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Estimating the economic impact of natural hazards on shared accommodation in coastal tourism destinations

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ABSTRACT

The increasing number of natural hazards in coastal tourism destinations has negatively affected their local lodging industries. The recent boom in shared accommodation in coastal destinations is also under threat due to increasing sea levels and extreme weather events. Thus, estimating the economic impact of natural hazards on shared accommodation is a critical prerequisite for effective tourism destination crisis management. This study aimed to estimate the economic impact of natural hazards on shared accommodation. To achieve this purpose, HAZards U.S. MultiHazard (HAZUS-MH) hurricane/flood models were employed in a case study of Hurricane Irma and 822 Airbnb properties in Collier County, Florida, for 2017. The estimated direct combined losses from wind gusts and storm surge flooding were $22, 683, 054, and the indirect losses to rental income were as high as $19,120 per day. This estimation method can help individual owners and local government managers predict problems related to natural hazards and more effectively prepare for future hazardous events in coastal tourism destinations.

1. Introduction

Coastal attractions, such as scenic views, historic sites, and various beach-based recreational activities, have made coastal tourism one of the fastest growing areas of contemporary tourism in the world (Lithgow, Martínez, Gallego-Fernández, Silva, & Ramírez-Vargas, 2019). Local governments and businesses have invested in increasing tourism capacity, resulting in higher concentrations of infrastructure in coastal areas. The recent boom in shared accommodation also reflects the popularity of coastal destinations, as one-third of shared properties are near coastlines, based on Airbnb listings in 167 countries (Adamiak, 2019). According to a 2017 National Oceanic and Atmospheric Administration (NOAA) report (National Oceanic and Atmospheric Administration, 2019), ocean- and coastal-based tourism and recreation contribute $124 billion in gross domestic product to the U.S. economy. However, coastal areas are vulnerable to multiple natural hazards because such events occur at the dynamic interface between the ocean and land (Yang, Madden, Kim, & Jordan, 2012). Among all natural hazards, tropical cyclones are one of the most devastating threats to coastal tourism destinations (Gall, Borden, & Cutter, 2009; Mohleji & Pielke, 2014). The strong winds and heavy precipitation of tropical cyclones cause storm surges and flooding. These dangerous natural events can directly damage coastal tourism industries. For example, natural hazard events can cause critical infrastructure failures, which interrupt the supply and demand of the tourism industry (Faulkner, 2001; Lee & Harrald, 1999; Ritchie & Jiang, 2019); these events can also significantly influence the way in which tourists perceive a destination (Faulkner, 2001; Schumann, 2013; World Tourism Organization, 1998). In addition, the vulnerability of coastal tourism destinations will increase because of the combination of the rise in sea level and increases in extreme weather events due to climate change. Increased sea levels are expected to accelerate the severity of coastal flooding when tropical cyclones make landfall (Sweet & Park, 2014; Vitousek et al., 2017). Thus, the public and private sectors in coastal tourism destinations should have a comprehensive hazard management plan to ensure an economically sustainable tourism industry.

Tourists enjoy shared accommodation because of its less expensive prices, household amenities, and the possibility of obtaining more authentic local experiences compared to traditional hotels (Gutiérrez, García-Palomares, Romanillos, & Salas-Olmedo, 2017). According to estimates by Olson and Kemp (2015, pp. 1–76), shared accommodation may account for as much as 10% of all accommodation bookings in the

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U.S. by 2025. One of the most popular shared accommodation platforms, Airbnb, has more than 5 million listings in over 191 countries and collected more than $1 billion in tourism taxes in 2018 (Airbnb Inc, 2018, 2019a). Shared accommodation also has positive influences on the sustainability of local economies (Heinrichs, 2013; Palgan, Zvolska, & Mont, 2017). For instance, shared accommodation provides extra income for hosts and generates new work opportunities from underused assets, thus increasing the economic resiliency of a tourism destination (Palgan et al., 2017). As shared accommodation has emerged as a new socioeconomic phenomenon, recent research has focused on its business model (Gutiérrez et al., 2017; Oskam & Boswijk, 2016), accommodation performance (Lee, Jang, & Kim, 2020; Xu, Pennington-Gray, & Kim, 2021), regulation (Nieuwland & van Melik, 2020; Sklar & Edwards, 2017), user experience (Mansfeldt, 2015; Moreno-Izquierdo, Ramón--Rodríguez, Such-Devesa, & Perles-Ribes, 2019), and sustainability (Martin, 2016; Palgan et al., 2017; Yang, Kim, & Pennington-Gray, 2021a). Studies have also investigated the spatial patterns in shared accommodation (Gutiérrez et al., 2017; Quattrone, Greatorex, Quercia, Capra, & Musolesi, 2018) and their relationships with the traditional hotel business (Zervas, Proserpio, & Byers, 2017) and crime (Xu, Pennington-Gray, & Kim, 2019).

Although estimating the economic impact of natural hazards on shared accommodation is becoming increasingly important, there is still a lack of empirical research on this topic. For shared accommodation properties in coastal tourism destinations, hazard management is especially important because of the relatively high density of properties facing the threat of natural hazards. Hence, the purpose of this study is to empirically estimate the economic impact of natural hazards on shared accommodation. To achieve this purpose, Hurricane Irma in 2017 was selected as a hazard scenario and 822 Airbnb properties in Collier County, Florida, where several prominent coastal tourist destinations are located, was selected as a case study site. Considering the brief history of shared accommodation and limited data availability, this study focused on only the short-term impacts. Specifically, HAZards U.S. MultiHazard (HAZUS-MH) hurricane and flood models were employed to estimate the direct and indirect economic losses of Airbnb properties. The HAZUS-MH models were developed and are updated (Federal Emergency Management Agency, 2020) by the U.S. Federal Emergency Management Agency (FEMA), and they have been applied to quantify the impacts of natural hazards on humans and property as well as financial and socioeconomic aspects (Cummings, Todhunter, & Rundquist, 2012; Ding, White, Ullman, & Fashokun, 2008).

A comprehensive plan for hazard management involves multiple social levels, namely, the individual, community, and governmental levels. Previous studies have suggested that ‘bottom-up’ citizen-driven activities that are initiated by individuals and communities can improve local resilience (Thaler & Seebauer, 2019). Awareness of hazards might encourage individuals to purchase insurance and to invest in property improvements to mitigate their losses. At the community level, communications within a community help to integrate viewpoints and convey local knowledge, thus enhancing the quality of hazard preparation (Cronin et al., 2004). Alternatively, traditional ‘top-down’ hazard planning by the government is also important since hazard management requires a systematic vulnerability assessment and planning (Fuchs, Röthlisberger, Thaler, Zischg, & Keiler, 2017). Combining the previous literature with the hazard response and news articles regarding Hurricane Irma, this study also discuss the hazard management of shared accommodation at the levels of the individual host, community, and local government. The findings of this study enable individual shared accommodation owners and local government managers to better understand the short-term impact of hazard events, which is important for hazard preparation and mitigation, for ultimately providing guidelines for the formulation of sustainable coastal tourism destination crisis management and strategies.

2. Literature review

2.1. Natural hazards in coastal tourism destinations

As the tourism industry has become a very important source of income for coastal areas (National Oceanic and Atmospheric Administration, 2019), stakeholders should have a comprehensive hazard management plan to establish resiliency in the tourism industry. Faulkner (2001) adopted the response stages of communities from Fink (1986) and Roberts (1994) and suggested a disaster management framework for tourism destinations. Among all the process steps of his suggested framework, risk assessment is one of the first principal components for hazard managers to identify the potential impacts of hazards before further planning can take place.

To assess the impact of natural hazards, researchers have collected damage reports and economic loss information to develop numerical models for simulation, thus better preparing for and mitigating natural hazards (Ding et al., 2008; Pan, 2015). Previous studies have examined the impacts of natural hazards caused by tsunamis (Ismail et al., 2012), winter storm surges (Phillips & Jones, 2006), tropical cyclones (Sealy & Strobl, 2017; Tsai & Chen, 2011), and rising sea levels (Lithgow et al., 2019) in coastal areas. Take Venice as an example. Various studies have investigated the impacts of climate change, sea level rise and pluvial flooding on Venice tourism (Carbognin, Teatini, Tomasin, & ; Molinaroli, Guerzoni, & Suman, 2019; Sperotto et al., 2016). For instance, Sperotto et al. (2016) combined hazard, exposure, physical, and environmental vulnerability assessments to estimate the pluvial flooding risk in the Venice municipality and developed a regional risk map showing that 41% and 27% of commercial and industrial areas are located in very highly and highly vulnerable areas.

Among all natural hazard events, tropical cyclones have the greatest economic impact on coastal tourism destinations (Gall et al., 2009). Gall et al. (2009) applied four commonly used natural hazard loss databases to investigate the estimated economic losses from various natural hazards and found that in the U.S., from 1960 to 2005, tropical cyclone events caused the greatest economic loss, accounting for 27%–48% of the total losses. Kim and Marcouiller (2015) examined the vulnerability and resiliency of 10 coastal tourism destinations in the U.S. after tropical cyclone events and concluded that these events had a significant negative effect on regional economic performance (i.e. the proportion of the service industry in the economy and per capita income) and that areas with better economic conditions faced smaller economic losses.

The increased awareness of climate change has also brought more attention to the rise in sea level and the frequency of extreme weather events. Climate change can accelerate the threats from tropical cyclones by causing the sea level to rise and more frequent coastal flooding (Cooper & Chen, 2013; Sweet & Park, 2014; Vitousek et al., 2017). Combining climate change models and socioeconomic data, Mendelsohn, Emanuel, Chonabayashi, and Bakkensen (2012) estimated the regional economic damage from hurricanes in the year 2100. They suggested that North America will have the highest damage among all regions due to the increasing population and infrastructure in its coastal regions. Lithgow et al. (2019) integrated the migration status and long-term sustainability of the rise in sea level and the prediction of flood risk to study the vulnerability of tourist properties along the Mexican coast of the Gulf of Mexico and the Mexican Caribbean. They found that more than 60% of the study area is located in a region with a moderate to severe degree of vulnerability to the threat of climate change. These findings suggest that hazard management in coastal tourism destinations is becoming progressively more important for sustainable coastal tourism.

2.2. Modeling economic losses from natural hazards and HAZUS-MH models

Several studies have estimated the economic impacts of natural hazards on the tourism industry in coastal areas. Most previous studies have provided a general estimation of economic losses for the entire tourism industry based on taxable sales records (Baade, Baumann, & Matheson, 2007), resident population, personal income, real per capita income, and transfer payments (Coffman & Noy, 2012). One modeling method is the synthetic control methodology, which compares the economic parameters in an area with and without impacts to estimate the economic losses caused by an event (Abadie & Gardeazabal, 2003). Coffman and Noy (2012) utilized the synthetic control methodology to study the long-term impact of Hurricane Iniki in 1992 on Kauai, Hawaii. Their results showed that compared to the non-hurricane scenario, in the hurricane scenario, the population of Kauai is 12% smaller, and the island lost 3400 private sector jobs and $650 million in personal income from 1992 to 2009. While this method is a good way to model local/-regional economic losses, it does not have a spatial component, which makes it difficult to precisely calculate the degree of physical damage.

Thus far, only a few studies have specifically focused on estimating and modeling the economic losses of the lodging industry. Most studies have applied geographic information systems (GIS) to integrate environmental characteristics, social characteristics, hazard scenarios, and damage curves to estimate losses from natural hazards. For instance, Tsai and Chen (2011) integrated hazard, vulnerability, and financial analysis models to investigate the tropical cyclone and flooding risk of the hotel industry in Hualien, Taiwan. They listed hotels with high disaster potential and developed an index of risk factors to categorize hotel properties into three risk categories. Sealy and Strobl (2017) assessed the risk of loss for coastal properties in the Bahamas, which included residential, rental, hotel, infrastructure, business, and communal amenities. They applied pre-existing wind and storm surge damage curves as the damage functions and the cost of replacement values and potential annual income generated as the economic conditions for simulating the probabilistic cumulative losses from 4000 synthetic storm tracks. Their results showed that most of the potential losses came from storm surges, and a storm with a 50-year return period might cause $238 million in losses.

In the 1990s, FEMA started developing HAZUS-MH models by combining peer-reviewed and validated methods to assess the impacts of natural hazards with three separate models (i.e. earthquake, hurricane wind, and flood models), which in turn can be used to estimate the risk posed by natural hazards (Schneider & Schauer, 2006). In particular, two major steps of the modeling process include hazard and loss estimation analysis. Taking the flood model as an example, the user first inputs the flooding parameters, which include the flood surface and ground elevation, to determine the depth of the flooding. With the depth-damage curves, which indicate the flooding depth versus the property damage percentage, the HAZUS-MH model estimates the structural and content losses based on the depth of the flooding (Scawthorn et al., 2006a, 2006b). Several studies have used HAZUS-MH models to estimate the losses due to natural hazards, such as hurricanes (Pan, 2015), floods (Cummings et al., 2012; Remo, Pinter, & Mahgoub, 2016) and sea level rise (Shepard et al., 2012). Despite the urgent need to estimate the economic loss of shared accommodation, to date, relatively little research has employed HAZUS-MH models to estimate this type of loss. However, they have been used in other U.S. and international studies (Levi, Bausch, Katz, Rozelle, & Salamon, 2015; Park, Shin, & Cho, 2016). For instance, Pan (2015) applied the hurricane model to estimate the economic losses of residents and businesses from Hurricane Ike in the Greater Houston area. The results indicated that the estimated building damage loss was $24.5 billion, which was comparable to the insurance claims after Hurricane Ike. Given its established history, it is logical to apply this modeling approach to estimate the direct loss of shared accommodation properties. Note that this study followed the definition in HAZUS-MH modeling, where direct losses include physical damage to property and indirect losses include losses of income (Schneider & Schauer, 2006).

3. Study site and Hurricane Irma

Collier County is located in southwestern Florida. Aside from a few sand ridges and dunes along the Gulf Coast, most of the area is low-lying swamp and marsh land and was covered with cypress forests and prairies before its development (Davis, 1943). The highest elevation in Collier County is approximately 10 m in the north, and the majority of it is less than 5 m above sea level, with low relief (Fig. 1A). Most of the infrastructure and residential properties are distributed along the coast of the Gulf of Mexico, and a large portion of the land in the eastern part of the county is designated as conservation areas. According to the U.S. Census Bureau (2018), 31.5% of the population is older than 65. The top four industries in terms of employment in 2015 included retail trade (20, 775 people), accommodation and food service (19,066 people), health care and social assistance (17,561 people), and construction (13,302 people) (Westley, Weeks, & Beatty, 2017), which indicates that tourism and services associated with people who are retired are important income sources in Collier County. Airport passenger activity and tourist tax revenues show a strong seasonal trend in tourist activities, with the peak travel months being February, March, and April (Westley, Scheff, Breitbach, & Shannon, 2018). According to the U.S. Census Bureau (2018), 72.1% of the properties are owner-occupied, and the median property value is $316,200, which is much higher than that for Florida as a whole ($115,500) and the U.S. as a whole ($193,500). Collier County also has the highest-earning rental market in southwest Florida. The median monthly contract rent in Collier County was $918 in 2015. In 2015, there were 36,155 rental units, with 31% of them in the $750 to $999 range and 24% of them in the $1000 to $1499 range (Westley et al., 2017).

To better understand the spatial pattern in economic loss estimation, Collier County was divided into three zones based on distance to the coastline (Fig. 1B). Zone 1 is within 8 km of the coastline and is mostly west of Interstate 75 (I-75). It includes the most populated communities and famous tourist attractions, such as Naples Park, downtown Naples, and Marco Island. Zone 2 is between 8 and 24 km to the coastline and is approximately between I-75 and the west side of the Golden Gate Estate. A few subdivisions and communities, such as Golden Gate and Orange Tree, are included in zone 2. The last zone includes mostly inland areas with distances greater than 24 km to the coastline. The towns in zone 3, such as Immokalee and Ave Maria, are more than a 45-min drive from any public beach access. According to the data from AirDNA (2014–2016), 822 listings are entire homes, comprising almost half (48%) of all Airbnb listings in Collier County. Ninety percent (744/822) of these property listings are in zone 1. Zone 2 includes 9% (73 listings) of all Airbnb listings, and zone 3 has only 5 listings, accounting for the remaining 1% of Airbnb properties. The average daily charge and listing prices indicate that the coastal area (zone 1) has the highest rental income and listing prices. Finally, zones 1, 2, and 3 have similar occupancy rates, which are 0.14, 0.11, and 0.13, respectively (Table 1).

In Collier County, the Airbnb listings are clustered in the areas of Naples Park, downtown Naples, and Marco Island (Fig. 1B). According to the daily revenue data from October 2014 to October 2016, house properties produced the highest revenue out of all property types. The Airbnb market in Collier County has seasonal variation, with the period from June to September being the low season and the period from January to April being the high season. Among the three study zones, the coastal zone (zone 1) has the most listings, highest rental income, and highest improvement values (Table 1), which indicates that coastal amenities are the main driver of the Airbnb market in Collier County, similar to the real estate market in Florida's coastal communities overall (Chen & Fik, 2017). Naples Park, downtown Naples, and Marco Island have the highest density of Airbnb listings, and they are all close to the coastline. The spatial pattern in Airbnb properties also shows spatial concentration along major roads, such as State Road 40 and I-75 (Fig. 1B). Ave Maria also has a few Airbnb listings, but this is because of a local college and Catholic church instead of the attraction of its coastal

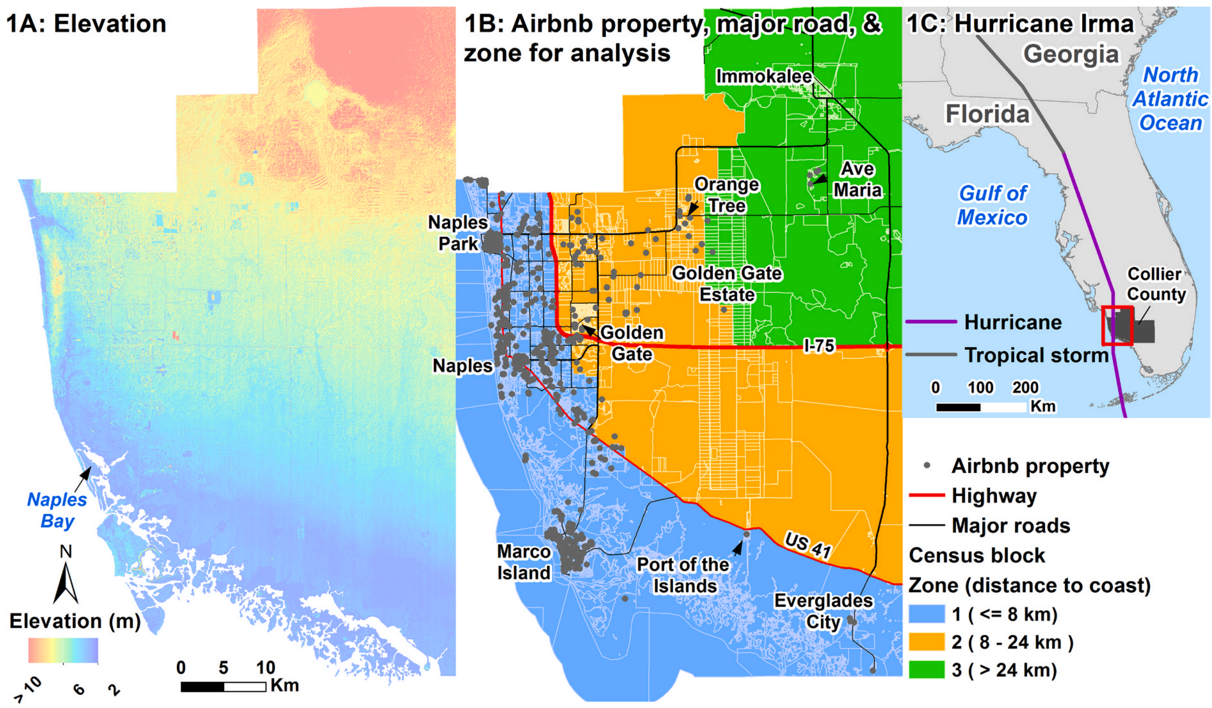

Fig. 1. Study area map for the elevation (A), the distribution of Airbnb properties, major roads, highways, and zones for the spatial pattern analyses (B), and the overview of Florida and the best track of Hurricane Irma (C).

Table 1
Information of Airbnb properties in Collier County, Florida.

Attribute	Zone		
	1	2	3
Number of Airbnb properties	744	72	6
Average daily charge (USD)	161	86	79
Average listing price (USD)	346	259	142
Total rental income in 2017 (USD)	4,586,599	215,499	28,021
Average occupancy rate (% year)	0.14	0.11	0.13
Total improvement values (USD)	178,608,645	18,950,780	970,564

Note. We divided Collier County into three zones based on the distance to coastline to determine the spatial pattern. The average daily charge was calculated based on the rental records on 2017, and the average listing price was the initial price when the hosts posted their listing.

amenities.

From August 30 to September 12, 2017, Hurricane Irma, which reached Category 5 intensity on the Saffir-Simpson Hurricane Wind Scale, was one of strongest and costliest hurricanes in U.S. history. Hurricane Irma was a Category 4 hurricane with sustained surface winds of 212 km per hour (km/h) when it made landfall in the Florida Keys on September 10, and it was a Category 3 hurricane, with estimated maximum winds of 209 km/h when it struck Marco Island in Collier County (Fig. 1C). Due to its strong intensity, Hurricane Irma caused storm surge inundation levels of 0.9–1.5 m above ground level in the study area. Approximately 6 million Florida residents were affected by Hurricane Irma. According to NOAA's National Centers for Environmental Information (NCEI), the wind and water damage in the U.S. caused by Hurricane Irma was estimated to be $50.0 billion (Cangialosi, Latto, & Berg, 2018). In Collier County, there was a great deal of wind and flood damage to structures, with 88 buildings destroyed and 1500 buildings badly damaged. In addition, Marco Island, Golden Gate and portions of Naples experienced heavy tree and utility pole damage and were without power for several weeks (Cangialosi et al., 2018). According to estimates by Tourism Economics (2018), in January 2018, the demand for hotel rooms decreased by approximately 11% compared to 2016, and Visa card sales from out-of-state visitors decreased by approximately 26% in the southwest region of the state. Thus far, a detailed estimation of the losses of the shared accommodation industry has not been conducted.

4. Method

To estimate the direct and indirect economic losses of shared accommodation from Hurricane Irma in Collier County, Florida, in 2017, HAZUS-MH models and Airbnb property data were applied in this study. Airbnb and parcel data were first compiled and imported into HAZUS-MH models. Both hurricane and flood models were utilized to compute the building damage loss from combined wind and storm surge damage to estimate the direct economic loss. The indirect economic loss was calculated based on the daily charge, listing prices, and occupancy rates, and calibrated with a seasonal index. To avoid the complexity of modeling the structural damage to multistory condominium properties, this study specifically focused on the Airbnb properties listed as in the 'entire home' category and assumed that these listings were one-story single-family houses. ESRI ArcMap 10.4.1 and FEMA HAZUS-MH 4.2 were utilized for data processing and analysis.

4.1. Data acquisition and preprocessing

Table 2 shows the dates and sources of the datasets used in this study. The Airbnb data was acquired from AirDNA, a database company for

Table 2
Data applied in this study.

Data	Date	Source
Airbnb properties	2017	AirDNA
Single family parcel (improvement value)	2018	Collier County Appraiser
National elevation model (1/9 arc-second)	2013, 2016–2017	The National Map, USGS
Best track for Hurricane Irma	2017	National Hurricane Center, NOAA

shared accommodation, which include the location of Airbnb properties and their operational information such as daily charges, listing prices, and occupancy rates. Parcel data was acquired from the Collier County appraiser, who provides the estimated land and improvement values of each residential property. The 1/9 arc-second National Elevation Dataset (NED) and the 2017 best track data were downloaded from the U.S. Geological Survey (USGS) National Map and the NOAA National Hurricane Center. Due to the lack of the physical addresses of Airbnb listings, the x- and y-coordinates of the Airbnb listings were coupled with the nearest single-family parcels with the GIS-based spatial join function. The individual Airbnb listings were then aggregated into the census block level for HAZUS-MH modeling.

4.2. Wind and storm surge simulations

Using the Comprehensive Data Management System (CDMS), which is a separate database management software for HAZUS-MH, the default dataset of single-family residences (RES1) was replaced with the aggregated Airbnb listing data. To estimate both wind and storm surge damage, two HAZUS-MH models, the hurricane and flood models, were built. The modeling started with the hurricane model by inputting a new hurricane scenario according to the best track data of Hurricane Irma (National Hurricane Center, 2017), which included times from the starting point of the hurricane, the radius of 118-km/h winds, the maximum wind speed, and the central pressure. While the hurricane model computed the damage from hurricane wind, it also used the hurricane parameters for Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and Simulating Waves Nearshore (SWAN) modeling, which are two built-in models in HAZUS-MH for simulating storm surges and wave heights (Federal Emergency Management Agency, 2018). According to the Naples tidal station (Center for Operational Oceanographic Products and Services, 2018), the tide was 1.62 m high around the time Hurricane Irma made landfall; therefore, 1.62 m was input as the initial water level for simulation. Once the hurricane model simulation was finished, flood model was switched to process simulation data and results. Coastal surges were selected as hazard type and elevation model was imported to couple with the storm surge elevation grid from the SLOSH model, and the wave height grid from the SWAN model to compute the flood depth and delineate the flooding area.

4.3. Economic loss estimation

To estimate the economic losses incurred by Airbnb properties in Collier County, both direct losses from building damage and indirect losses in rental income were considered. For the direct losses, the HAZUS-MH model was developed for calculating the damage to several types of properties (e.g. single-family houses, multifamily houses, commercial properties), and each type had different damage curves, which indicated the percentage of the cost of replacement based on the degree of impact. For example, the flood damage curve for building structures represented the relationship between the flooding depth and the percentage of the cost to replace the building. HAZUS-MH hurricane and flood models were applied to estimate the building damage from wind and storm surge separately and the combined wind and storm surge function in the flood model were computed, which is calculated as follows:

$$Max\ (W,\ F) \leq C \leq \min\ (W + F,\ 1.00) \tag{1}$$

where W is the percentage of building damage from wind, F is the percentage of building damage from storm surge, and C indicates the combined damage percentage from wind and storm surge. This combined matrix was designed to avoid overestimating the losses (Federal Emergency Management Agency, 2018).

For the indirect economic losses, the daily revenue loss was computed by the daily revenue per available room (RevPAR), which is one of the most widely used indexes for estimating performance in the hospitality industry (Peiró-Signes, Segarra-Oñ; Wei & Lee, 2009, pp. 853–856; Yang, Kim, Pennington-Gray, & Ash, 2021b). RevPAR was calculated as follows:

$$RevPAR = P^{ave} * O^{ind} \tag{2}$$

where P^{ave} indicates the average daily charge of individual Airbnb listings and O^{ind} denotes the occupancy rate for each listing. The Airbnb dataset from 2017 indicated that among 822 Airbnb properties, only 478 units had been occupied. To consider the potential indirect losses incurred by all the Airbnb properties, the daily potential maximum revenue per available room (PMRevPAR) was also computed as follows:

$$PMRevPAR = P^{list} * O^{ava} \tag{3}$$

where P^{list} indicates the listed property asking price and O^{ave} denotes the average occupancy rate. Both the direct and indirect losses were computed for the entire study site as well as for zones 1, 2, and 3 separately to determine the spatial pattern in the incurred economic losses. Finally, to calibrate the seasonal effect to the market, the seasonal index was calculated as follows:

$$Seasonal\ Index = monthly\ amount / average\ amount \tag{4}$$

Then, the seasonal index was applied to calibrate both RevPAR and PMRevPAR to estimate the monthly indirect economic losses.

5. Result

5.1. Wind and storm surge

The simulation results of wind and storm surge flooding showed two distinct spatial patterns (Fig. 2). The peak wind gusts ranged from 150 to 175 km/h, which were within the range of Category 1 and 2 hurricanes. One of the areas with stronger wind gusts occurred on Marco Island, which matched the landfall location. Compared to wind, storm surge flooding was concentrated in the south. Marco Island and Everglades City were two major cities located in the flood area, and the remaining areas were low-lying coastal swamps with limited population. The barrier islands and area around the lagoon bordering the Gulf of Mexico also suffered storm surge flooding, but the flooded area was small compared to that in the south. According to the damage percentage results, most of the Airbnb properties sustained minimal damage due to wind, but the damage sustained from storm surge flooding was concentrated in the communities near the south and west coasts. Everglades City and Marco Island had the highest storm surge flooding, ranging from 1 to 4 m. The west coast around Naples Bay and the west side of Naples Park had the most extensive flooding, which was up to 3 m.

5.2. Direct and indirect economic losses

The building damage estimates from the HAZUS-MH modeling results were used to assess the direct economic losses brought about by Hurricane Irma. The total building damages from wind, storm surge and their combination were $2,515,863, $20, 461, 428 and $22, 683, 054, respectively. The damage from storm surge was eight times higher than that from wind. In terms of the spatial distribution, unsurprisingly, the coastal zone (zone 1) sustained the most building damage compared to the other two zones; 98% of the total damage according to the combined hazard result, and the other two zones accounted for only 2% (zone 2) and 0.2% (zone 3) of the total damage. Interestingly, in zone 1, the storm surge damage ($20, 423, 348) was 9 times higher than the wind damage ($2,192,165); however, in zone 2, the storm surge damage ($38,080) was much lower than the wind damage ($279,635), and in zone 3, there was only wind damage ($44,063) and no storm surge damage. The average direct losses for individual Airbnb listings were $30,002, $4405,

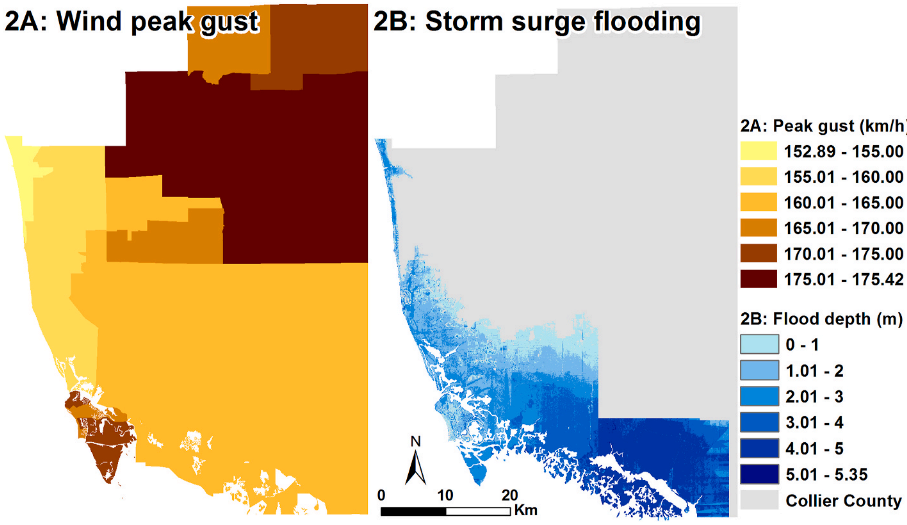

Fig. 2. Simulated results for wind peak gust (A) and storm surge flooding (B) from the HAZUS-MH models.

and $7343 for zones 1, 2 and 3, respectively (Fig. 3 and Table 3). The direct damage estimate was highly related to the spatial distribution of wind and storm surge. The storm surge damage was mostly distributed in the low-lying barrier islands and bay area, and the wind damage was spread out across the entire county (Fig. 4). However, the damage from storm surge flooding was much more severe than wind damage, which led to higher total and average direct losses in the coastal zone (zone 1).

The indirect losses incurred by the Airbnb market were estimated according to RevPAR and PMRevPAR. To calibrate the seasonal effect to the Airbnb market, a seasonal index of 0.50 in September (Fig. 5) was multiplied. After calibration, the total daily RevPAR and PMRevPAR were $13,126 and $19,120, which indicated the daily indirect loss of Airbnb income. Because of the spatial distribution of Airbnb listings in Collier County, the coastal zone (zone 1) had the highest estimated daily indirect losses, which were $12,282 and $18,038 for RevPAR and PMRevPAR (Table 3). Considering a one-month vacancy, the RevPAR and PMRevPAR for all of Collier County reached $393,780 and $573,600, respectively.

Table 3
The estimated direct and indirect economic losses from Hurricane Irma.

Type of economic loss	Attribute	Zone			Total
		1	2	3	
Direct loss (USD)	Number of properties	744	72	6	822
	Building damage (combined wind and storm surge)	22,321,837	317,154	44,063	22,683,054
	Average building damage	30,002	4405	7343	
Daily indirect loss (USD) – seasonal index calibrated	RevPAR	12,282	782	63	13,126
	PMRevPAR	18,038	1027	56	19,120

6. Discussion

6.1. Economic loss estimation of shared accommodation

As the purpose of this study was to empirically estimate the economic impact of natural hazards on shared accommodation, this study applied Airbnb data and HAZUS-MH modeling to calculate the direct and indirect economic losses from Hurricane Irma in Collier County, Florida, in 2017. The modeling results of wind and storm surge flooding were comparable to the Hurricane Irma reports by the USGS (Cangialosi et al., 2018). The highest observed wind gusts on Marco Island (209 km/h) and Naples Municipal Airport (227 km/h) were higher than our results, but this difference is because best track data was applied to model the wind hazards, which did not include the peak gusts that were locally observed. Conversely, the observed high water markers were 1.0 m–1.5 m on Marco Island and on the west coast of Naples (Fig. 2), which were similar to the modeling results. These estimates produced using the sophisticated models provide valuable information for increasing the resiliency and, in turn, the sustainability of coastal tourism destinations.

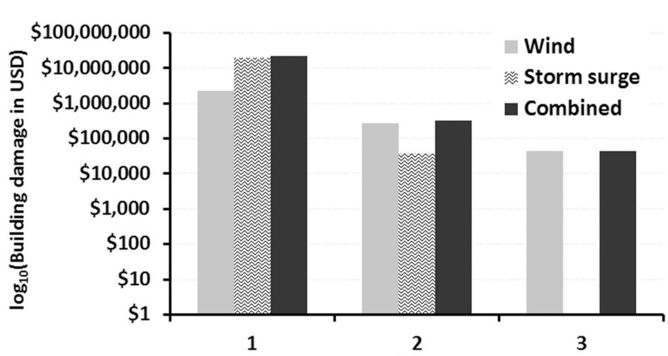

Fig. 3. The estimated building damage from wind, storm surge flooding, and combined hazards for the three analysis zones. Note that y-axis was $\log_{10}$-transformed to show a better visual comparison.

The overall economic loss estimation indicated that storm surge flooding caused much greater building damage ($20, 461, 428) than did wind ($2,515,863), and the estimated combined building damage was $22, 683, 054. The daily indirect losses from RevPAR and PMRevPAR were $13,126 and $19,120, respectively (Table 3). In spatial terms, the coastal zone (zone 1) had the greatest direct and indirect losses. This spatial heterogeneity of economic losses is because Hurricane Irma caused the most damage in areas that are in close proximity to the ocean; zone 1 had the most Airbnb listings. Additionally, the local variation in elevation relief and the high concentration of Airbnb properties in coastal zones due to coastal amenities led to the differences in the

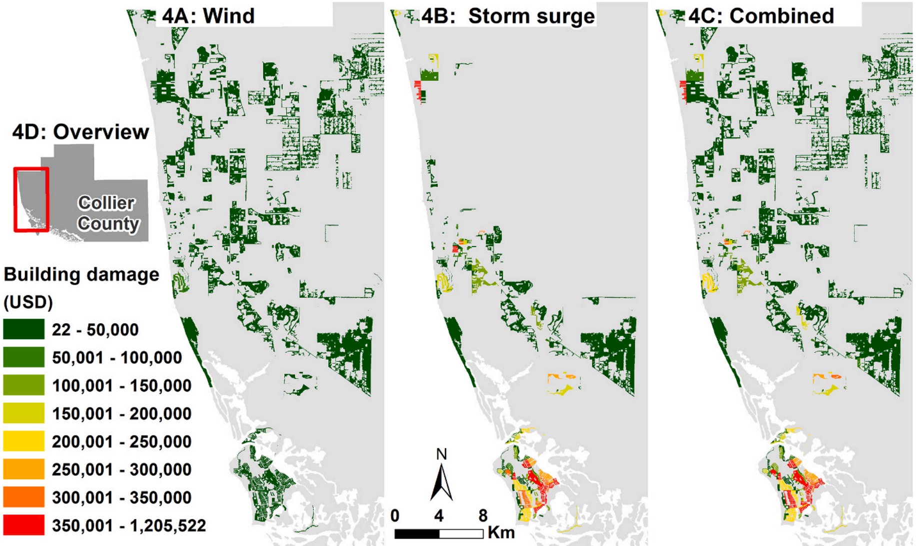

Fig. 4. Estimation of the building damage from wind (A), storm surge flooding (B), and the combined hazards (C). To demonstrate more details, only the area on the west coast of Collier County is presented, and the red rectangle indicates the zoomed-in area (D). Note that this census block layer from HAZUS-MH modeling excluded the areas without properties for a more accurate estimation. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

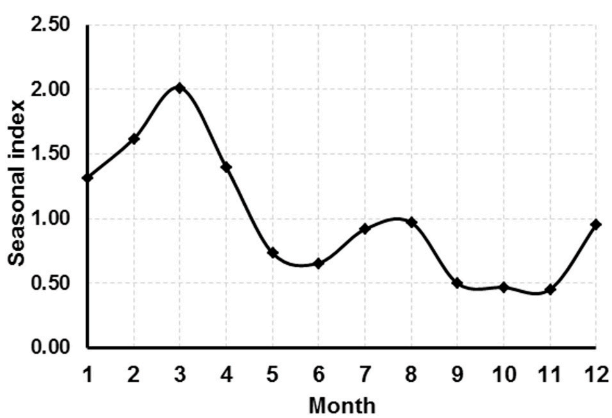

Fig. 5. Seasonal index according to the Airbnb revenue data from October 2014 to October 2016.

estimates. While Faulkner (2001) suggested that one of the first steps in conducting hazard management for tourist destinations is accurately identifying which areas are vulnerable to damage, the census-block-level analysis provided a great deal of comprehensive quantitative estimation and detailed mapping (Fig. 4) compared to prior studies (e.g. Lithgow et al., 2019; Scott, Simpson, & Sim, 2012). Outcomes of this study are beneficial for shared accommodation hosts and investors, as they can consult our estimates to maximize their investment by avoiding hazard-prone areas. For example, in Collier County, the sand ridge and dune area along the Gulf of Mexico (Davis, 1943) is less vulnerable to storm surge flooding than the surrounding low-lying areas. Therefore, communities south of Naples Park (Fig. 1A and B) are less vulnerable because of their relatively higher elevation and the presence of a wetland to buffer the impact from high storm surges.

6.2. Hazard management of shared accommodation

To develop a comprehensive hazard management plan for shared accommodation, individual hosts, communities, and local governments should all be involved. Insurance covers the losses of individual shared accommodation hosts; however, the current insurance program offered by Airbnb, Inc., mainly covers bodily injury or property damage caused by guests (Airbnb Inc, 2020). While local governments are starting to recognize the necessity of regulating shared accommodation, most policies do not require standardized insurance (Nieuwland & van Melik, 2020). In Collier County, some property owners were still waiting for approval from their insurance company and repairing damaged buildings up to a year after the hurricane hit (Beeson, 2018). An approach similar to that used in Collier County can also be applied to other hazard-prone areas for shared accommodation owners to better determine the vulnerability of their properties and prepare for the impacts of future hazards, for example, by improving construction and purchasing business insurance. By taking steps now as part of the pre-hazard event stage, hosts can prepare for the next hazard, reduce their long-term recovery time, and begin generating revenue more quickly after an event.

Studies on resiliency have shown that close-knit communities recover more quickly than communities with weaker social ties (Aldrich & Meyer, 2015; Dynes, 2006). Shared accommodation can be one of the connections for hazard responding in tourism destinations. Airbnb, Inc., launched the Open Homes program, which aims to encourage Airbnb hosts to list their properties for free to help displaced evacuees and deployed relief workers, in 2012 (Airbnb Inc, 2019b). Airbnb, Inc., posted requests as part of its Open Homes program from September 6 to October 12, 2017, during Hurricanes Irma and Maria in the Southeast U. S. (Airbnb Inc, 2017). Local and national media recognized this program and promoted it to the general public (Herrera, 2017; Shen, 2017; Trejos, 2017). According to a news article from September 9, 2017, 84 hosts in the Atlanta, Tallahassee, and Pensacola areas offered free accommodation to evacuees (Shen, 2017).

As some local governments have started regulating shared accommodation to compensate for the negative externalities that it causes (Nieuwland & van Melik, 2020; Sklar & Edwards, 2017), shared accommodation could play a more active and positive role in hazard management. In 2014, Airbnb, Inc., announced a cooperative agreement between the company and two cities: the Emergency Preparedness Partnership with San Francisco and Portland (Airbnb Inc, 2014; Napier, 2014). This agreement not only preidentifies Airbnb hosts who will commit to providing free accommodation, but also integrates platforms for educational materials and emergency information and offers community emergency response training. At present, this type of agreement is a good example of an integrated platform that bridges local governments and shared accommodation owners.

7. Limitations and future studies

Despite the significant practical implications of this study, several limitations exist. First, the findings of this study are limited by the use of basically required datasets when building the HAZUS-MH models. Tate, Muñoz, and Suchan (2015) estimated the uncertainties of the HAZUS-MH flood model by applying various digital elevation models, hydraulic models, building inventories, and depth-damage functions, and they suggested that user-supplied and up-to-date data are key to accurate estimation. For instance, using up-to-date datasets that have a higher spatial resolution, such as the Hurricane Research Division (HRD) Real-Time Hurricane Wind Analysis System (H*WIND), can enhance the accuracy of wind hazard estimation (Landsea & Franklin, 2013; Powell, Houston, Amat, & Morisseau-Leroy, 1998). In addition, an estimation model at the individual property level with detailed building characteristics (e.g. first floor height and building type) can improve the modeling accuracy (Chen, Fik, & Mossa, 2014). Another concern is the quality of the AirDNA data. Agarwal, Koch, and McNab (2018) investigated data from Virginia Beach, Virginia, and they argued that AirDNA does not utilize the Smith Travel Research (STR) standard to collect their data, which might induce bias in our estimates.

This study did not estimate the long-term impact of Hurricane Irma on Collier County. Few studies have suggested that the impacts of natural hazards or disasters on the local economies (Baade et al., 2007; Coffman & Noy, 2012) and the image (Faulkner & Vikulov, 2001; Ryu, Bordelon, & Pearlman, 2013) could be long-term. Therefore, future studies should estimate the long-term impact of Hurricane Irma to determine the recovery timeline of the shared accommodation industry. The recent impacts of coronavirus disease 2019 (COVID-19) (Dolnicar & Zare, 2020) might have combined effects on the study area, and further research is warranted to conduct an integrated assessment of the long-term impacts of multiple hazards.

8. Conclusion

Coastal areas are dynamic and attract many tourists, which results in high densities of infrastructure, including high densities of shared accommodation. Natural hazards such as hurricanes and the associated storm surges often have substantial direct and indirect impacts on tourism properties. A hazard management plan is therefore essential, and estimating the economic impact of natural hazards on shared accommodation is an important first step. This study applied HAZUS-MH models and used Hurricane Irma as a scenario to estimate the economic losses of 822 Airbnb properties in Collier County, Florida, to shed light on the short-term impact of natural hazards on shared accommodation in coastal tourism destinations.

The results indicated that the total estimated direct losses were $22, 683, 054 and that the daily indirect losses based on RevPAR and PMRevPAR were $13,126 and $19,120. The study site was divided according to distance to the Gulf Coast to explore spatial patterns. The results suggested that the coastal zone (zone 1) had the greatest direct and indirect losses because it had the highest density of listings and the most severe impact from storm surge flooding. This study provides an estimation of the short-term economic losses from hurricanes in the shared accommodation market in coastal tourism destinations. Combined with the modeling and estimation approaches, an integrated communication platform should be established and applied to other hazard-prone areas to build more resilient and sustainable coastal tourism destinations.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have approved the final version of manuscript. Further, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the Journal of Destination Marketing & Management.

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