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Natural Hazards and Earth System Sciences
Discussions

The Emergency Accessibility Analysis based on Traffic Big Data and Flood Scenario Simulation in the context of Shanghai Hotel industry

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Abstract. Underlying the impact of global warming and rapid growth of the tourism industry, the increasing frequency of flood post threats to the sustainable development of the coastal cities in China. The article proposes a methodological approach to evaluate the emergence response capability. This approach combines the flood simulation scenario method, traffic big data with the path navigation interface of the web. This article provides an empirical study to evaluate the emergency response from Fire & Rescue Service (FRS) to the tourist hotel in Shanghai from spatial accessibility perspective. The findings show that (1). The emergency response from FRS has significant relationships with the situation of transportation, the location of hotels, the intensity of flood inundation and the number, location of the urban FRS. (2). The emergency accessibility of a city caused by floods depends on the prevailing traffic conditions. The more severe traffic congestion has a significant impact on the spatial accessibility. (3) Flooding and real-time traffic conditions can change the fastest path from FRS to tourist hotels, resulting in delays in emergency response times, and the selection of the most appropriate travel routes is critical to improving the emergency response capability of cities. The results proved the validity of this proposed approach. Consequently, the approach contributes to the enhancement of the level of emergence response ability of urban tourism when they encounter disasters.

1 Introduction

Extreme weather events experienced by the hospitality industry, including floods, heat waves and bushfires, have steadily increased over the past few decades. Flooding has become more frequent, nearly accounting for half of all disasters. Each year, flood inundation costs five billion dollars worldwide, which accounts for approximately one percentage of GDP and is directly and indirectly linked to 300,000 death tolls. The hospitality industry is one of the most vulnerable industries for flood disasters. For example: Hurricane Katrina’s impacts on New Orleans which resulted in the 1409 hotels shutting down, leading to approximately 33,000 employees lose jobs in hotel industry (Pearlman & Melnik, 2008). The 2004 Indian Ocean tsunami led to a massive loss of visitors to Thailand, causing a 27% drop in inbound flights to Phuket in January 2005, an

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Preprint. Discussion started: 17 December 2021

Natural Hazards and Earth System Sciences Discussions

85% drop in international visitors, and a 10% drop in hotel occupancy (Henderson, 2007). These examples highlight how flood events can affect tourism. Confronting unexpected events, effective disaster management and preparedness is significant for tourism practitioners to mitigate these effects.

As the frequency of flooding has increased, research concerning disaster management has achieved substantial attention in the hospitality management field. Lin Moe & Pathranarakul (2006) elaborated that disaster management can be framed into a model, which combines both proactive and reactive approaches. The model illustrates all planned activities executed before disasters to mitigate the effects for emergency events as proactive approaches, while activities conducted during response and recovery in the post-disaster phrase as reactive approaches.

The extant literature tends to focuses on the recreative approach. The following topics are developed, including disaster risk assessment (Brown et al., 2017; Sevieri et al., 2020; Tsai & Chen, 2010, 2011), disaster risk management, impact mitigation and assessment (Schmude et al., 2018; Shi et al., 2020), and recovery circumstances (Bird, 2009; Brent, 2008; Ye et al., 2020). Among these studies, research models are constructed to aid tourism destination recovery in the aftermath of disaster period. For example: Bird (2009), Brent (2008), and Ye et al. (2020) established the rapid risk assessment model to evaluate the influence of tourism facilities, suffering from typhoons and earthquakes. Mao et al. (2010) employed regression analysis to elaborate the tourism recovery patterns based on catastrophe theory. Huang & Min (2002)adopted a forecasting approach to measure destination recovery time from earthquakes. In addition, time series and Box-Jenkins models are normally used to calculate the data related to timing.

One research gap is identified based on the above literature. The previous studies almost all concentrate on recovery strategies from the post-disaster period. These recovery plans are only considered from self-help perspectives. However, the survival of a tourism enterprise during and post-disaster periods should depend on the exterior support from public resources (Brent, 2008; Hystad & Keller, 2008). The Fire & Rescue Service (FRS), also known as the emergency response service team in China, delivers professional firefighting and flood service to rescue people's lives and property upon an accident occurring. The priority task of the FRS is to deliver a quick and agile response to targeted places; hence, timely response is a paramount component for emergency services. According to Carr et al. (2006), the overall FRS service time consists of four intervals, that is activation, response, on-scene, and transport. This study concentrates on the FRS response time interval. For example: the time for the dispatch to arrive at the targeted places. Anything that postpones the arrival of the FRS service, such as the traffic congestion or flooding blocking alterative roads to reach destinations (Li et al., 2021). The flashing lights and alarms on the FRS devices, which normally remind people to give way for emergence services. Unlike normal conditions, extreme weather poses difficulties in the FRS reaching targeted places in the shortest time, not only traffic congestion, but also the choice of alternative routes to destinations (Yu et al., 2020).

In the public social service field, the evaluation of spatial accessibility is an effective index to identify the capacity of public service and the convenience to obtaining this service (Hashtarkhani et al., 2020; Shi et al., 2020; Yu et al., 2020). The efficiency of spatial accessibility of a public service depends on the capacity of the supply and the number of demand (M. Li et al., 2018). Shanghai, as the commercial hub in China, has been suffering from flood inundation over the last two

Natural Hazards and Earth System Sciences
Open Access
EGU
Discussions

decades (Yin, Yu, & Yin et al., 2016). For these reasons, an important number of public resources are allocated to emergency service agencies to optimize the influence by unexpected events.

This study aims to examine how the spatial-temporal variation about traffic congestion on FRS' accessibility under the flood situation in the context of Shanghai inner-city. The purpose of this study is to construct a traffic flow mode underlying a Marco-traffic simulation to identify the FRS service accessibility. Within this model, the variables are consisted by different travel times at various periods within a day, as well as the level of flood inundation to targeted place. By identifying the FRS service time to targeted place under the flood situation, this study will remind authorities to consolidate the effective of FRS delivery and eliminated the resource inequality issues in the contemporality society.

The paper is organized as follows: The following section presents the literature review of studies on emergency planning in tourism industry and spatial accessibility. The third section clarified the Research methodology, including flood inundation simulation, identification of traffic congestion and emergency response capacity calculation. The results are discussed in the fourth section. The final two sections present the discussion and conclusions, which include the limitations of this study, implications for disaster planning management for DMOs as well as the possible research directions.

2. Literature review

2.1 Emergence planning study

The last two decades have witnessed considerable growth in disasters in the tourism industry, which pose a severe challenge to the development of the economy and sustainable tourism (Orchiston, 2012; Wut et al., 2021). In particular, the hotel industry has suffered from natural disasters for many years and leads to economic loss (Brown et al., 2018; Brown et al., 2017; Tsai et al., 2020). Adopting effective emergency planning is to secure guest's lives, prevent economic loss of business operations as well as shorten the recovery time when an emergency occurs (Becken & Hughey, 2013; Brent, 2008). Emergency planning is driven by two objectives when dealing with environmental hazards: hazard assessment and risk reduction (Becken & Hughey, 2013; Brent, 2008). Hazard assessment contains identification of previous disasters affecting the local community, the adoption of advanced technology to forecast and simulate the potential disasters (Faulkner, 2001; Ritchie, 2004). Emergency planning is a process, the establishment of plans and strategies for emergencies should be tested and evaluated through the practice (Morakabati et al., 2017). Emergence planning can be viewed as the standard for preparedness. According to Morakabati et al. (2017), the definition of an emergency plan is 'a coordinated set of protocols for managing disaster events, whether expected or unknown in the future'. Although each disaster is unique, with the development of technology and computer science, which provides the novel approach to make predictions, forecasting, warning and planning (Becken & Hughey, 2013). Hence, it is significant to make use of extant algorithms to simulate disaster situations under different scenarios.

The extant studies concentrate on constructing the strategy model as the best approach for tourism business (Brent, 2008; Faulkner, 2001; Ritchie, 2004; Tsai et al., 2020). The tourism business can use these models to prepare for, react to and recovery from when the emergency occurs. These studies share similarities across their framework, and both stress the adoption of different stages to deal with emergency planning. These mainly include these phases: Pre-event, Prodromal, Emergency, Intermediate, Long term, and Resolution (Faulkner, 2001). Ritchie & Jiang (2019)proposed a framework stressing the importance of these stages of emergency planning: (1) preparation and planning, (2) response and recovery, and (3) resolution and reflection. The extant literature concentrates on the latter phase, that is the 'resolution and reflection' stage and can be viewed as the reactive approach. The reactive approach stresses the importance of recovery activities and response in the aftermath of disaster (Brent, 2008).

However, each disaster can make different influence on the destinations, these strategy models have the limited applications when the disaster occurs. With the development of technology, the disaster simulation system can precisely stimulate and predicate the influence of disaster on destination. However, the associated simulation methods have received the little attention in tourism studies (Reimann et al., 2018; Shi et al., 2020). Using the simulation methods can reduce the influence of disaster. In addition, pre-disaster planning and drills can avoid confusion and repetition during a disaster, making the response quicker and more effective and reducing the level of panic.

The survival of a tourism enterprise from a disaster is not sufficient based on their own recourse (Becken et al., 2014; Tsai et al., 2020). Gaining the support from the local community is important, as they have authority to coordinate the resources to mitigate the effects of the disaster (Brent, 2008). Pre-disaster efforts are mainly concerned with disaster risk assessment, stakeholder collaboration, development of disaster management strategies and education of staff (Oloruntoba et al., 2018). Assessing potential disaster situations that may arise and their relative probability of occurrence is a crucial first step. Understanding the types of disasters or crises that a destination or organisation may be subject to, and the nature of such events, is important for developing appropriate plans and strategies to prevent or limit the impact of such events (Brent, 2008; Reimann et al., 2018; Ritchie, 2004). In light of these circumstances, a number of scholars have called for the need to conduct scientific risk assessments of tourism sites by combining the power of multidisciplinary research (Brent, 2008; Filimonau & De Coteau, 2020; Tsai & Chen, 2010) to better plan and prepare for tourism disasters.

2.2 Spatial Accessibility

Accessibility can be understood as the degree of convenience in moving between the origin to destination within a transport network system. Accessibility is both an important element of equity in public services and an important indicator of a city's ability to manage them, emphasizing both equity and efficiency (Shi et al., 2020). Under unexpected events or emergencies, urban emergency services such as Fire and Rescue Services (FRS) and Emergency Medical Services (EMS) are required to reach the location in the shortest possible time to rescue people and property (Yu et al., 2020). Emergency accessibility is an important indicator of a city's ability to prevent and mitigate disasters and is key to improving the disaster response capacity of the tourism industry (Li et al., 2021; Morakabati et al., 2017).

Emergency services in both developed and developing countries are often required or recommended to meet prescribed response time frames for different types of events. For example, UK legislation requires FRS and EMS to arrive at 75% of 'Red 1' incidents within 8 and 10 minutes respectively of the initial report being recorded (Coles et al., 2017; Green et al., 2017). Although there is no national legislation requiring emergency response times in China, targets do exist in some cities (Coles et al., 2017; Green et al., 2017). For FRS, the recommended response time limit in China is five minutes, but in practice most FRS targets are to reach an incident within 10 minutes in built-up areas and 15 minutes or longer in suburban or rural areas (Yin et al., 2020). However, the achievement of these response goals is often influenced by a variety of factors. Traffic congestion, for example, where the movement of millions of people within cities leads to daily changes in traffic and demand, will limit the efficiency of urban emergency response (Li et al., 2021). And natural disasters, such as floods and earthquakes will lead to disruptions in road accessibility and loss of emergency response capacity for emergency agencies, which in turn will increase response times and even create emergency blind spots (Alabbad et al., 2021; M. Li et al., 2018; Yu et al., 2020).

In this study, the researcher stresses the importance of extreme flood impacts on the emergency accessibility. The increasing frequency of flood as one of the greatest threats to the survival and development of human societies, especially in urban areas with dense population and infrastructure (Yin, Yu, & Wilby, 2016). On the one hand, extreme flood events can lead to a sudden rise in demand for emergency services as people are exposed to the threat of flooding. On the other hand, impassable roads and incapacitated emergency providers due to flooding may result in the inability to reach the location of need within the mandatory response time (Yin, Yu, & Wilby, 2016). Several studies have noted the impact of severe flooding on emergency accessibility. For example, Yin et al. (2020) assesses emergency response accessibility in urban areas under different flood scenarios in Shanghai. By considering the probability of flash flooding, Rizeei et al. (2019) assesses emergency response coverage and predicts the best locations to serve vulnerable residents with redundant or delayed emergency response·. However, there are some shortcomings in these studies. Firstly, most previous studies have used vector data-based network analysis for road network modelling, but this approach is more demanding and varies significantly from the actual road network data (Li et al., 2021; Zheng et al., 2020). In addition, most previous studies have focused on urban or vulnerable groups, and few studies have focused on tourism enterprises (Shi et al., 2020).

In addition, traffic congestion problem also affected the time to emergence accessibility. Traffic congestion is a significant indicator affecting the spatial accessibility under flood inundation context. Large volumes of traffic on roads beyond the capacity of the road results in a slower travel speed and leads to the low efficiency to reach the targeted location.

With the rapid development and widespread use of spatial awareness and mobile positioning technologies, location-based big data is closely linked to the development of society and penetrates into the daily lives of people (Li et al., 2021; Zheng et al., 2020). The wave of big data has provided new insights into the value of data and significantly changed the way they are used (Mudigonda et al., 2019; Qiang & Xu, 2020; Zheng et al., 2020). Users of web navigation platforms become data producers through real-time movement trajectories (Xu et al., 2020). At the same time, online platforms expose data to users through application programming interfaces (APIs). Researchers can use the APIs provided by Web GIS platforms such as Google Map, Yahoo Map, and online maps such as Baidu Map and Gaode Map in China to obtain optimal travel routes and time costs for different traffic conditions with precision (Mudigonda et al., 2019; Qiang & Xu, 2020; Zheng et al.,

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

2020). The emergence of big data provides an opportunity to address the difficulty of dynamically measuring the impact of traffic conditions on emergency accessibility. Some scholars have already applied big traffic data to accessibility measurement, but related studies are not common in tourism research (Li et al., 2021; Qiang & Xu, 2020). This research combines real-time traffic big data from Web GIS with flood simulations to provide new insights into disaster emergency planning for the tourism industry.

3. Research methodology

This study proposes a framework to examine how the degree of flood inundation in the city and traffic congestion affect the spatial accessibility (Figure 1). The flood simulation model and big traffic data was integrated into the Web GIS platform for the purpose of visualization. The visualization shows how the spatial accessibility of the FRS was affected by the degree of flood inundation and traffic congestion in the city.

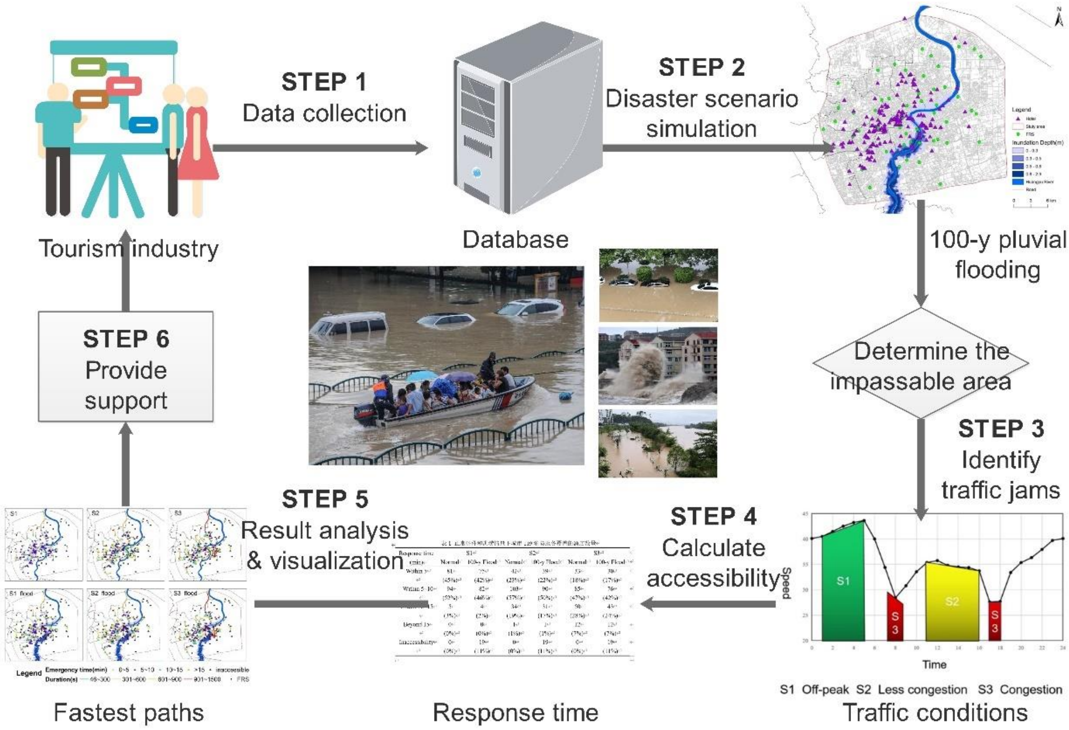


Figure 1. A framework for assessing flooding and traffic congestion disruptions to tourism emergency response capacity.

3.1 Flood inundation simulation model

Flood numerical simulations were executed underlying the FloodMap inundation model, which is a 1-D/2-D-coupled research code for flood inundation modelling. You can see the detailed process of model building in the article by Yin et al., (2013); Yu & Lane (2006a, 2006b).

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

3.2 The identification of traffic congestion

Commuting time is an important factor affecting the spatial accessibility of the FRS. Traffic congestion significantly increases the commuting time between the FRS and targeted location. To identify how traffic congestion affects the FRS commuting time between the FRS and the targeted location during a day. This study identified three phases that affect travel time: off peak time (S1), normal traffic time (S2) and rush hours (S3) (Figure 2, Figure 3). S1 indicates off-peak time period with the fastest travelling speed, data obtained from 1am to 5am. S2 indicates normal traffic (light congestion) with slower speed, corresponding to afternoon, and the data is obtained from 11am to 3pm; S3 indicates morning and evening peak (heavy congestion) with the slowest speed, corresponding to morning The data are obtained from 7:30am to 8:30am and from 5pm to 6pm The three phases of time are used to incorporate real-time traffic conditions into the urban tourism emergency accessibility measurement model and to consider the spatial heterogeneity of traffic congestion.

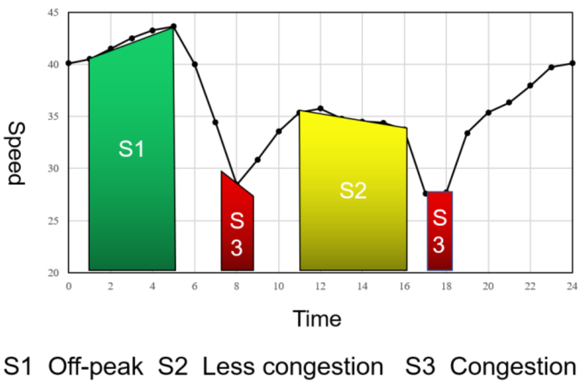


Figure 2. Traffic speed change in Shanghai in 24 hours on Wednesday, February 3, 2021

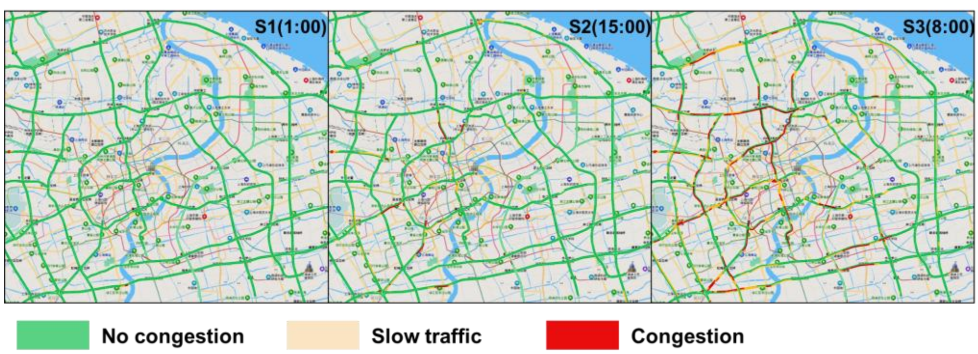


Figure 3. Shanghai traffic conditions on Wednesday, February 3, 2021 (from Baidu Maps).

3.3 Emergency response capacity calculation

To improve the accuracy of the model calculations and to reduce the difficulty of the modelling, this study did not use accessibility calculations based on Euclidean distances or network-based analysis. A web mapping route planning APl service provided by the Web GIS platform Gaode Map was used to obtain read-time travel times for different traffic

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

Natural Hazards and Earth System Sciences
Open Access
EGU
Discussions

conditions. The route planning API is a set of HTTP-based interfaces for walking, public transport, driving queries and distance calculation, which return query data in JSON or XML format for the development of route planning functions. Based on large quantities of traffic and travel data, it introduces real-time feedback on road congestion, which is more accurate than previous accessibility calculations based on network analysis. When a route planning request is initiated to Gaode Map, the system will plan different travel options based on travel mode and real-time road conditions, and the least time-consuming option (fastest path) is chosen as the main calculation result in this study (Figure 4). Related studies have proven that these mapping services are based on a large amount of historical and real-time data and use scientific calculation methods to provide accurate and reliable results (Qiang & Xu, 2020; Qin et al., 2020; Zheng et al., 2020).

In addition to traffic conditions, unexpected traffic events can also influence the choice of emergency routes. When flooding occurs, some roads in the flood zone will be inundated to a depth of 25-35 cm (the typical height of vehicle exhaust outlets, the standard for waterlogged road closures in some cities), making it difficult for the average vehicle to pass. When traffic congestion and flooding act together on urban transport networks, conventional routes sometimes take a significant amount of time and rescue vehicles have to choose more suitable roads in order to reach their destination as quickly as possible. This study, based on flood scenario simulations and big traffic data, maps the shortest paths for emergency services from firefighting agencies to tourist hotels under normal conditions and flooding scenarios, and identifies which shortest paths vary with traffic conditions and inundation.

In this paper, we provide a new reachability metric approach based on the flood inundation extent. The researcher used the web map API to obtain travel times from 54 FRS to 180 tourist hotels in the study area under different traffic conditions at different times, considering both flood scenarios and normal scenarios. The technical process is as follows: (a) build the web application by writing code that resolves the geographical coordinates and id numbers of the study object to determine the starting and ending points; (b) construct the corresponding OD (origin-destination) travel matrix with the five closest facility points (FRS) to the destination (hotels) as the starting points; (c) set the travel mode by setting the parameters into the web terminal, the travel time consumed by OD and the corresponding travel itinerary are obtained in bulk, taking the fastest time as the criterion. Some important input parameters and output results are shown in Table 1. In Figure 4, the five closest FRSs to the destination were first found, after which the flooded area was used as an obstacle surface to obtain the travel time and travel route for each OD using the time-minimal navigation function of Gaode Map route planning. For the specific calculations, the study only selected each Fastest path that reached each destination as the data source.

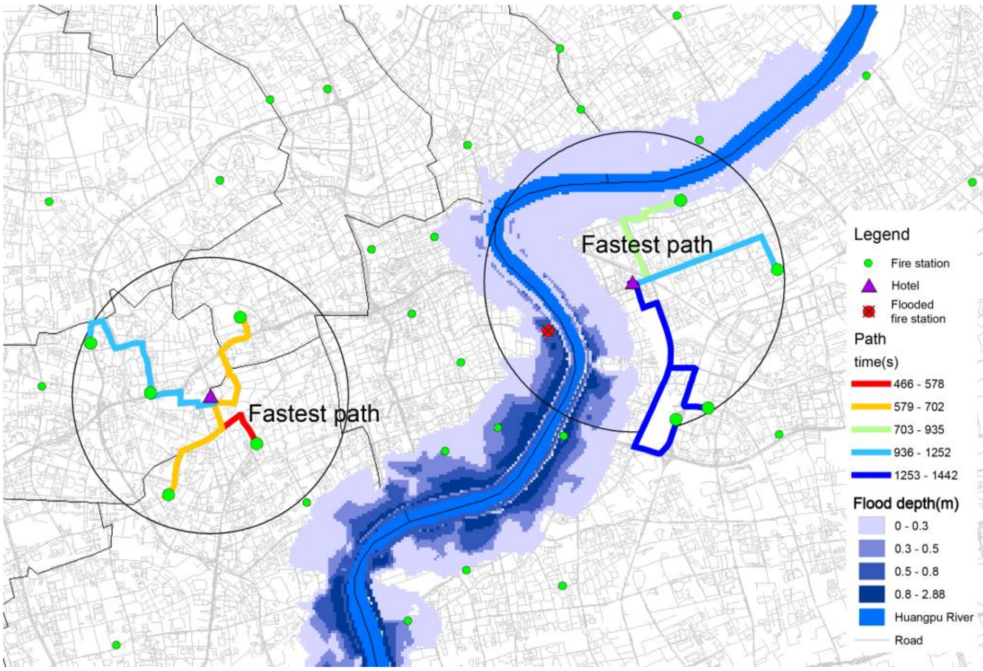


Figure 4. Example of accessibility

Table 1. Parameters and outputs for the quantitative measurement of emergency accessibility in tourism in Web GIS

Input parameters	Essential output results
Origin coordinates & Origin id	Route list
Destination coordinates & Destination id	Paths
Strategy	Duration
Avoid polygons	Distance
Real-time	
Base URL	

To identify the impact of flood scenarios and traffic conditions on the emergency accessibility of the tourist hotel industry in Shanghai, the study obtained emergency response times and fastest paths under normal scenarios and flood conditions for S1, S2 and S3 traffic conditions several times in January 2021, and used GIS technology and mathematical statistics to represent them visually.

4 Case analysis

4.1 Context

This study chose Shanghai city as a case study. The city as the biggest metropolis in China has an 11.35 million population in 2017 and covers about 666km2 in area. Shanghai has suffered from flood disasters for over 1,000 years, as a result of its

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

Natural Hazards and Earth System Sciences
Discussions
Open Access

low level of terrain, the reduction of stream channels, the growth of impervious surfaces and severe ground subsidence problems (Yin et al., 2015). Shanghai has had a high standard of flood defence wall alongside the Huangpu since the 1950s to reduce the damage level from heavy floods. Also, sea walls with a 200-year coastal flood return level design that protect its coastal area, and flood walls with as 1,000-year riverine flood return level along the Huangpu River to protect the city from riverine flooding. However, as the sea level has risen and ground subsidence has led to the need for improved defences. Hence, the potential overload and breach of the Huangpu River and its branches have caused great economic losses and loss of life in Shanghai.

Shanghai is an economic centre in China with affluent tourism resources. The statistics show that Shanghai had 361,405,100 of domestic tourists, 8,972,300 inbound tourists and generated over 23 million yuan in 2019. The tourism industry is one of the key pillar industries of Shanghai, contributing 6.1% of the city's GDP (Bureau, 2020). In 2020, there were 195 tourist hotels, 1,758 travel agencies and 113 A-class tourist attractions in Shanghai.

The hotel data of this research was extracted from the Shanghai public data platform (https://data.sh.gov.cn/), which is open access for researchers to utilise. The location of the FRS used in this research was extracted from the Shanghai fire department website http://sh.119.gov.cn/). Figure 5 shows the 180 tourist hotels in the central city of Shanghai and 54 FRS.

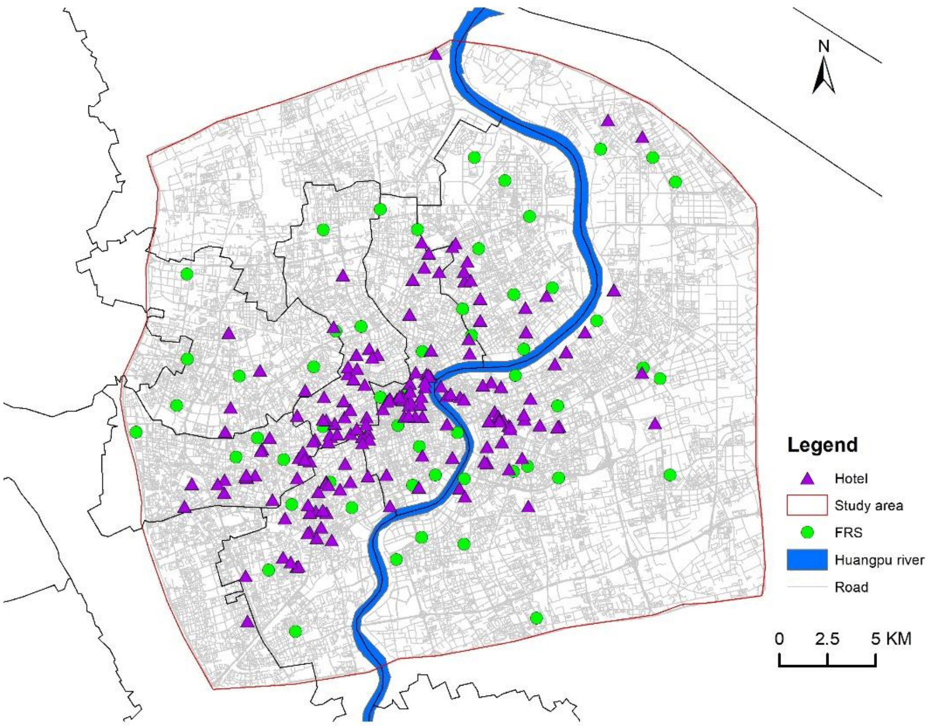


Figure 5. Study Area

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

4.1 Flood inundation analysis

The simulation results of the maximum inundation extent where the inundation depth reached the 100-year flooding scenario in the central city of Shanghai (Figure 6). The characteristic of flood scenario simulation results are as follows: Firstly, the inundation extent and depth of inundation tends to increase from the northern part to the southwestern, because of the higher elevation in the north and lower elevation in the south of the city centre. In addition, due to the flood control wall, the flood inundation is mainly concentrated within 2-3 km along the banks of the Huangpu River, with the inundation depth decreasing the further away from the river.

The adoption of the overlay analysis function in ArcGIS software enables combining of the flood simulation results with the spatial location of tourism elements. This function can identify the highest risk level for flooding. The total of 23 hotels were identified within the flood inundation zone, accounting for 12.78% of the total number of hotels. The 9 hotels were identified to require the emergence service, as their inundation depth was over 20cm. The most severely affected hotels as a result of flooding, including the Intercontinental Shanghai Expo, was inundated to a depth of almost 1m and required arrangements to be made to evacuate visitors as soon as possible.

Additionally, there are indirect impacts to tourism businesses as a result of flood inundation as tourism businesses are highly dependent on water supply, electricity, transport, and communication systems. Flooding will lead to poor connection of water supply network, shutdown of power transmission lines, disruption to road access and failure of communication facilities. In addition, flooding may affect the normal access to the road network along the river area (especially the river crossings), thus causing disruptions or delays to the emergency travel and rescue services in the areas along the Huangpu River.

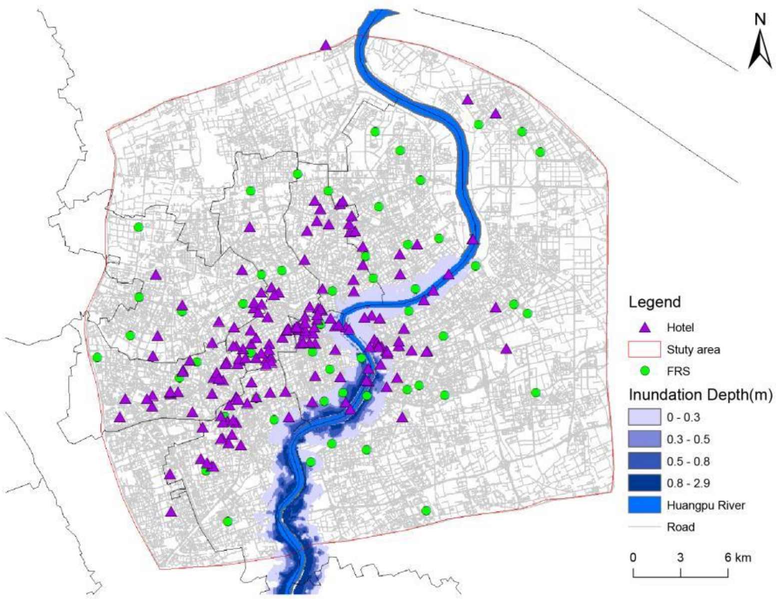


Figure 6. Inundation extents and depths for once-in-a-century floods scenarios in the city centre of Shanghai

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

4.2 Emergency Response Time Analysis

Traffic congestion and flood inundation has a significant impact on the emergency accessibility of hotels in Shanghai. Figure 7 indicates that a delay occurred in travel times from the FRS to the associated hotel without any flooding inundation during the period of S1 and S2. The extended travel times was identified when compared with S2 and S3 period. For example: some hotels normally took only 12 minutes to receive assistance in S1, but took over 20 minutes to receive assistance when in S3 traffic conditions, which clearly exceeded the response time target set by the city of Shanghai. Notably, when comparing emergency response times for S2 and S3 traffic conditions, there was significant heterogeneity in the impact of traffic congestion on emergency response. While the majority of hotels experienced a 2-minute increase in emergency response time, some hotels experienced a decrease in response times. The value of real-time data is reinforced by the fact that longer or shorter access times are largely determined by congestion on the roads. The study also compared the impact of flooding scenarios on the emergency accessibility of hotels under different traffic conditions. As shown in Figure 7, the impact of flooding on hotel emergency response times was not significant under S1 traffic conditions. During the S2 period, the emergency response time for 2 hotels is significantly longer. Under the context S3 period, more hotels have significantly longer emergency times. This suggests that the extent to which flooding affects the accessibility of urban emergencies depends on the prevailing traffic conditions. This result suggests that future studies will need to incorporate traffic conditions into the model when assessing disaster impacts.

Under normal conditions (roads unaffected by waterlogging), rapid emergency response is available to almost all tourist hotels in the central city due to the high number of fire agencies in the central city as shown in Figure 8 and Figure 9 and Table 2. In the S1 traffic scenario, FRS vehicles can reach 45% of the hotels in the central city within 5 minutes, 97% of the hotels within 10 minutes and the remaining 3% of hotels can be reached within 15 minutes, with a high degree of overlap in the FRS service area and a very high emergency response capability. Under normal traffic conditions (traffic congestion on some roads) S2, the number of scenic areas with access to 120 emergency response services within 5 minutes decreases to 23%, with over 50% of hotels accessible within 5-10 minutes and nearly one fifth of hotels requiring 10-15 minutes to access emergency services. During peak commuting traffic (very congested road traffic) S3 conditions, only 18% of hotels were able to access emergency services within 5 minutes and 28% of hotels required 10-15 minutes to access emergency services. 12 hotels, or 7% of the total, were unable to access emergency services within 15 minutes.

Under the once-in-a-century flood inundation situation, the depth of water on the roads exceeded 30cm, and some roads along the banks of the Huangpu River, including Xuhui district, Huangpu and Pudong New Area to the south of the Bund, were impassable. 19 hotels, or 11% of the total, were in a blind emergency zone and could not access emergency services. Under the flooding scenario, the scope of emergency services was reduced due to the inundation of roads and the loss of service function of some FRS emergency. In S3, the number of hotels covered by the emergency service within 15 minutes is 19 less than under normal conditions, representing approximately 11% of the total number of hotels.

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

This result findings are in line with Bureau (2020), 100-year pluvial flooding results in minor to moderate impacts on response coverages to hotels when traffic conditions are not congested. This is because of the overlapped FRS covered by corresponding area, in particular, in the downtown area. This compensates for significant reductions in the service areas because of the pluvial flood inundation.

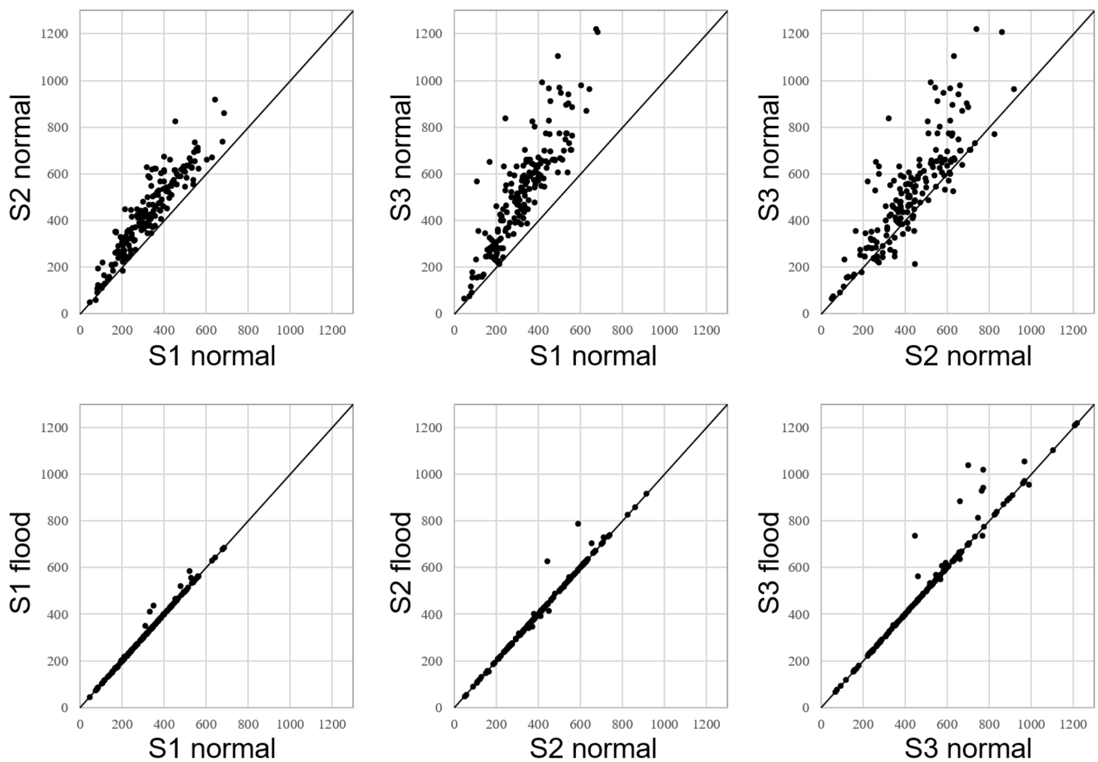


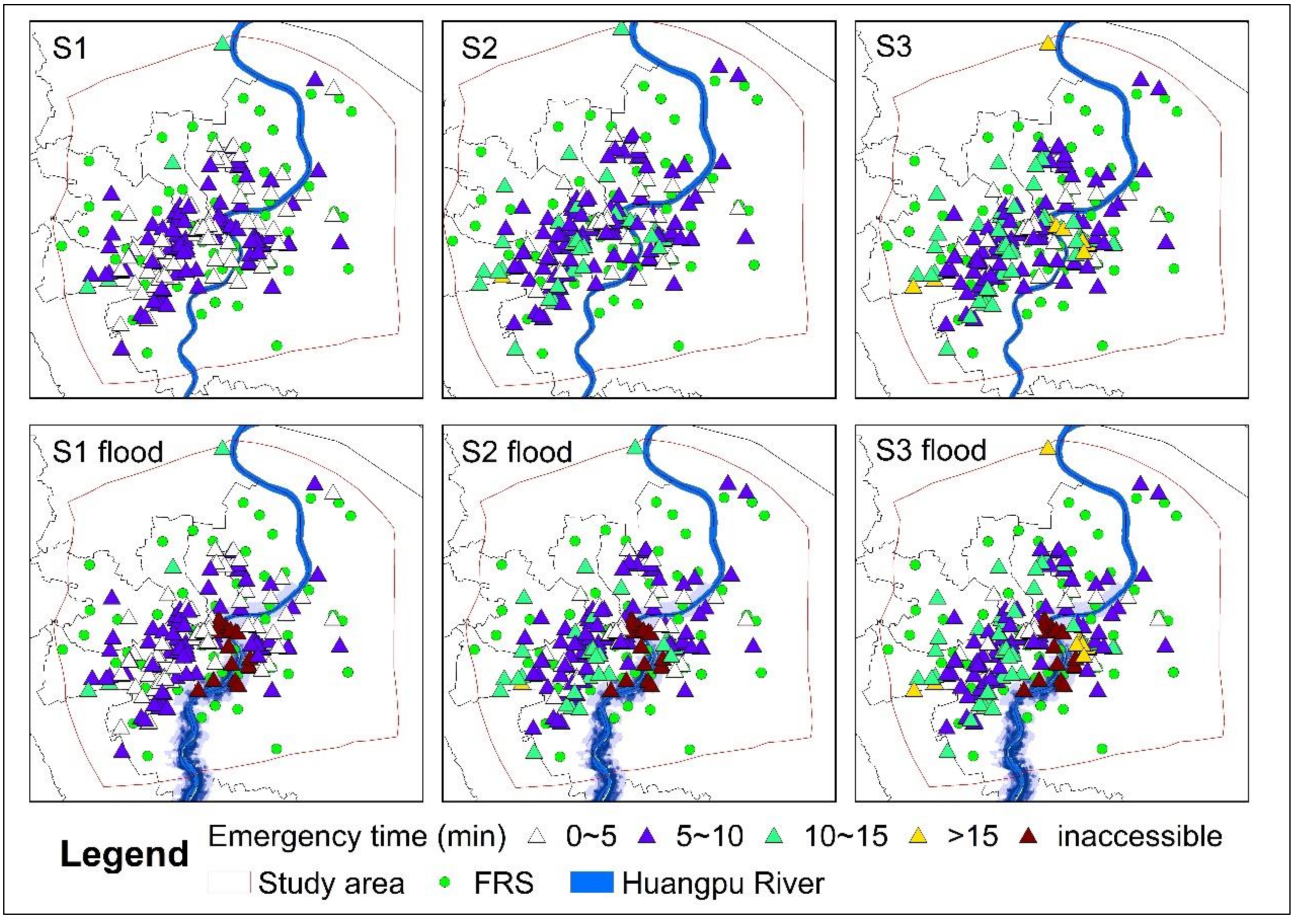
Figure 7. Impact of traffic conditions and flood on emergency accessibility

Table 2. The comparison of number of hotels covered by urban FRS under different traffic congestion between normal period and flood period

Response time (min)	S1		S2		S3	
	Normal	100-y Flood	Normal	100-y Flood	Normal	100-y Flood
Within 5	81 (45%)	75 (42%)	42 (23%)	39 (22%)	33 (18%)	30 (17%)
Within 5~10	94 (52%)	82 (46%)	103 (57%)	90 (50%)	85 (47%)	76 (42%)
Within 10~15	5 (3%)	4 (2%)	34 (19%)	31 (17%)	50 (28%)	43 (24%)
Beyond 15	0	0	1	1	12	12

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

	(0%)	(0%)	(1%)	(1%)	(7%)	(7%)
Inaccessibility	0	19	0	19	0	19
	(0%)	(11%)	(0%)	(11%)	(0%)	(11%)



315 **Figure 8.** Emergency Response Time

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

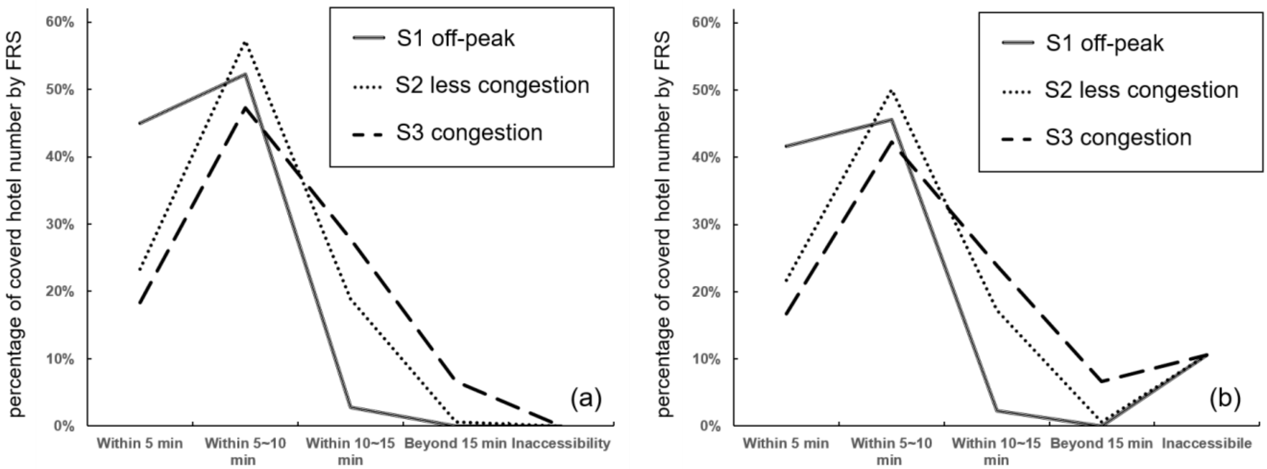


Figure 9. The accessibility time from FRS to hotel between the normal context and flood context

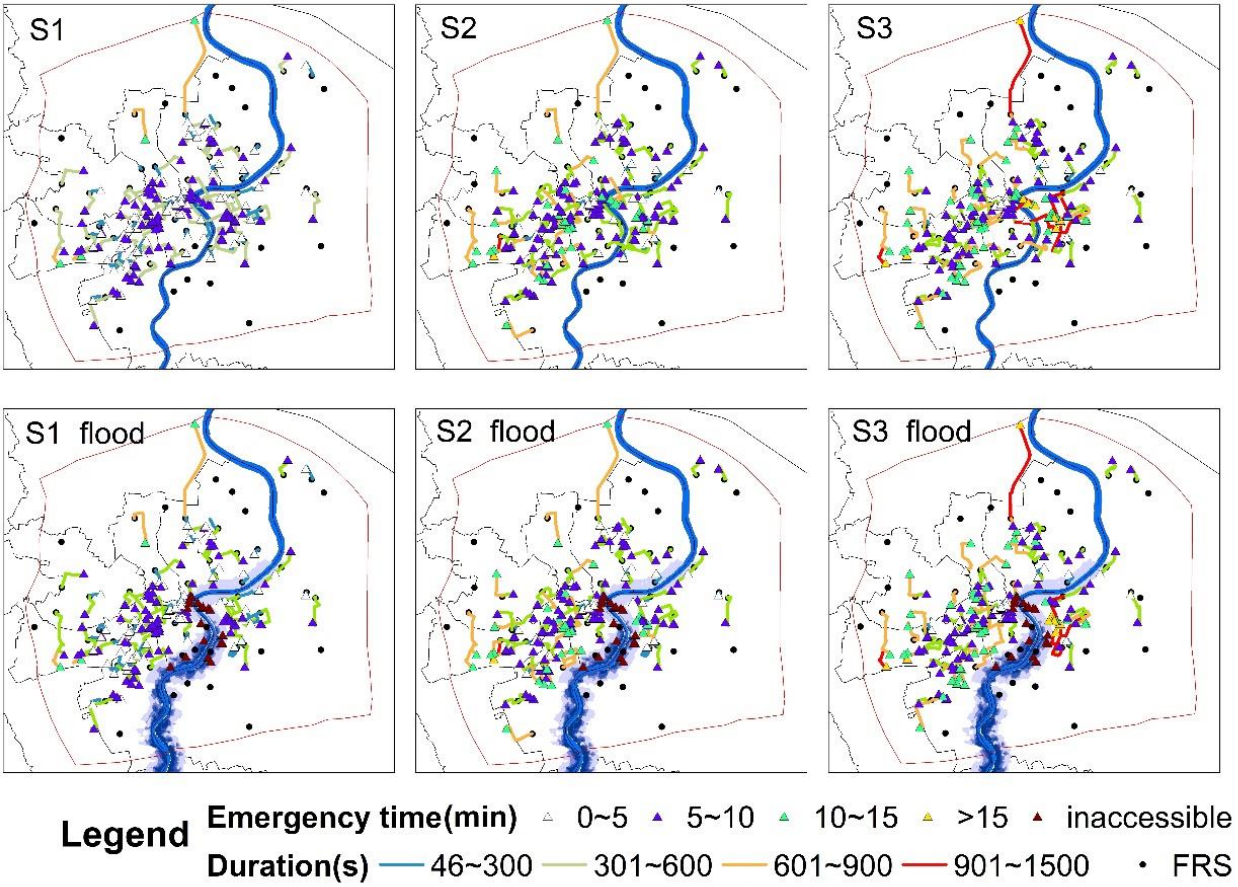
4.3 The shortest path analysis

Urban emergency response requires emergency response agencies to travel as quickly as possible to the incident site. However, cities, especially central urban areas, are crowded, traffic conditions change rapidly, and uncertain events (e.g., flooding) will make some roads impassable. Therefore, using only the indicator of the shortest passable route as the basis for emergency route selection may not achieve the requirement of reaching the incident site as quickly as possible. Therefore, it is important to map the fastest routes under different traffic conditions to improve the emergency response capability of cities. This study addresses this issue by plotting the fastest paths from FRS to each hotel within the central city of Shanghai in the face of S1, S2 and S3 traffic conditions under normal and 100-year flooding inundation scenarios (Figure 10).

Under normal flood-free and S1 traffic conditions, the average arrival time from each FRS to its nearest corresponding hotel is 5.4 min and the latest response time is 11.4 min. Under the S2 condition, the average time required for the FRS to get to each hotel is approximately 7.1 min, and the worst response time is approximately 15.3 min. S2 compared to S1, where 106 routes showed changes, costing approximately 314 min more in total time. When S3 traffic conditions, the average time required for FRS to each hotel was about 8.7 min, and the latest response time was more than 20 min. 110 lines showed changes in S3 compared to S2, and the total time spent was about 279 min more. When faced with a 100-year flood, some sections of the road were forced to be interrupted, and some emergency routes were changed in addition to 19 hotels that could not receive emergency relief. Compared to the normal no-flood scenario, in the flood scenario, 7 routes changed during S1 traffic conditions, extending the average arrival time by about 0.86 min. 9 routes changed during S2 traffic conditions, extending the average arrival time by about 0.70 min. 17 routes changed during S3 traffic conditions, extending the average arrival time by about 1.66 min. Although the impact of flooding in the central city is not large and constrained by the area along the Huangpu River, the impact of flooding on hotels in Shanghai is still significant because some hotels in

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

Shanghai are concentrated on both sides of the Huangpu River in Yangpu and Huangpu districts, which are more seriously affected.



340

Figure 10. Fastest route to emergency in Shanghai hotels

4.4 Disaster Management Strategy

The combination of risk identification and disaster mitigation strategies can be used to help the tourism industry select appropriate risk control strategies (Becken & Hughey, 2013). At the same time, a variety of risk control strategies can be used to minimise the risk of flooding. Specific coping strategies include the following (Table 3). For the government, urban emergency management have to adopt the effective policy to ensure the emergence FRS service to the key nodes within the city. Firstly, consideration could be given to strengthening and raising flood control walls, improving flood control standards and maintaining flood control facilities. Secondly, the city's emergency response department should be equipped with some special vehicles and hovercraft with better water wading capabilities to ensure that emergency rescue missions are completed in areas with deep water. Finally, real-time flood forecasts and real-time traffic information can be combined to provide

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

route navigation options for emergency vehicles to avoid flooded areas and ensure spatial accessibility to urban emergency public services.

For tourism enterprises and industry organizations, they should strengthen their own capacity to cope with flooding while identifying their own exposure to flood risk. Firstly, tourism businesses should identify their own exposure to flood risk based on scientific research from academics, government and non-profit organisations. Secondly, tourism enterprises located in areas of high flood risk should improve their own capacity to prevent flooding and drainage. This can be done by building waterproof walls and drains, constructing steel gates, installing flood-proof glass and customising their own temporary defences. Thirdly, the tourism sector and industry organisations should play a bridging role to strengthen the link between the tourism industry and urban emergency response. Clarify and publicise the vulnerability and value of tourism in times of disaster and attract more social participation in tourism disaster response. Fourth, design targeted on-site emergency response plans. Tourism enterprises should develop and implement regular flood prevention drills and plans for the emergency evacuation and relocation of tourists and the prevention and evacuation of valuables from disasters. Fifth, tourism enterprises should improve their emergency protection capabilities. This can be done in three ways: by allocating emergency relief materials, establishing emergency relief teams and setting up emergency relief funds. Sixth, tourism enterprises located in medium to high-risk areas should purchase disaster insurance while considering their operating costs, and transfer the risk by means of insurance. Seventh, carry out emergency training. Tourism enterprises and industry organisations should improve the safety awareness and the ability to avoid, save themselves and save each other of tourists and tourism workers, etc. through various means.

Table 3. Proposals related to flood risk management strategies for tourism

Risk category	Response department	Management strategy
Flood	Government	Consolidation of flood control facilities
		Configure rescue equipment
		The section of fastest route
	Tourism enterprises and DMOs	The identification of flood risk
		The enhancement of flood control and drainage capacity
		Strengthen the linkage with emergency rescue departments
		Development on-site treatment plan
		Improve emergency security capabilities
		Purchase Disaster Insurance
		Conducting emergency training

https://doi.org/10.5194/nhess-2021-368
Preprint. Discussion started: 17 December 2021

5. Discussion

Many scholars demonstrated that the combination of risk analysis, assessment and disaster mitigation strategies in tourism disaster management (Becken & Hughey, 2013; Brent, 2008). However, these suggestions have received little attention because of the small scale of tourism businesses (Cushnahan, 2004; Nguyen et al., 2018). Therefore, integrating the emergency management capacity of civil defence agencies into the tourism industries crisis management system will be key to improving the industry's response to disasters (Becken & Hughey, 2013; Hystad & Keller, 2008). However, current empirical research on cooperation between tourism and civil protection agencies is scarce (Becken & Hughey, 2013; Hystad & Keller, 2008). The only studies that have measured tourism emergency accessibility have failed to include real traffic conditions in their models, resulting in large discrepancies between the results of the studies and the real situation (Shi et al., 2020). To address this gap, this paper will introduce a scenario simulation approach to quantitatively assess and visualize the impact of a one in a 100-year flood on the emergency accessibility of the Shanghai hospitality industry for fire protection, based on the assessment of potential hazards, combined with big traffic data.

This study demonstrates the benefits of combining scenario modelling and traffic big data and its usefulness in assessing the emergency accessibility of urban facilities. The introduced methodology measures the emergency accessibility of the hotel industry in Shanghai using actual traffic road conditions and identifies the impact of flood hazards on urban emergency accessibility under different road conditions. Unlike traditional network analysis models constructed based on vector road networks, this approach has the following advantages. Firstly, there is no need to construct a network dataset and manually determine road directions, reducing the workload of researchers. Secondly, the calculation of road access time based on Internet maps considers the accessibility of roads, which can significantly improve the accuracy of the calculation results. Finally, the Web GIS-based road travel time calculation considers the congestion level of the road, enabling real-time traffic data to be obtained at a relatively low cost, reflecting the differences in road travel speeds at different times of day. In addition to Gaode Map, the measurement is also applicable to similar data services provided by Google Maps, ArcGIS for Developers and Uber Movement, among others (Shi et al., 2020). Despite the simple setup used in the case study (e.g., only the shortest route in time was selected as an accessibility indicator and three traffic conditions were set), the evaluation method used in the study can still be easily extended to larger areas, longer times, more facilities and higher sampling frequencies.

In addition, the weakness of this study exists, because lacking considering all complexity of flood emergency response to hotels. For example, the impact of disasters on society is a dynamic process, but this study does not consider the duration of floods. In addition, flooding may lead to disruptions in urban traffic networks, which in turn affect road speeds, but the study does not consider the impact of disrupted traffic on vehicle speeds. Finally, this study only included the hazard scenario of a one in a 100-year flood in the accessibility measurement model and did not consider the impact of more extreme scenarios, such as 500-year or 1,000-year flood on emergency accessibility.

When assessing the impact of urban flooding on tourism and emergency accessibility, future research work should, on the one hand, consider factors such as flood duration and flow rates. On the other hand, reference should be made to the impact of real disaster events on urban transport networks to provide more realistic spatial and temporal observations and simulations of urban road network traffic. In addition, multi-hazard scenarios can be combined with tourism disaster management to improve the resilience of the tourism industry in the face of multiple compound disasters.

6 Conclusion

This study introduces an empirical approach to assess the emergency accessibility of the tourism industry using traffic big data from Web GIS and numerical flood simulations, providing a typical case study and research paradigm for assessing the emergency response capacity of the urban tourism industry. The study demonstrates the practicality of this approach in the case of the hotel industry in central Shanghai, and provides recommendations for managing flood risk in the tourism industry, both from the government and from tourism enterprises and industry organizations.

The results show that: (i) access times are largely determined by congestion on the roads, and even in the absence of a flood scenario, almost all FRS arrival times at hotels are delayed when traffic conditions change. (ii) The extent to which flooding affects emergency urban accessibility depends on the prevailing traffic conditions, and when traffic congestion is more severe, the impact of flooding is also greater. (iii)The presence or absence of flooding and the prevailing traffic conditions can alter the fastest route from the FRS to the hotel, resulting in delays in emergency response times, and the selection of the most appropriate travel route is critical to enhancing the city's emergency response capability.

To improve the tourism industry's ability to cope with flooding, this paper proposes response strategies from both the government and tourism businesses and industry organisations. Using a combination of transport big data and scenario simulation, this study establishes a framework for assessing the accessibility of urban tourism to disaster emergencies. The results of the analysis can help hotel managers, emergency response agencies and other relevant stakeholders to better understand the impact of urban storm events on the tourism industry and helps to develop policymaking for flood risk management and hotel contingency planning.

Data availability. The results of the disaster risk simulation are taken from yin (2013), https://doi.org/10.1007/s10584-013-0749-9. The calculation process of emergency accessibility can be seen in 3.2 and 3.3 of this paper.

Author contribution. Q.Y. analysed the data and wrote the paper; Y.S. conceived and designed the research and edited the paper; Z.C., J.L., and Q.W. reviewed and edited the paper. All authors have read and agreed to the published version of the manuscript.

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