, not all warning systems work in the same way, nor have they reached the same level of completeness in the information provided.

In the United States, the Emergency Alert System (EAS) is in use, which is overseen by governmental entities such as the Federal Emergency Management Agency (FEMA), the Federal Communications Commission, and the National Oceanic and Atmospheric Administration, and it constitutes a fundamental pillar for emergency management. This system allows for the interruption of regular television and radio programming to broadcast urgent messages, which can include presidential communications in the case of national emergencies or local alerts regarding weather warnings, accidents, or specific situations. Additionally, the system supports multiple languages and formats, such as on-screen text, audio attachments, and messages for specific geographic areas.

To complement the EAS, in 2012, the Wireless Emergency Alerts (WEA) were introduced, allowing authorities to send notifications directly to mobile devices. This system uses geolocation to ensure that only people in areas affected by emergencies, such as storms, fires, or earthquakes, receive the alerts. Among the tools available in the United States, the American Red Cross's Emergency app stands out, offering a complete range of services: from personalized alerts for over 40 types of emergencies to the ability to monitor the safety of loved ones, to detailed guides for preparing and responding to natural disasters.

In Canada, the Alert Ready system is used. It is similar to the American WEA, as it allows for sending alert messages to citizens' smartphones for a variety of situations, including natural disasters, nuclear or radiological emergencies, chemical crises, and AMBER alerts, specifically designed for searching for missing children. This system uses Cell Broadcast technology to reach all mobile devices in the affected areas, without the need for user registration. The messages, available in English and French, are accompanied by specific auditory signals and are designed to be accessible to people with disabilities, thanks to options such as voice messages or vibrating notifications.

Other systems of significant importance have been developed in Japan, a country particularly prone to natural hazards such as earthquakes and tsunamis, which has developed a series of technologically advanced applications designed to promptly alert the population. Among these, Yurekuru Call is one of the best-known: connected to the country's early seismic detection system, it sends timely notifications that can arrive up to two minutes before an earthquake. The app also provides seismic intensity maps,

alerts for tsunamis, and educational content on disaster prevention. Another fundamental application is NERV Disaster Prevention, which integrates a wide range of information, from earthquakes to weather hazards, to volcanic eruption warnings. Thanks to interactive maps and critical notifications that sound even in silent mode, NERV represents an essential tool for those living in Japan. Other applications in use in Japan are Bousai Sokuhou, developed by Yahoo! Japan, and Tokyo Bosai, promoted by the Tokyo Metropolitan Government, and they are able to offer valuable resources. The former focuses on personalized notifications for earthquakes and floods, while the latter stands out for its educational approach, with risk maps, preparation checklists, and evacuation guides. In Mexico, where the seismic risk is high, the SkyAlert app is used, which is considered one of the most advanced warning systems. With a network of over 120 seismic sensors distributed in the most at-risk areas, SkyAlert detects earthquakes in real time and sends personalized notifications, indicating the expected intensity and the time of arrival of the tremors. The app is internationally recognized for its speed and reliability, supported by technologies such as AWS to ensure the simultaneous transmission of millions of notifications. SkyAlert also includes features for detecting microseisms in Mexico City, offering a unique service of its kind.

In Australia, the EWN (Early Warning Network) system is in use, which is responsible for alerting the population in the event of extreme weather events, such as cyclones, wildfires, hailstorms, and floods. The app provides detailed alerts based on the geographic location of users, allowing them to customize notifications according to the types of events and their severity. Additionally, EWN offers interactive maps, social media information sharing, and an emergency function to send one's location to trusted contacts in case of danger. This system has proven particularly useful in a country like Australia, where extreme weather events are frequent and represent a significant threat to the population. In Italy, the IT-Alert system, developed by the Civil Protection, is a recent but promising initiative to improve emergency management. Using Cell Broadcast technology, IT-Alert sends text messages to all mobile devices located in a specific geographic area, without the need for an Internet connection or specific apps. This system is designed to alert the population in the event of tsunamis, volcanic activity, industrial or meteorological incidents, ensuring that people involved can take self-protection measures. Currently in the experimental phase, IT-Alert represents a significant step forward towards greater safety in Italy.

Globally, systems such as the Global Public Health Intelligence Network (GPHIN) and ProMED focus on the prevention and management of health emergencies. GPHIN, developed by the Canadian government in collaboration with the WHO, collects information from international media sources to identify disease outbreaks and alert relevant authorities. ProMED, on the other hand, uses a digital network to monitor infections and toxins, sending real-time updates to tens of thousands of subscribers worldwide. These systems are crucial for preventing epidemics and responding quickly to health crises on an international scale. Below is a table of the main features of each warning system (Table 1).

In conclusion, population warning systems, thanks to their innovative technologies and the ability to reach millions of people in an instant, represent an indispensable tool for public safety. Each country, based on its own needs and vulnerabilities, has already

Table 1. Summary table of Warning Systems.

Country	United States			Canada	Japan		Mexico	Australia	Italy
Systems' Names	EAS	WEA	Emergency App	Alert Ready	Yurekuru Call	Tokyo Bosai	Sky Alert	EWN	IT-Alert
Customization of alerts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Geolocation function	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Multilingual Support	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Sharing Function	No	No	Yes	No	Yes	No	Yes	Yes	No
Interactive Map	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Customized Routes	No	No	No	No	No	Yes	No	No	No
Contact with law Enforcement	No	No	No	No	No	No	No	No	No
Real-time Information	No	No	Yes	No	Yes	Yes	Yes	Yes	No

developed specific solutions, and all share the same goal: to protect human lives by informing and preparing the population in the event of emergencies. Their continuous technological evolution and refinement are essential to address future challenges, ensuring greater resilience in the face of global risks.

2.2 Technology Proposed

The project on which the authors are working involves the design of a highly innovative emergency application. The application will not only be able to alert users of the ongoing emergency but also to locate itself and provide them with personalized routes based on the users' location and the roads closed due to the emergency. This latter aspect has not yet been proposed by any of the existing systems.

The technology indeed leverages the ability of Artificial Intelligence to collaborate with the Internet of Things to obtain information about what is happening on the roads. This is achieved not only by gathering information from cameras or other devices present in our cities but also by retrieving satellite images, which will then be processed by artificial intelligence to identify clear routes and distinguish them from those made impassable by emergencies [6–8]. After collecting the necessary data, the artificial intelligence will be able to process information on the fastest and safest evacuation routes, using machine learning techniques [9, 10]. Below is a comparison table of the features of existing technologies and those of the technology proposed by the authors' research group (Table 2).

Table 2. Comparison with the Proposed Application.

Country	Systems' Names	Customization of Alerts	Geolocation Function	Interactive Map	Customized Routes
United states	EAS	Yes	Yes	No	No
	WEA	Yes	Yes	No	No
	Emergency app	Yes	Yes	Yes	No
Canada	Alert ready	Yes	Yes	Yes	No
Japan	Yurekuru call	Yes	Yes	Yes	No
	Tokyo Bosai	Yes	Yes	Yes	Yes
Mexico	SkyAlert	Yes	Yes	Yes	No
Australia	EWN	Yes	Yes	Yes	No
Italy	IT-alert	No	Yes	No	No
	Proposed application	**Yes**	**Yes**	**Yes**	**Yes**

2.3 User Propensity

In the previous chapter, the warning technologies that various governments around the world have already adopted were discussed and described. While theoretically these systems appear extremely efficient and well-designed, an important assessment is missing: to what extent a user is actually willing to rely on the information provided by the device in an emergency situation.

Although daily life now revolves around the messages, notifications, and emails we exchange via smartphones, when an emergency event occurs, things change. Users become much more reluctant to blindly trust information without more details, without being able to cross-check, and often having to act immediately. A study conducted in 2021 by Lyu and Adams states that there is a gap between the issuance of weather forecasts and the actual action taken by users, specifically by families. There was indeed a tendency towards inaction even in the presence of specific warnings. The research therefore focused on the factors that determined this inaction and identified three main sources of bias: optimistic bias, which underestimates the risk in the early stages; cognitive biases that do not allow for an accurate interpretation of meteorological information, and cultural biases that influence the perception of risk and the responses to it by certain categories of users. Therefore, there is an underestimation of the risk until the danger is directly observed [11]. Both the authors of this study and several other scholars argue that these biases can be corrected through a process of user training and preparation [12]. When a catastrophic event occurs, the first reaction of humans is to deny what is happening. When it is no longer possible to perpetuate this process of denial, panic sets in. Panic, very often, is even more dangerous than the event itself. When a crowd is in a state of panic, its behavior is no longer rational, but rather it takes on a particular motion, comparable to the behavior of fluids in situations of turbulent flow.

Helbing et al. [13] This phenomenon is very dangerous because it makes people's behavior unpredictable, with the risk of injuries, people falling and being trampled by the crowd, or even deaths due to crushing.

Since the purpose of the RISK research project, conducted by the authors of this article, is to design a tool that physically guides users in the evacuation process from a city affected by an emergency, time has been dedicated to experimenting with how willing users are to follow the instructions of a mobile application during a dangerous situation.

3 Experimentation

It was therefore decided to simulate an emergency situation in the industrial area of Rende, a few kilometers from the University of Calabria. The industrial area of Rende is entirely located along the Crati River. Some industrial warehouses are situated just a few meters from the riverbanks. The Crati River is the most important watercourse in Calabria. It originates at an altitude of about 1700 m in the municipality of Aprigliano, in the province of Cosenza. From Aprigliano, it descends towards the city of Cosenza, where it doubles its flow by merging with the Busento River, before skirting the city. It then continues along the entire city of Rende, before diverting at Tarsia, crossing the Sibari Plain, and flowing into the Gulf of Corigliano. As reported by Macchione et al., in the past, the Crati River has overflowed several times following significant floods. The first documented flood occurred on October 30, 1590, when the Crati overflowed, flooding the Spirito Santo and Sant'Agostino neighborhoods of the municipalities of Rende and Cosenza. In 1729, another flood caused the collapse of the San Lorenzo bridge. Later, in 1789, there was a flood that destroyed part of the "Rivocati" river. In 1790, the river overflowed again. Then, on October 14, 1839, another violent flood destroyed parts of the Spirito Santo and Sant'Agostino neighborhoods and the San Lorenzo bridge. Several similar events followed in subsequent years, up to the flood on November 24, 1959, which affected several areas of the old city, leaving about 600 people homeless [14]. The most recent flood occurred on February 13, 2016, when the Crati River overflowed at three points [15].

Given the risk associated with the presence of industrial and commercial activities along the river, the authors have therefore decided to simulate an emergency scenario that concerns one of the activities located closest to the Crati.

A company and an assembly point (see Fig. 1) have therefore been identified, where the company's employees must go in case of an emergency. For convenience, it is assumed that the assembly point is the one designated by the Italian Civil Protection for the municipality of Rende.

From their workplace, workers can reach the assembly point by two routes: Route A and Route B. Route A has longer travel time, Route B shorter (see Fig. 2).

The scenario involves the flooding of the Crati River following heavy rainfall. In this scenario, the flood causes the collapse of an important bridge that connects the industrial area of Zumpano with the industrial area of Rende, rendering the surrounding roads impassable. For this reason, a company located upstream of this bridge has been considered, as under normal conditions, the lowest-cost route (Road B) to reach the

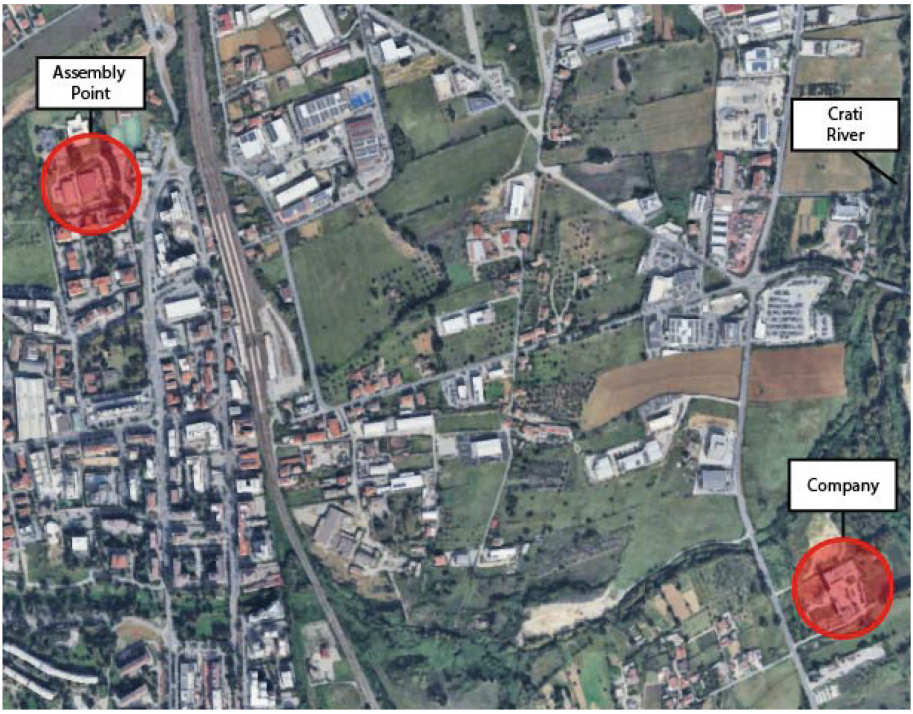

Fig. 1. View of the Company and the Assembly Point on the map. On the right, the Crati River. Source: Google Maps

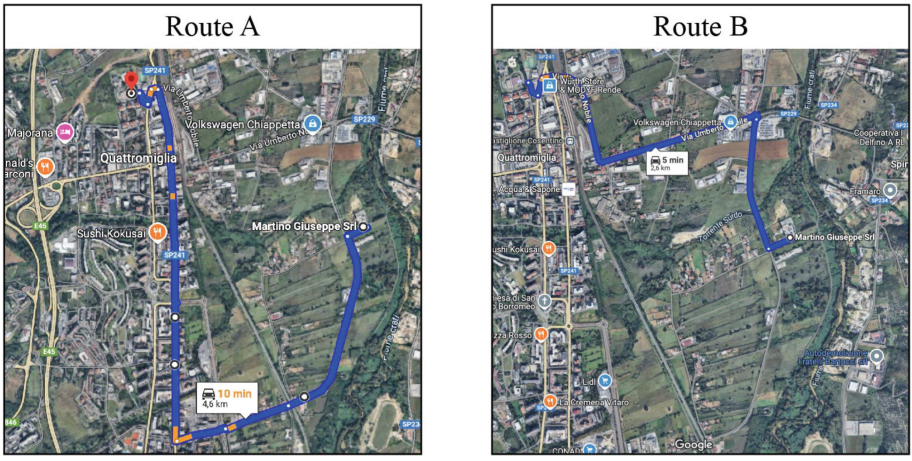

Fig. 2. Comparison of Travel Time between Road A and Road B. Source: Google Maps

assembly point designated by the Civil Protection becomes inaccessible. As a result,

users are forced to opt for the higher-cost route (Road A) to reach the Civil Protection assembly point.

3.1 Survey on Workers

The company in question has 30 employees. The objective of the study is to understand whether people will follow or not follow the instructions coming from a mobile device, even when the device advises them to take the route that the employees know to be more costly (Route A). This is all without knowing any other details from the outside world, unable to verify that Route B, which is less costly, is actually impassable, and thus blindly trusting the device. Therefore, the company's employees were given a questionnaire.

Before handing it out and asking them to fill it in, the workers were informed about the existence of an application capable of guiding them along the safest route to reach the assembly point designated by the civil protection. Therefore, the first question was to ascertain that all employees knew how to reach the assembly point from their workplace.

1) Would you be able to identify one or more road routes to drive from your workplace to the assembly point?

All respondents answered this question affirmatively. The question was meant to ensure that all the company's workers were aware that there are two routes to reach the assembly point. Route B is the shorter one, while Route A is the longer one. To understand whether the employees are actually aware of which route is the shortest, two questions were asked:

2) Which of the two roads, A or B, do you think is the fastest to reach the destination, starting from your workplace?

This question was asked before discussing the ongoing emergency, so in normal situations. The purpose of the question is to understand whether users are aware of the costs of the two routes. Understanding this is very important because later they are asked not to take the less costly route, but to trust what the application says and choose the longer route to escape. The results show that more than 80% know which is the shorter route (Table 3):

Table 3. Results of Question 2.

Route	All	%	Male	Female
A	5	17	5	0
B	25	83	13	12

To understand whether the employees actually know how much difference there is in terms of travel time between the two routes, the following question was then asked:

3) Can you provide an approximate estimate of the time needed to travel Road A and Road B?

With this question, the authors ensured that the employees were aware of the significant difference in the costs of the two routes. All users responded consistently with the previous question.

At this point in the questionnaire, it was explained that due to the flooding and the collapse of the bridge, Route B had become impassable. They were then asked the following question:

5) The application reports that, due to flooding, Road B is impassable. In this case, would you choose to follow Road A or would you still attempt to travel Road B?

This is the main question of the survey. It is very direct and leaves no room for misinterpretation by the user. It is the moment when the user faces a choice: to trust or not trust what is communicated by the application, without the ability to verify the accuracy of the information provided. It is important to emphasize that the test was conducted anonymously, so there is no possibility that users were influenced by the fear of being judged for their response (Table 4).

Table 4. Results of Question 5.

Route	All	%	Male	Female
A	28	**94**	17	12
B	2	**6**	1	0

A question posed exactly for the purpose of understanding the sincerity reliability of the users' responses is the following:

4) In case of danger, would you prefer to head to the assembly point indicated by the Civil Protection or reunite with your family?

This question was quite important to understand the sincerity of the users because it appeared statistically unlikely that a strong majority would choose to go to the assembly point indicated by the Civil Protection. Such a choice, in fact, was an excessively rational decision, which is difficult to find in a group of people larger than the initial sample. Roland W. Perry and Joanne M. Nigg report that during emergencies, families often delay evacuating their homes until they have reunited with all members. This behavior reflects the concern of having information about the location and conditions of separated family members [16]. Therefore, from this question, the authors expected that a significant portion of the surveyed users would opt for the answer "Reunion with family members." It was thus a question posed with the aim of assessing the users' propensity to respond honestly (Table 5).

Table 5. Results of Question 4.

Choice	All	%	Male	Female
Assembly point	12	**39**	8	3
Family Reunion	18	**61**	10	8

3.2 Results

From the collected data, it appears that more than 90% of the respondents claim that they would follow the instructions received on their smartphone in emergency situations. The authors consider this data to be quite reliable, but at the same time, they believe that an important detail needs to be analyzed. Before the employees were given the test, they participated in a meeting where the questionnaire was contextualized.

During this meeting, it was explained to them that they should imagine themselves in a dangerous scenario, and in that context, they would have an application available that would guide them along the safest route and support them with real-time information about the ongoing emergency. The authors believe that this informational meeting can be considered a form of training. It can therefore be assumed that in this case, the users who took the survey were informed users.

This consideration would actually explain the excellent result obtained in terms of trust in the information received on their phones [17].

A rather expected result, already mentioned earlier, is that 60% of the users responded that they would choose to reach their family members rather than go to an assembly point. This data, which may seem negative, is actually the most important because it demonstrates the reliability of the experiment conducted. The workers were only explained the functioning of the application through the appropriate notifications, without specifying the option to go directly to the assembly point and not waste time trying to reach their family members. Therefore, they were not trained on this step specifically in order to obtain the most truthful result possible. The users who opted to reach the assembly point are users who already have a pre-existing civic consciousness and know that in dangerous situations, it is very risky to waste precious time.

4 Conclusions

This study confirms the fundamental role that innovative technological solutions can play in improving emergency preparedness and in safeguarding the population. The analysis of the warning systems currently in use in different countries highlights important progress in the ability to warn in real time about different types of risks but also highlights a common limitation: the lack of personalized indications for evacuation and for reaching safe places. In fact, the moment of emergency evacuation is very critical, because if not properly managed it can lead to more problems than the emergency itself. The RISK project directly responds to this gap, integrating the Internet of Things and Artificial Intelligence to provide personalized evacuation routes, dynamically adapted to the user's position and changing road conditions. The experiment conducted near the University of Calabria not only confirms the technical feasibility of this approach but also highlights the crucial importance of user training. After a brief illustration of the application and its functioning, over 90% of the interviewees stated that they would follow the application's instructions, provided they were adequately informed.

However, the behaviors observed in the questionnaire highlight a fundamental human dimension in emergency contexts, namely the tendency to prioritize reunification with one's family members over institutional indications. This data should not be interpreted

as a limitation, but as a valuable signal: future systems should aim for greater psychological harmony with users' priorities. For example, one could think of integrating features for tracking family members or reporting safe meeting points could make these tools more intuitive and empathetic, thus increasing the level of trust and compliance. After all, the goal of these systems is also to reassure users in order to lead them to have more disciplined behaviors.

From a technical point of view, the use of real-time data, coming from satellite images and from different sensors scattered in the urban environment, opens up very promising perspectives for future development. Machine learning algorithms could be further trained not only to identify practicable routes, but also to predict secondary risks, such as fires, subsequent collapses or chemical hazards, and adapt evacuation strategies accordingly. Furthermore, extending the platform to interoperate with already existing public warning systems (such as IT-Alert) would further improve coverage and coordination.

In conclusion, the work presented here lays the foundation for a new generation of emergency management tools, capable not only of high technological efficiency, but also of social awareness and behavioral response. Future research should focus on large-scale validation of the system in different urban and cultural contexts, on the integration with wearable technologies to detect the location of any missing persons and on the development of training plans aimed at training and preparing people through the simulation of possible emergency scenarios. Such evolutions would further strengthen the role of mobile applications as critical tools in the safe, timely and humane management of emergencies. In conclusion, the authors believe that the technological aspect of innovative solutions must go hand in hand with the behavioral and psychological study of the individuals to whom the tool is addressed.

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