Assessing the Spatial Distribution of Volcanic Risk for Tourists on the Island of Santorini

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Abstract

Tourists visiting the islands of Santorini, Greece, currently have little insight into the potential volcanic risks associated with the geographical location and geological conditions. To date, a wide body of research has mostly focussed on volcanism in and around Santorini, both past and present. In recent years, the number of tourists that visit Santorini has increased significantly (2.3 million in 2019) and this is expected to keep growing. Volcanic risk and the potential impact this may have for tourists and tourism has not yet been researched. Whilst the local authorities in Santorini have produced a general emergency response plan (named 'Talos'), the connection between the volcanic risks and the distribution and understanding of tourists' specifically has not been assessed. This study begins to address this gap, spatially highlighting the risks to tourists on Santorini as well as gaining insight into their perceptions of volcanic risk. Using a mixed-methods approach; a tourist-targeted questionnaire, a spatial survey of tourist accommodation, and GIS mapping of risks associated with an eruption. This study shows that the most popular tourist areas (for hotel accommodation or for visiting) are also those of highest risk. It also reveals that tourists have an inaccurate perception of volcanic risks, and of which areas of the islands are most or least at risk in the event of an eruption. From this work it is recommended that further research be conducted into how best to educate tourists of the risks whilst not deterring them from visiting Santorini. The emergency plan should also be updated to account for tourism on the island.

Acknowledgments

This study would not have been possible without the support and guidance of my supervisors. I wish to thank Dr. Chris Satow, who has been encouraging, determined and a source of knowledge throughout this process. Ever since the initial email, outlining my interest in doing a MSc by research on an area (Santorini) that we had worked on before up until the complete version, he has been available to run through ideas and issues whenever needed. Prof. Adrian Parker for providing necessary attention to detail as well as extensive knowledge to all areas of research. Prof. Helen Walkington, for her expert knowledge on areas of research that I had little experience on, she guided me through the production of a questionnaire that was key to this study. Also my thanks must go to Alex Friend for his specialist support on the use and implementation of ArcGIS within this study, a programme that I had no knowledge of beforehand.

A section of the data used in this study was only available thanks to the kind contribution of Susanna Jenkins (Assistant Professor at Earth Observatory of Singapore). Making available data from her paper 'Rapid emergency assessment of ash and gas hazard for future eruptions at Santorini Volcano, Greece', meant this study could really look at the genuine risks to tourists visiting and therefore a massive thanks to her for allowing us to use it. Finally, I wish to thank Georgios Vougioukalakis, who has given an insight into the research and planning that has already been carried out in Santorini regarding future volcanic activity, giving a point of view from those involved with the decision making process, allowing this study to see both sides of the issues.

Contents

1.0 Introduction

Santorini, located in the Southern Aegean Sea, is the southernmost of the Cycladic Islands (Sarantakou and Terkenli, 2019). The island has a population of around 15,000 people (Hellenic Statistical Authority, 2011) and a southern Mediterranean climate (Sarantakou and Terkenli, 2019). It is the site of one of the most active volcanic complexes in Europe and is the most active volcano in the South Aegean Volcanic Arc (Jenkins et al., 2015). The complex as whole comprises five islands: Thera, Therasia, Aspronisi, Nea Kameni and Palea Kameni (Vespa et al., 2006) as can be seen in figure 1.1 below.

The people of Santorini are seemingly reliant on the existence of the volcanic complex. Santorini is a world-famous tourist destination (Sarantakou and Terkenli., 2019) and the volcanic complex is a key reason for the millions of tourists visiting the island every year (Medova, Mackova and Harmacek, 2021). Tourism is the largest contributor to the island's GDP. Furthermore, with the large amount of tourism that comes to the island, so does development to the island's infrastructure and social development, such as the modernization of the local community (Delitheou and Georgakopoulou, 2017). Without the volcanic activity of the island, it could be hard to see Santorini as developed as it is. In addition, the traditional aspects of life, such as farming would be far less productive if it were not for the fertile volcanic-rich soil (Loughlin et al., 2015). However, it is known that a previous eruption dated back to 3.5 ka years ago (Druitt et al., 1989) within the complex was one of the largest recorded in human history (Jenkins et al., 2015) and therefore the volcanic complex, although important for tourism and agriculture, is one where the understanding the processes and risk is also vital.

Santorini is not unique in the way that its history and future volcanism acts as a source of tourism, however, the likelihood of another eruption (Pyle and Elliot, 2006) and the apparent lack of emergency planning (Dominey-Howes and Minos-Minopoulos, 2004; Vougioukalakis et al., 2016) currently highlights it as an area in need of study. Not only do the locals need to be prepared for the possibility of an eruption but so do the millions of tourists known to visit each year (approximately 2.3 million visited the island in 2019 (Medova, Mackova and Harmacek, 2021)). This study hopes to highlight the need for this preparation specifically for tourists, showing their perception of the risks as well as showing the genuine volcanic risks present in Santorini. To demonstrate this, the study intends to map the risk occurring from the most likely eruption scenario in relation to the most popular tourist areas.

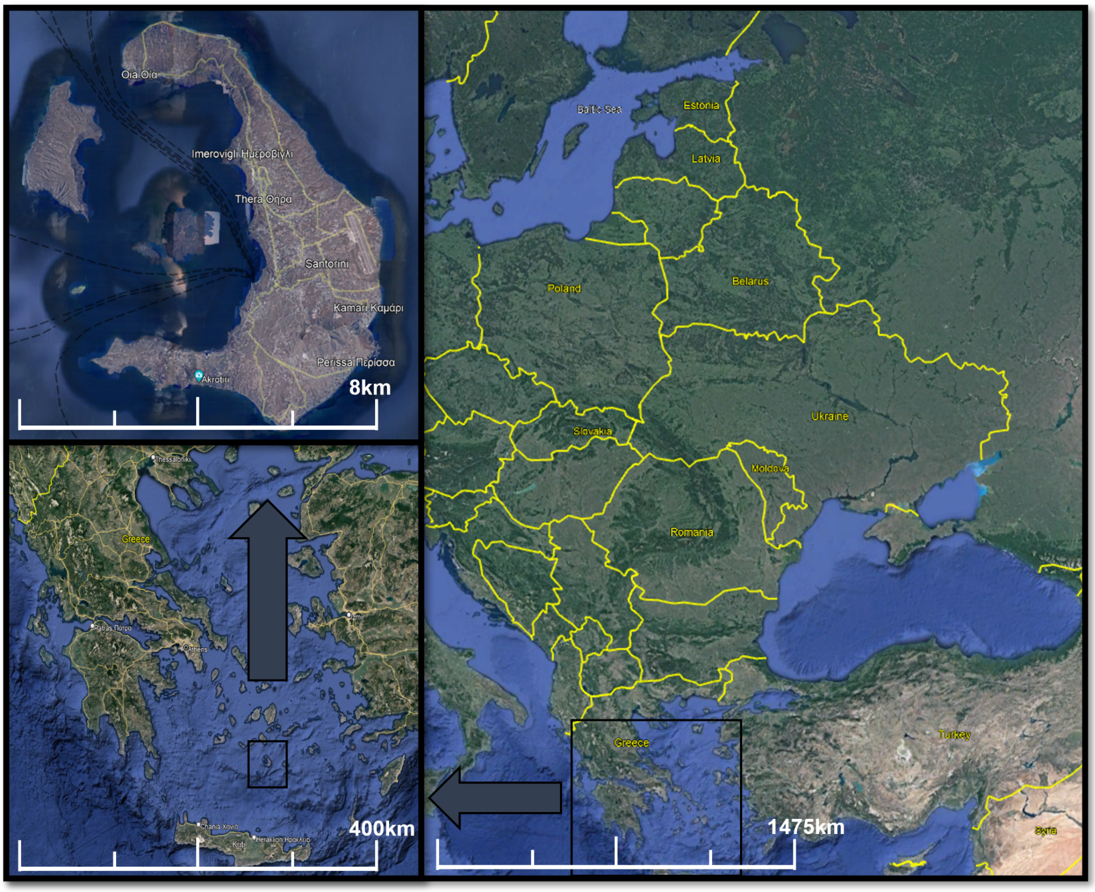

Figure 1.1, Google Earth imagery showing the location of Santorini within the Eastern Mediterranean.

1.1 Volcanic History and Background

Volcanic and seismic activity from the Santorini complex has been recorded over the past 650 ka with activity continuing to the present day (Druitt et al., 1999). Activity has varied through time from periods of slight unrest, such as in 2011-12, to large scale events, such as the Minoan (LM) (or Late Bronze Age) eruption that occurred around 3.6 ka years ago (Druitt et al., 1999). In terms of major pyroclastic eruptions, twelve have been recorded (Druitt et al, 1989 and Pyle and Elliot, 2006) (Table 1.1), which occurred during two main explosive cycles over the last approximately 200 ka (Druitt et al.,1989). The LM eruption was the last major event to have occurred in the second explosive cycle making this the most recent of the major pyroclastic eruptions. The LM eruption has been studied extensively (Dominey-Howes and Minos-Minopoulos., 2004) and provides information from the mechanisms that occur to the hazards and risks that result from such large-scale eruptions. The scale of the LM eruption can be put into perspective as it is thought to have contributed to the demise of the Minoan civilization and is regarded as one of the largest eruptions in human history (Jenkins et al., 2015).

The geophysical reason behind the volcanic activity on Santorini, is that it is part of the South Aegean Arc. The South Aegean Arc is the surface representation of the subduction of the African plate below the Eurasian plate (Druitt et al., 1989; Dominey-Howes and Minos-Minopoulos, 2004; Vespa et al., 2006). Furthermore, the volcanic activity is heavily influenced and linked to two tectonic lineaments, namely the Kameni Line and the Columbos Line (Druitt et al., 1999; Vespa et al., 2006). A considerable amount of the volcanic activity has occurred along the Kameni line (Druitt et al., 1999). This line has also been associated with the reasoning behind the numerous caldera collapses that have occurred throughout the volcanic history of Santorini. This shows the Kameni line to be a key boundary and weakness (Druitt et al., 1999), which is highlighted through the eruption history of the complex. Along with these two tectonic lineaments, the major volcanic activity that has occurred most recently has focused on a deep NE-SW basement fracture which acts as a primary pathway for magma to ascend (Druitt et al., 1989). This fracture or fault is a key driver of seismic activity, which has at times been responsible for damaging key infrastructure and buildings in the recent past. For example, an earthquake hit and severely damaged the town of Oia in July of 1956. The magnitude of the earthquake was measured at 7.8 on the Richter Scale (Mercalli intensity X) and resulted in 53 deaths on the island of Thira (Druitt et al., 1999), demonstrating the magnitude of seismic activity along this basement fracture.

Furthermore, the extent of historic volcanism around Santorini is manifested through the creation of the islands of Palaea Kameni and Nea Kameni. Both islands have been formed due to volcanic activity that has occurred in the complex. It is thought that creation of these islands began soon after the LM eruption, as the lavas found there are all post-Minoan in age (Druitt et al, 1999; Dominey-Howes and Minos-Minopoulos., 2004). The most recent eruption on the Kameni Islands was in AD 1950; having supposedly broken the surface in 197 BC (Druitt et al., 1999). Due to these two islands being much more recent formations, the history of volcanic activity is far less detailed than that preserved so well in the cliffs of Therasia (Table 1.1) but Druitt et al., (1999) did produce a very brief chronology that is summarised in Table 1.2.

Table 1.1, The 12 Major Pyroclastic Eruptions and their dates (Druitt et al., 1989)

Name of Pyroclastic Eruption	**Time at which it is thought to of occurred**
Cape Therma 1	Cycle 1 (<940 ka)
Cape Therma 2	Cycle 1
Cape Therma 3	Cycle 1
Lower Pumice 1	Cycle 1 (~100 ka)
Lower Pumice 2	Cycle 1 (~100 ka)
Cape Thera	Cycle 2
Middle Pumice	Cycle 2 (~79 ka)
Vourvoulos	Cycle 2
Upper Scoriae 1	Cycle 2 (~54 ka)
Upper Scoriae 2	Cycle 2 (~37 ka)
Cape Riva	Cycle 2 (18 ka)
Minoan	Cycle 2 (3.5 ka)

Table 1.2, chronology of the Kameni Islands (adapted from Druitt et al., 1999)

Date	**Description of Activity occurring**
197 BC	Cone called Iera formed from explosive activity. No longer visible as now thought to be below sea level.
AD 46-47	Thia island (Now known as Palaea Kameni) formed through extrusive activity.
AD 726	Seven centuries of repose was followed by explosive activity near Palaea Kameni.
AD 1570-73	Activity moved to the northeast and in so doing formed Mikri Kameni.
1707-11	An eruption of very slow extrusion lava started on Mikri Kameni along with later eruptions of both extrusion and explosive, leading to the formation of Nea Kameni.
1866-70	Slow lava extrusion was at the beginning of the eruption. After a couple of days there was some explosive activity, with a 2km eruption column.
1925-28	This activity began with jets of water and then was followed with lava and explosive activity. These eruptions shifted to the northeast and the centre of Dafni. There was a long period of repose from May 1926 till January 1928 and then came extrusive activity finishing the eruption.
1939-41	Submarine explosions started this eruption. The centre then shifted to the centre of Nea Kameni. The lava extrusion built up flows and domes of Ktenas, Fouque, Smith-Reck, and Niki.
1950	First was some phreatic activity and then extrusion of the Liatsikis lava. The final phreatic phase created the twin-tunnel crater.

1.1.2 Seismic background

Connected with all volcanic activity is seismicity. This activity is strongly linked to the tectonic system and volcanic processes (Papadimitriou et al., 2015), with the deep NE-SW basement fracture being where most seismic activity is seen. This can be seen in figure 1.2 where the pattern of epicentres follows a NE-SW direction, as they are closely following the Kameni line (Druitt et al., 1999) (section 1.1.1). Northeast of the Santorini islands, where the submarine Columbo Volcano is located, is where the most activity is situated. Figures 1.2 and 1.3 show the amount of seismic activity that has occurred in the area between 1966 to 2011 (Chouliaras et al., 2012) and 2012 to August 2021 (University of Athens - Earthquake Catalogue Search (uoa.gr)). Figure 1.2 is derived from the work of Chouliaras et al (2012), whilst figure 1.3 was produced in ArcGIS, using data provided by the Institute of Geodynamics, National Observatory of Athens. The figures show there to be a much greater density of activity northeast of the island in comparison to the rest of the area shown. This demonstrates that this is a hazard that needs to be considered moving forward as highlighted by the previously mentioned earthquake that struck Oia in 1956.

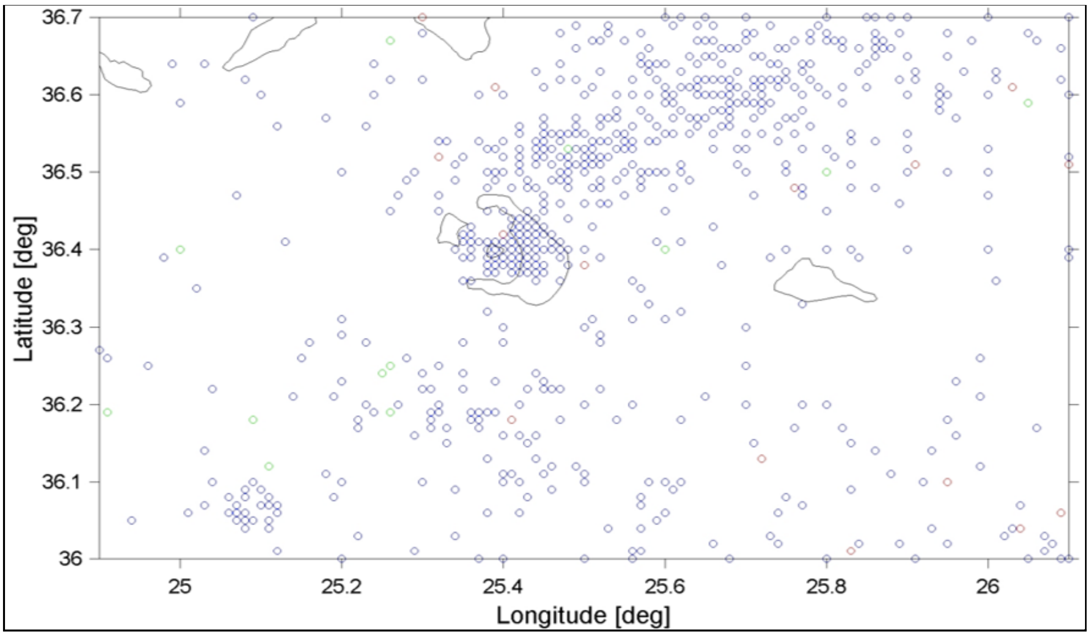

Figure 1.2 Seismicity recorded between 1966 and the end of 2011. The circles show earthquake epicentres, with the NE-SW trend seen reflecting the Kameni Line (from G. Chouliaras et al., 2012)

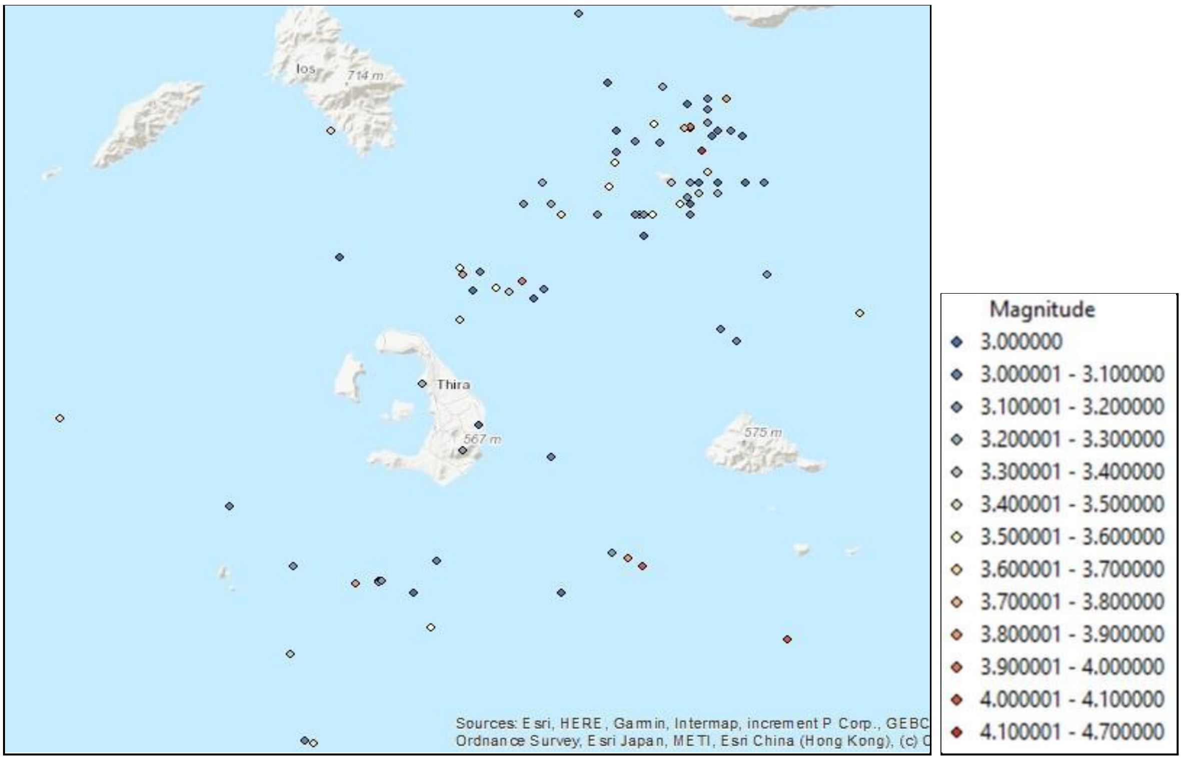

Figure 1.3 ArcGIS map showing the seismicity recorded between Jan 1st 2012 to Aug 1st, 2021. Note the scale of seismic events shown by the colour of each diamond.

1.2 The Human Dimension of Santorini

Previous work relating to tourism in Santorini is plentiful with a strong focus on the geological history of the island. Medova, Mackova and Harmacek (2021) highlight in their literature review the large number of websites that provide general information on the island's tourism statistics as well as listing many of the previous works that have highlighted tourism of Santorini. The resident population of Santorini is approximately 15,000 people (Hellenic Statistical Authority 2011) but the number of tourists visiting the island is continually increasing, with some 2.3 million people visiting the island in 2019 (Medova, Mackova and Harmacek, 2021). With increasing visitor numbers, most recent work has focused on the issue of over-tourism that is affecting, and will continue to affect, the island if it is not properly managed.

In terms of the type of tourists that Santorini attracts, it is popular with the younger traveller with a smaller budget, however, parts of the island are increasingly expensive and therefore the island does get regularly visited by the wealthier traveller as well (Dominey-Howes and

Minos-Minopoulos, 2004). Oia is one of the most popular destinations on the island, but it is also the most expensive town in terms of accommodation (Stanchev, 2018).

When looking at the infrastructure for tourism to the island, Santorini welcomes many tourists by air, but cruises to the island are quickly becoming the most popular way for tourists to visit the island with between 780,000 to 900,000 people arriving via cruise ship annually. Although many think that Santorini benefits economically, it was calculated that in 2016 it only received 55.8 euros of income per cruise ship passenger (Stanchev, 2018). This number is small, especially when there is a considerable need to upgrade infrastructure to deal with the ever-growing number of tourists visiting the island, whilst also keeping up the development of the other sectors of the economy such as agriculture.

The primary sector (i.e. the agriculture and mining industries) of the island is now becoming an issue as tourism becomes ever more the sole focus of the island (Delitheou and Georgeakopoulos, 2017). Furthermore, the tourist activity on Santorini that is required to push development is seasonal (Medova, Mackova and Harmacek., 20201). As a result, most hotels and restaurants close during the winter months, thus largely affecting the economy for this period of the year. Developing winter tourism is difficult due to strong winds that occur during that time of year, thus prohibiting travel to Santorini (Delitheou and Georgeakopoulos, 2017). This highlights the need to maintain and improve the primary sector as well as the general infrastructure of Santorini to support the island and its huge tourist activity.

Recent work, undertaken by Sarantakou and Terkenli (2019), highlighted that within a very dense population, local residents are withdrawing themselves from the high tourist areas as tourist accommodation takes over. The takeover by tourist accommodation can be seen in the increase of hotels since 2015, which has risen from 280 to 313 in 5 years (Hellenic Statistical Authority) and the population density in Santorini is 200.9 inhabitants per square kilometre (Sarantakou and Terkenli, 2019). With the movement of local residents, some areas of the island are going to see an even higher population density. Areas that are increasing the number of permanent residents include Kamari and Perrisa (Delitheou and Georgakopoulou, 2017) and the issue can be seen as Kamari already has the highest density population of the island (433 residents/km^2) (Batzakis et al., 2020). This highlights the serious issue of over tourism on the island and the reason as to why the focus from previous studies has been specifically on this issue.

It is important to note the work of Medova, Mackova and Harmacek (2021) as the tourist industry surrounding Santorini is currently being affected by current travel restrictions implemented due to the Covid-19 outbreak. Restrictions include certain countries not being allowed to travel abroad. For example, no travel from any countries within the European Union would cost Santorini 71% of the tourists that visited in June 2016 (Hellenic Statistical Authority). The most recent tourist numbers visiting the island are not a true representation of those visiting prior to the global outbreak of Covid-19, with the 2020 bringing a 65% decline in overall tourist numbers, with the numbers dropping from approximately 2.3 million tourists transported to the island in 2019 to just over half a million in 2020 (Medova, Mackova and Harmacek, 2021).

1.2.1 Santorini's Advertising

The initial perceptions of tourists to the island will always be built through what is seen through the advertising of the island, whether this is through brochures, websites or other forms of media. Through previous research it has been found that individuals select elements from media reports and use their own frame of reference to create an understanding and meaning when looking at natural hazards and the risks (Wachinger et al., 2013). Therefore, it is important to review what advertising of Santorini is available for prospective tourists to see. This will focus here only on advertising in English as this investigation only surveys tourists who can speak English. Is it advertised that there is genuine risk in visiting this volcanic island or is the risk of the island hidden behind the obvious natural beauty? Research in this area is largely untouched by academics with the exception of extreme/adventure (natural hazard) tourism where the risk is one of the primary attractions (Kane and Tucker, 2004). Therefore, what is stated below remains relatively unexplored within the academic literature but hopes to stimulate a greater research focus and understanding into this area of tourism marketing.

Lonely Planet, a well-known large travel guidebook publisher, also produces website pages on tourist attractions. Although mentioning that when sailing into Santorini you are above the drowned volcano (Santorini travel | Greece, Europe - Lonely Planet, 2021), there is no mention of volcanic activity within the area. When going further into the Lonely Planet website and finding the page titled 'Santorini for first-timers', this does mention the volcanic history but does not mention any recent activity or the possibility of future activity.

The second website to look at is www.greeka.com, which has a specific page about Santorini. This page goes into more detail about the history of the volcanism of the island, giving it as the reason for the amazing landscape that surrounds you on the island. However, it again does not go into any recent activity or the possibility of future activity. By not mentioning this, it could be argued that it leaves tourists unaware of the possibility of activity while they are planning on visiting.

In addition to the two previously mentioned websites, the final website looked at is that of Santorini.net (Santorini.net - The comprehensive guide to Santorini, Greece), which is the third website that comes up when searching for Santorini on Google. Here, under the heading 'About Santorini' there are pages outlining the geography and geology of the island. These pages go into some details about the history of the volcano and explain that the most recent activity has come from the islands of Palaea Kameni and Nea Kameni. This website does provide links to research undertaken on volcanism, for example, figure 1.4 below shows a Volcanic Hazard Zonation map produced by Fytikas and Vougioukalakis (2005). However, what must be noted is that the information is not easily understandable for a tourist. Furthermore, it dates back to 1996 and the more recent research is not highlighted on the website or available to tourists to see. Therefore, not allowing visitors to be properly informed as to the situation regarding the island.

To highlight this further, the methodology for this project includes a questionnaire of current or potential tourists and through this will show whether they are aware, when planning and travelling to the island, as to possible hazards and risks.

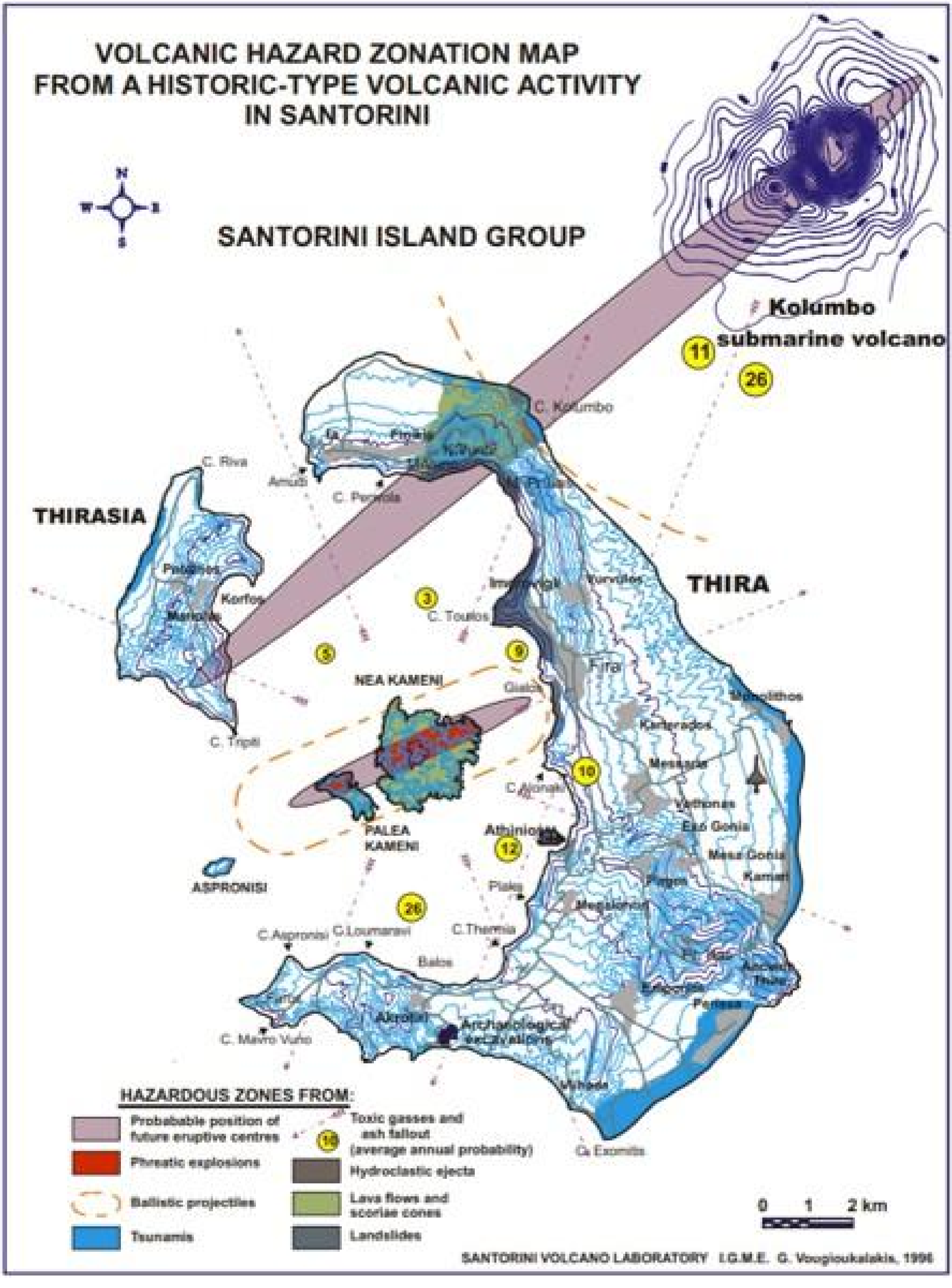

Figure 1.4, The Volcanic-Hazard Zonation Map produced by Vougioukalakis (1996) and available on the santorini.net website and so therefore the latest available information to tourists visiting the island. The arrows show the toxic gases and ash fallout

1.3 Volcanic Risk Background

Risk assessment general

It is estimated that 800 million people live within 100 km of a volcano that has the potential to erupt (Loughlin et al., 2015). Therefore, volcanic risk is something that is having to be assessed and dealt with globally. To be able to fully understand this, it is first important to define risk and from this volcanic risk. Bird, Gisladottir and Dominey-Howes (2010) use the definition from UNISDR (United Nations International Strategy for Disaster Reduction) (2009, p.25) "*the combination of the probability of an event and its negative consequences*". Using this for risk, it can then be said that volcanic risk is the probability of volcanic activity and the negative consequences that could occur from that activity.

In terms of the documented number of lives lost from volcanic eruptions, this is estimated to be approximately 280,000 since 1600 AD (Auker et al., 2013). Loughlin et al. (2015) highlights that although this number is relatively modest in comparison to other natural hazards (e.g. flooding), only a small number of eruptions are responsible for a large percentage of those fatalities, emphasising the risk that can be associated with one eruption. The magnitude of an eruption can be put into perspective through the Volcanic Explosivity Index (VEI), which gives a general indication of the explosive character of the eruption. This is undertaken by giving an eruption a value between 0 and 8 taking into account numerous factors including; magnitude, intensity, destructiveness, dispersive power (although this is less regular), violence, and energy release rate (Newhall and Self, 1982). An example of this is for the 2010 Eyjafjallajokull eruption had a VEI of 3 (Gudmundsson et al., 2012) whilst the Krakatoa eruption of 1883 had a VEI of 6 (Polvani and Camargo, 2020). Furthermore, it is not just the physical loss of life that comes under volcanic risk, there is also the economic aspect. The 2010 Eyjafjallajökull eruption in Iceland, although having no direct fatalities, had a huge economic impact (Costantini and Thierry, 2012) globally as large amounts of European air traffic was disrupted by the volcanic ash cloud that was generated by the eruption. It is estimated that airlines lost a total revenue of US$1.7billion (Ragona et al., 2011). The global economic loss accumulated to around US$5 billion (Ragona et al., 2011; Loughlin et al., 2015).

There have been many assessments of the risk and hazards associated with volcanoes globally. One example is that by Scaini, Folch and Navorro (2012), who undertook a tephra hazard assessment of Concepcion Volcano in Nicaragua as it is seen that the tephra fallout from it could jeopardise surrounding populations, whilst the possible ash clouds would have ramifications on the air travel in the region. Another more extreme example is assessing the possible ash fall distribution in the event of a super eruption from the Yellowstone volcano (Mastin, Van Eaton and Lowenstern, 2014). Although through the assessment it is seen with 99.9% confidence that 21st century society will not experience an eruption from the Yellowstone volcano (Mastin, Van Eaton and Lowenstern., 2014), the assessment was undertaken to characterise the potential effects of such an event. Along with these two cases there are many more examples of assessments and forecasting undertaken on volcanoes across the globe (Solana et al., 2008, Lindsay, 2010, Roberts et al., 2011, Marzocchi & Bebbington, 2012, Wadge et al., 2014)

1.3.1 Volcanic risk on Islands

Some countries have had large amounts of research undertaken into their volcanic risk, for example, Iceland, an extremely volcanically active island. The Bird, Gisladottir and Dominey-Howes (2010) study outlines volcanic risk and tourism in southern Iceland, which examined the implications for hazard, risk and emergency response education and training. Iceland, and many other island nations or municipalities, are often either actively volcanic or have been volcanic in the past. By being an island, this brings its own risks and hazards when faced with any possible natural disaster (Kelman et al., 2011). With many islands comes generally smaller populations and resource constraints which can, in turn, limit the technical capacity of the island to deal with challenges that can arise from natural hazards (Kelman et al., 2011; Hay, Forbes and Mimura, 2013). Research has been undertaken by Pelling and Uitto (2001), which investigated the natural disaster vulnerability and global change with respect to Small Islands Developing States (SIDS). This research helps to show the risk and vulnerability there is to islands, not just those defined as SIDS but also islands such as Santorini as the issues highlighted are comparable. SIDS are seen to have small populations, limited resources, and susceptibility to natural disasters (United Nations Division for Sustainable Development-SIDS-List of SIDS, 2007).These factors can also be seen on the island of Santorini, which clearly has a small population (~ 15,000 people (Hellenic Statistical Authority, 2011)), limited resources (Lichrou, O'Malley and Patterson, 2017) and the susceptibility to natural disasters is evident. Within their study, Pelling and Uitto (2001) highlighted the intrinsic vulnerability that comes in small islands, and it is these that bring a large component of volcanic risk to islands. Figure 1.5 below highlights these vulnerabilities for Santorini specifically having been adapted from the work of Pelling and Uitto (2001), while Table 1.3 highlights some of the most impactful eruptions to occur on islands worldwide over the last few centuries.

Small size
- Limited natural resource base
- Immediacy of interdependence in human-environment systems

Insularity and remoteness
- High external transport costs
- Time delays and high costs in accessing external goods
- Delays and reduced quality in information flows

Environmental Factors
- Small exposed interiors
- Large costal zones

Disaster mitigation Capability
- Complacency

Demographic Factors
- Limited human resource base
- Small Population
- Rapid population changes (Tourism effect)

Economic Factors
- Dependence on external finance
- Small internal market
- Dependence on natural resources

Figure 1.5 Small island vulnerabilities to natural disasters, as is the case for islands such as Santorini island (adapted from Pelling and Uitto (2001)

Table 1.3 Selected island eruptions and a description of effects these eruptions

Name of Volcano (Location) *References*	**Date**	**Description of eruption and effects**
Krakatoa (Indonesia) *Mandeville, Carey, and Sigurdsson (1996)* *Carey et al. (2000)* *Mutaqin et al. (2019)*	**1883**	**A famous eruption as it is one of the deadliest volcanic eruptions in modern history. Estimates suggest over 36,000 people died, with the tsunamis that followed being the major hazard along with serious pyroclastic flows. The eruption is thought to have happened due to pressure build up for the neck plugging in previous eruptive activity. The magma chamber was ruptured during the initial explosion which allowed water to come into contact with hot lava creating a phreatomagmatic event. The island is now becoming a popular tourist destination as it is only three hours from Jakarta (Capital of Indonesia).**

Montserrat (Caribbean) *Young et al. (1998)* *Skinner (2018)*	**1997**	**A phreatic eruption occurred after a three-year period of heightened volcano-seismic activity (Young et al., 1998). This eruption led to the burial of the town of Plymouth under 1.4 m of Ash. Leading to full abandonment of the town. Slowly since this eruption dark tourism has created an income through tours occurring around the outskirts of the buried city (Skinner, 2018).**
Eyjafjallajökull (Iceland) *Woodhouse et al. (2013)* *Ragona et al. (2011)* *Loughlin et al. (2015)*	**2010**	**A worldwide known eruption due to its effects on international flight traffic. The explosive eruption occurred from the 14th of April until 20th May, with interaction of the explosive activity and ice causing very fine-grained ash and this continued with each explosive phase (Woodhouse et al., 2013). In that time, it is thought direct ash fall from the eruption was up to 250 million tonnes. The disruption and damage caused is thought to have come to a global economic loss around US$5 billion. However, now situated not far from the volcano is the lava centre, a museum dedicated to the volcanoes of Iceland.**
Mount Ontake (Japan) *Kaneko, Maeno and Nakada (2016)*	**2014**	**This was a sudden eruption in September of 2014 and caused more than 60 fatalities including those of missing persons. The area was an immensely popular hiking area.** **The eruption was a phreatic one following the pattern from its previous eruptions. It caused an eruption plume up to 11 km above sea level and pyroclastic flows occurred down the slopes. However, it is thought that the ballistics from the eruption were the main cause for the many casualties (Kaneko, Maeno and Nakada., 2016).**
Whakaari /White Island (New Zealand) *Andrews (2019)*	**2019**	**This Phreatic eruption was quoted by a volcanologist and earth scientist at University of Auckland as being “the actual worst-case scenario”. A quick series of violent blasts occurred, throwing out ash up to 12,000 feet into the sky as well as showing the surrounding**

		floor with hot debris. It is known that several tourists were on the island at the time, and several of them were next to the volcano's active vent (Andrews, 2019). The total number of deaths is thought to be 22 (www.tvnz.co.nz, 2020)
La Soufriere (St Vincent and the Grenadines)	**2021**	**After a 42-year period of dormancy, an explosive eruption began on April 9th. The eruption caused the displacement of 20% of the population (~20,000 people)** (OECS - Stronger Together, 2021)**. The key hazard forming in the eruption being pyroclastic flows.**

Bird, Gisladottir and Dominey-Howes (2010) highlighted the need for Iceland to address the risk created by being a volcanically active island. The study looked specifically at the risk for the large number of tourists visiting the island. The tourist sector needs to be worked with, as tourists are regularly located in high-risk regions whilst lacking understanding of the hazards around them and the emergency procedure that they should follow (Bird, Gisladottir and Dominey-Howes 2010). However, this type of study has not been undertaken in every populated island that has a history of volcanism. Coincidentally, the Bird, Gisladottir and Dominey-Howes (2010) study was published in the same year of the infamous Eyjafjallajökull eruption. The eruption caused great disruption for Iceland as well as large parts of the globe due to the large ash clouds that were produced from the eruption. Although there were no direct fatalities from this eruption, locals did suffer from respiratory issues, Furthermore, the issue surrounding the safety of tourists can be highlighted through the events of the 2010 eruption. There were two fatalities from hypothermia resulting from tourists trying to access a better view of the erupting volcano (Bird and Gisladottir, 2020), thus showing the need to better communicate with tourists and the public in general as to the actions to take in the event of an eruption.

When relating these issues to the situation in Santorini, no similar study has ever been undertaken highlighting the volcanic risk to the millions of tourists that visit annually. Dominey-Howes and Minos-Minopoulos (2004) did, however, investigate the perceptions of hazards and risks on Santorini, but this focused on the permanent residents and certain representatives of the local authorities. Dominey-Howes and Minos-Minopoulos (2004) findings for Santorini were slightly different when compared to those found in Bird, Gisladottir and Dominey-Howes (2010) for Iceland. In Santorini, residents fear the negative impacts on tourism and the effect of that on the community following a future eruption as foreign tourists would be scared off by an eruption. Whilst in Bird, Gisladottir and Dominey-Howes (2010) it was seen that tourism will benefit from a future eruption by making it more interesting and attractive to visit, as long as no one was hurt by the eruption itself (Bird, Gisladottir and Dominey-Howes, 2010).

1.3.2 Volcanic Hazards creating the risk on Santorini

Whilst investigating the risks to tourists and others living within the vicinity of a volcano, it is just as important to highlight the hazards that create that risk. Risk was defined earlier as "*the combination of the probability of an event and its negative consequences*" (UNISDR, 2009 p.25). A natural hazard is defined by the same source as a "*natural process or phenomenon that may cause a loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage*." (UNISDR, 2009 p.20).

Hazards associated with volcanoes include ballistics, volcanic ash and tephra, pyroclastic flows, lahars, landslides, tsunamis, volcanic gases, and volcanic earthquakes (Loughlin et al., 2015) (Table 1.4). There is great risk in the probability that a volcanic eruption would raise some or all these hazards on Santorini (Jenkins et al., 2015; Vougioukalakis et al., 2016 and Plan Talos). An example of one of these hazards occurring from a volcanic event include the tsunami reported to have occurred after the 1883 eruption of Krakatau, Indonesia (Self and Rampino, 1981). It is thought that a large proportion of the 36,000 fatalities were due to the tsunami (Mandeville, Carey, and Sigurdsson, 1996; Loughlin et al., 2015). Additionally at the time of this study's writing, an eruption of the Hunga Tonga–Hunga Ha'apai volcano has occurred causing a tsunami to cause great destruction to the infrastructure and livelihoods of those on the island of Tonga, along with the island also suffering from hazardous ash fall. This highlights an issue very similar to what could be possible for Santorini given proximity to the Kolumbo submarine volcano.

Furthermore, the effect of volcanic ash was felt as a hazard in the 2010 eruption of Eyjafjallajökull mentioned earlier, and again as recently as April 2021 in St Vincent with the eruption of La Soufriere. In the La Soufriere eruption, the ash forced evacuations from the island and caused serious distress for all those involved. Along with the ash was the serious hazard of pyroclastic flow currents occurring. These pyroclastic flows affected approximately seven villages that now require complete reconstruction of infrastructure (OECS - Stronger Together, 2021). Furthermore a Red Zone was created in the direct path of these pyroclastic flows, which included an area of prime fertile agricultural land (OECS - Stronger Together, 2021). The agriculture sector contributes between 6-8% of the country's GDP meaning that this area being affected will come at an estimated loss of USD153.1 million (OECS - Stronger Together, 2021).

Following the eruption on St Vincent in April 2021 was an eruption in the Democratic Republic of Congo from the Mount Nyiragongo volcano, one of the most active volcanoes in Africa (Burgi et al., 2014). Unlike previous eruptions mentioned, the key hazard in this eruption was the lava flow. The lava itself is thought to have killed 24 people at the most recent count and left thousands of people homeless (OCHA, 2021). The surprise of the eruption may be due to the reported lack of proper monitoring since the Goma Volcano Observatory had its funding from the World Bank cut due to reports of corruption (BBC News, 2021). These examples show the variety of hazards that can come from eruptions and therefore show the need to be as prepared as possible for any future eruptions.

Table 1.4 The relationship of volcanic hazards and their potential risks (Costantini and Thierry, 2012).

	PHENOMENON	MAIN ASSOCIATED THREATS
VOLCANO HAZARDS	**Thepra fall/Ballistics**	Burns and burial Buildings and infrastructure destruction Disruption of road traffic and network systems (power lines, irrigation etc.) Disruption of air traffic Impacts on plant growth and livestock
	Pyroclastic Density Currents	Burns and burial Buildings and infrastructure destruction
	Lava flows	Burns Destruction of buildings by fire, lateral stress or burial
OTHER GEO-HAZARDS	**Lahars**	Drowning Buildings and infrastructure destruction and burial Impacts on crops
	Gas emissions	Toxicity for humans and livestock, acidity and corrosion Impacts on plant growth (especially roots)
	Sector collapses, landslides and rock falls	Impacts, scouring and burial
	Volcanic earthquakes	Burial under collapsed buildings Building and infrastructure destruction
	Volcano triggered tsunamis	Drowning Trauma by collision Buildings and infrastructure destruction

1.3.3 Mitigation and planning for Volcanic Risk and Associated Hazards

Mitigation measures and plans can form a large part in reducing volcanic risks and hazards. Researching volcanic risk and the perceptions of risk can help agencies plan risk mitigation strategies. Bird (2009) explained that within their other research (Bird and Dominey-Howes, 2008) a questionnaire had been used to gain data to help the Icelandic Civil Protection develop their risk mitigation for the area around the Katla Volcano. Iceland is a country that experiences volcanic hazards fairly regularly in comparison to many other parts of the world, and because of this it is seen that preparedness for the risks and hazards is increased (Paton et al., 2008 and Jochen et al., 2012). A clear example of this is the city of Kagoshima in Japan that is next to the Sakurajima volcano, where the city can experience ashfall or ballistic debris for around 113 days each year. This regular interaction with volcanic activity has led the city to develop procedures such as ash removal practises, building codes and most importantly it has developed community attitudes and preparedness, which means that society continues to function even during a period of volcanic activity (Paton et al., 2008). However, this regular volcanic activity is not experienced in all volcanic areas of the world. For example, although Santorini has a long history of volcanic activity, the last eruption was in 1950 (Druitt et al., 1999), meaning a large proportion of the population will have little memory or experience of the volcanic hazards and risks. Therefore, there is a need to mitigate the risk through other ways rather than relying on the experience of the population.

Another way in which to mitigate risk is through the communication of risk to those that are most vulnerable to it, for example, residents or tourists. Though the communication process is not easy, Chester, Dibben, and Duncan (2002) mention that the local Santorini people mistrust, resent and resist hazard evaluation as they think this in turn highlights the island's dangers and therefore damage its reputation as a tourist destination. But it is this risk communication that is an essential part of risk management as disasters are more likely to occur when the public is left unaware regarding the conditions and actions that make themselves vulnerable (Dransch, Rotzoll and Poser, 2010). It is the science behind the risk that needs to be passed across to the decision makers, stakeholders, and members of the public (Fitzgerald et al., 2017) for them to be able to make decisions about how to act in an eruption scenario.

1.3.3.1 Iceland: an example of communication mitigating risk

Iceland is a key example when looking into mitigating the risk for members of the public and the many tourists that visit the island. This is because it is impossible, with the extent of volcanic landscapes on the island, to restrict access to hazardous zones and therefore Iceland is reliant on communication to promote personal safety (Bird and Gisladottir, 2020). Since 2006 there have been a few key ways of communicating risk for those travelling in Iceland or for those living there. An example is the Safe Travel website (Safetravel – The official source for safe adventure in Iceland) which sets out detailed information about the safest ways to travel around the island. The website provides current alerts including weather and road conditions. Furthermore, there is the ability on the website to upload your travel plans meaning that the search and rescue teams have location details if needed and set up SMS alerts to be sent to you, so you are aware of any hazards or risks. Along with this was the creation of the ‘The Icelandic Pledge’ (Take the Icelandic pledge - Inspired by

Iceland (visiticeland.com)) which asks those travelling to sign a pledge that means they accept to respect nature and avoid risk-taking behaviours, such as those that caused the two fatalities during the Eyjafjallajökull eruption. The work of Bird and Gisladottir (2020) highlighted that although these measures have been in place since 2006 and have reached some tourists, they are largely still ineffective in communicating the risk. However, it must be said that Iceland is still ahead of other places in trying to communicate volcanic risk.

Table 1.5 Highlights of good practice for communication in managing a crisis (adapted from Bonfils and Bosi (2012)).

Dissemination of information	Define roles and responsibilities to inform the public and deal with the media.
Communication strategy	Share and discuss a communication strategy between the scientific community and the civil protection authorities. In this respect a very important point concerns the identification of authorised speakers
Collaborative agreement with the media	Establish a permanent and collaborative agreement with the media during a crisis. This can imply the organisation of regular broadcast reports. The agreement can include, for example, where, when and how the media will receive updates related to volcano activity and operational aspects
Never hide information	Give most of it or all, following a reasonable pre-ordered list based on priorities (the public and the media plan). When information is not available, give an explanation and indicate when and where information will be available.
Probabilities	Use the concept of probability during conferences/interviews. Forecasting of an eruption always includes probabilities.
Spokespersons, press conferences and	Commissions or boards of emergency management can be accompanied by the choice of spokespersons which

press-packages	should be selected among scientists, civil protection officers and operational forces. Common daily press conferences can be then organised to inform the public and the media about the situation and the counter-measures already taken or about the ones that need to be taken soon. The commission can prepare and disseminate a press package to civil protection stakeholders and scientists: this press package will represent the official voice. The press package will be also issued to the media, during or before press conferences or interviews. The press package has a twofold meaning: firstly, to help the speaker to give the right information, in a correct language, at the right time and in every locality and secondly to help the media understand the message with reduced margin of interpretation

1.4 Relating this Volcanic Hazard, risk, and mitigation to Santorini

In Santorini, plans are not fully in place, and research is still required, to help mitigate the risks and hazards that could take place during an eruption. This was highlighted by the discussion of Dominey-Howes and Minos-Minopoulos (2004, p. 307) where it mentioned:

"*The Santorini Xenocratis Emergency Plan would need to cater for the needs of tens of thousands of tourists, all speaking many languages.*" =

To date this has not occurred. In 2020, a plan was produced as a general emergency response and short management of the consequences in the event of volcanic activity at Santorini Volcanic Complex. This plan has been given the name 'Talos' (General Secretariat For Civil Protection, 2020). 'Talos' covers what the authorities believe will occur in a future eruption scenario and outlines what will be carried out by relevant authorities in the event of volcanic activity. Section 11.10 deals with informing the public about actions launched to deal with emergencies and the immediate / short-term management of the consequences of volcanic activity However, weaknesses of the plan, and of the approach of the Greek Civil protection in general, relate to limitations in resources and capabilities available to the island of Santorini. This still shows there is still work to be done in fully preparing for any future eruption. As well as this, it was mentioned *pers. comm. G. Vougioukalakis* that up-to -date hazard information is not readily available to tourists. This is something that is highlighted by the difficulty in finding the latest version of 'Talos' which itself is not readily available. . The need to take into account the possible number of tourists is displayed by the fact that Bird and Gisladottir (2020) believe that had the Eyjafjallajökull eruption occurred during high season, the death toll would have been much greater. Additionally, the need to assess these risks to the residents and tourists on Santorini will only increase as the population of the island and the number of tourists increases. Research by Satow et al, (2021) concluded that the likelihood of the small eruptions that have occurred in previous eruption phases is decreasing with current sea level changes, however, the large eruptions such as the LM eruption could remain a present-day threat as they occurred outside the periods of sea level change that prompted the previous eruption phases. This conclusion highlights the importance of being prepared for any future eruption.

Furthermore, to put a wider context on the importance of being prepared for a future eruption from the Santorini complex, the work by Mani, Tzachor and Cole (2021) highlights the Mediterranean and Santorini as one of a few pinch points found around the globe. A pinch point is an area they have highlighted that if was hit by a moderate volcanic event (Between 3-6 on the Volcanic Explosivity Index (Newhall and Self, 1982) it could cause a catastrophe as there is critical infrastructure and networks in the area. The fact that within their research they have highlighted the Mediterranean and more specifically Santorini, means that it is not only important to be better prepared, so as to help the locals and the tourists visiting the area, but also to reduce the impact on the wider global area.

1.5 Aims and objectives

In the previous four sections, this chapter has first conveyed the volcanic history surrounding the Greek island of Santorini, whilst then looking into its current economic and demographic situation, with it being regarded as one of the most popular tourist destinations in the world. After which follow sections looking into the background of volcanic activity and the risk and hazards that come with such activity, with the remaining sections looking into the management and mitigation of such hazards and risks. From this the aims and objectives of this study can now be set out.

The key question being looked into for this study is; '*What is the spatial distribution of volcanic risk for tourists on the island of Santorini?'* With a secondary aim of '*establishing the perceived eruption risk for tourists on the island'*. The way in which these aims are to be met is through a specific set of objectives. These being, first to compile a database of spatial distribution of tourist accommodation (number of beds/rooms for Hotels) for nine key centres of population and critical infrastructure (Jenkins et al., 2015) on Santorini. The second objective is to compile a primary database of the spatial distribution of perceived volcanic risk for tourists (through a questionnaire on the perceptions of volcanic risk from tourists on the island. The third is to extract data from Jenkins et al., 2015 to produce maps of actual volcanic risk using arcGIS. The final objective is to integrate these maps (from objective 3) with the spatial data from objectives 1 and 2 to assess the spatial relationships between tourists, perceived risk and actual eruption risk.

2.0 Methodology

This chapter breaks down the mixed methodological approach taken in this study, with figure 2.1 explaining how each of these separate methods work together to achieve the aims and objectives set out in section 1.5. The use of the questionnaire is required to ascertain the tourist's perception of volcanic risk as well as working out the general knowledge of tourists on volcanism. This is key for this project as without knowing the tourist's perception of risk, it is impossible to know how great the genuine risk is. Therefore, the questionnaire is placed first in the methods as it is the primary dataset. What cannot be attained through the questionnaire is data showing the spatial distribution of tourist accommodation, specifically hotels, therefore there was a requirement to do a spatial survey of the hotels on Santorini. However, data on where hazards and risks are most likely in the event of any future eruption, as highlighted by Jenkins et al (2015), are shown with a focus on nine key areas. Consequently, this survey method required focus on the nine key areas identified. The third method of this mixed methodology approach was the use of GIS mapping. This provides the ability to visually map the hazard risks to tourists visiting the island, through digitising the hazards spatially.

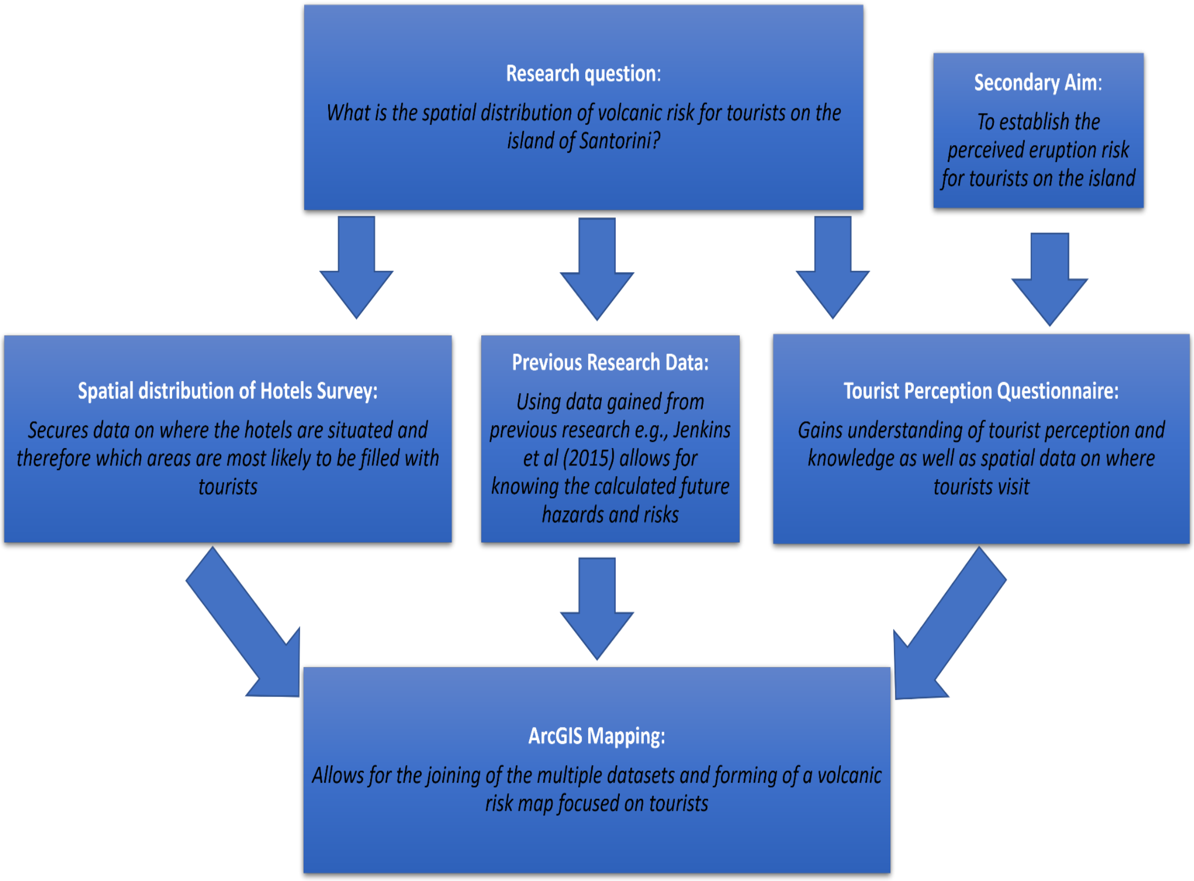

Figure 2.1 Research Design Diagram, showing the breakdown of how each of the methods work together for this project

2.1 Questionnaire Methodology

2.1.1 Previous uses of questionnaires in hazard risk research

Gaining an understanding of the perceived risk from tourists visiting Santorini is crucial for the future work required to reduce the total volcanic risk on the island. Questionnaires have been used as a source for gaining this understanding. Numerous studies such as Dominey-Howes and Minopoulos (2004), Davis, Ricci, and Mitchell (2005), Barberi et al. (2008), Bird, Gisladottir and Dominey-Howes (2010) and Ricci et al. (2013) along with studies highlighted in the work of Bird (2009) where 46 other articles that used questionnaires were reviewed. Bird (2009) and Ricci et al (2013) suggest that use of questionnaires is the most utilised tool for providing reliable data on the perception of risk from natural hazards. Furthermore, Bird (2009) concluded that questionnaires along with mixed methods can produce robust results, demonstrating the strength of this method when examining this topic.

Questionnaires being used as a key method for looking at the perception of volcanic risk can be seen in many previous studies.This then allows future studies to look back at these methods and draw comparisons as well as alter and reproduce these methods in that developing study. Bird (2009) states that it is important that each study produced contains sufficient methodological detail so as to allow for this comparison or reproduction to occur. It is clear from three specific past studies that this alteration and reproduction occurs as it is seen through the comparison and development of the methods. Davis, Ricci, and Mitchell (2005) distributed 2000, 50 item questionnaires, while Barberi et al (2008) went on to distribute far more with 3600 questionnaires. However, having based their method on that of Davis, Ricci, and Mitchell (2005), Barberi et al (2008) reduced their questionnaire item count to 45. Barberi et al (2008) state that this is due to findings found in the previous study by Davis et al. (2005) that certain items needed to be eliminated or tailored so as to work better. From here Ricci et al (2013) continued with a similar method as they produced a 46-item questionnaire and went back to distribute 2000 questionnaires. An obvious comparison with Barberi et al (2008) and Ricci et al (2013) is that the distribution was aimed at the same demographic, this being an equal proportion of males and females, but wide-ranging age groups.

The number of previous studies that have been conducted for such small islands like Santorini are few in number. However, as mentioned in section 1.3.1 (Volcanic risk on Islands) there has been research on SIDS that can be comparable to Santorini and therefore beneficial to this study. A specific study that closely relates is that by Meheux and Parker (2006), which looks at the tourist's sector's perception of natural hazards for the island of Vanuatu. Within this study's methodology it uses questionnaires and face to face interviews and the convenience sampling method. This sampling method is a non-random method where the participants meet practical criteria that allow more participants to take part so as to help uptake in the study (Etikan, Musa and Alkassim., 2016). Meheux and Parker (2006) only had 15 participants take their questionnaire, showing the need for a convenience sampling method. There is an aspect of this sampling method found in this study, as explained in section 2.1.4, along with the main technique of purposive sampling.

2.1.2 Function of the questionnaire

An underlying aim of this study is to gain a better understanding of the current perception by tourists of the volcanic risk whilst visiting the island of Santorini. Through the questionnaire produced in this study, it is hoped reliable data will be obtained showing this perception in a mainly quantitative way (Ricci et al 2013). Currently for the Santorini volcano complex, the only studies looking at perceptions of the risks have focused on the residents and key local dignitaries such as the mayor of Santorini (Dominey-Howes and Minopoulos, 2004), meaning that it is not possible to follow a study as closely as has been done by Ricci et al (2013). The reason why it is not possible is highlighted in Bird's (2009) review of 46 questionnaires. Bird's review included the article by Dominey Howes and Minopoulos (2004) and in the results looking at what the articles provided in terms of the Response format, Delivery mode, Sampling technique, Response rate and Questionnaire provided. Dominey-Howes and Minopoulos (2004) did not provide either the delivery mode or sampling technique making it impossible to properly reproduce the methodology (Bird, 2009).

Bird, Gisladottir and Dominey-Howes (2010) studied the perception of tourists visiting an area in Iceland, showing a methodology more closely linked to the aims of this study. The sample population comprised 116 tourists via the use of a questionnaire. Tourists were recruited for face-to-face interviews through a purposive sampling technique. This sampling technique relies on the judgement of researchers (e.g. Bird, Gisladottir and Dominey-Howes) in how people are approached and is a very selective way of sampling (Sharma, 2017). This type of sampling is a key part of their methodology that will be reproduced in this study, however, with slight alterations that are explained in section 2.1.4 (Questionnaire distribution). Furthermore, the aims of the questionnaires produced by Bird, Gisladottir and Dominey-Howes (2010) are similar to those used in this study. This means that further reproduction of the type of questions inserted into the questionnaire could occur with the aim of gaining perception of risk from tourists as well as insight into any prior knowledge that they may have.

2.1.3 Questionnaire design

The layout and design of the questionnaire has been established by looking at previous questionnaires such as that used by Bird, Gisladottir and Dominey-Howes (2010). Additionally, the work of Bird (2009) in her paper *"Use of questionnaires for acquiring* *information on public perception of natural hazards - a review of current knowledge and practice"* gave relevant information on how best to create such a questionnaire. The questionnaire developed was based on the five basic types of questions shown in table 2.1 below. Through a mixture of these questions the questionnaire aimed to gain a strong perception of what tourists know about the volcanism on Santorini and how prepared they are when travelling there. It was found that the majority of the questionnaire was made up of either multiple choice or checklist questions, with a few left open ended allowing for respondents to expand and elaborate on some of their closed answers (Bird, 2009). By having the majority though closed ended questions, it allows for simpler more quantitative analysis of the results and therefore a clear perception of the tourists knowledge, and personal perception of risk.

The first question on the questionnaire, after the consent questions, asked whether the participants were either a previous visitor, currently visiting or had plans to visit Santorini. This allowed for a broader range of people able to answer the questionnaire. When analysing the results of the questionnaire it is then possible to split the results up into these three different groups. This provides a greater idea of the perception of tourists who have been and may visit again, and those that are planning to visit but may not have been before, so therefore not know the risks. Furthermore, the nine key centres from Jenkins et al. (2015) were incorporated into the questionnaire, to help gain further information as to areas most visited by tourists. Question 6 asked the participants to select as many of the different centres shown on the map, given that they had visited or intended to visit. For those that had visited, but also planned to go again, they were asked to select those areas that they had visited previously. Question 6 is shown in the figure below, with the map included.

In terms of ordering the questions, the questionnaire was designed so that it went directly into the questions related to the risks and hazards on the island. This left the classification questions, such as the gender and age to the end, so that any partial completion is more likely to have the data that is most relevant to the results. Furthermore, the questionnaire was required to meet certain ethical criteria set out by the university, therefore at the top of the questionnaire were three consent questions along with a link, allowing them to read the information sheet, relating to the research taking place (Appendix 1).

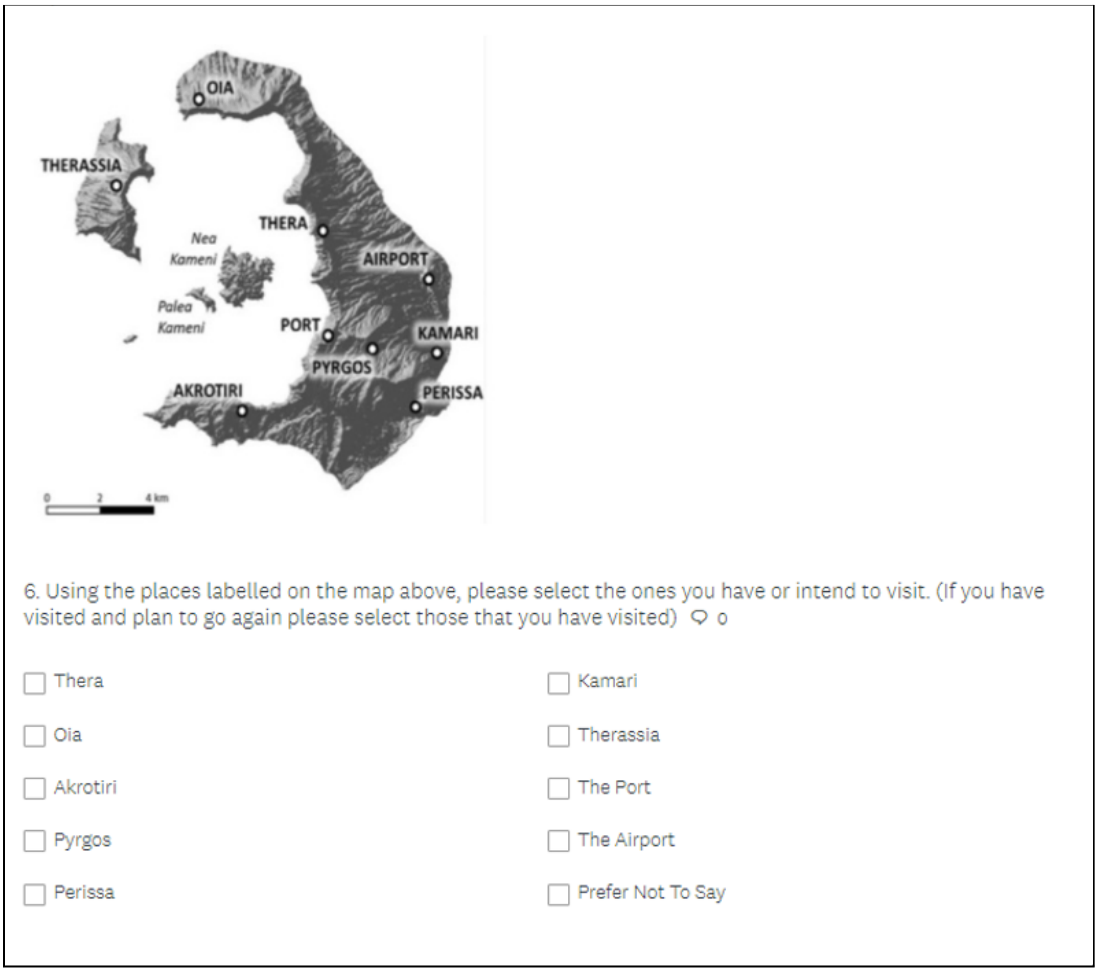

Figure 2.2, A screenshot showing question 6 of the questionnaire, where participants were asked to select all the places they had or intended to visit (key location areas visited/to be visited are based on Jenkins et al. (2015)).

Table 2.1, Breakdown of the different types of questions used in the questionnaire, with examples of which ones have been used in this study.

Question Type	**Aim of Question**	**Example from the questionnaire**
Classification	Identifies characteristics of the participants	To which gender identity do you most identify?
Behavioural	Gains an idea of what the person may do or has done in a situation	If you were on the island today and were told through local media announcements of the beginnings of volcanic activity but the need to

		evacuate is not mentioned, which of the following options would you do first?
Knowledge	Determines participants knowledge around a specific subject	Are you aware that Santorini is a volcanically active area?
Perception	Provides understanding of the cognitive and interpretive processes for each participant	Looking at the map and table, is there an area of the island you believe to be at less risk in the event of an eruption or not?
Feeling	Identifies emotional responses of the participants from experiences and thoughts	No example used in the questionnaire.

2.1.4 Questionnaire distribution

In terms of distribution of the questionnaire, a purposive sampling technique was chosen, which itself is a non-probability form of sampling (Etikan, Musa and Alkassim., 2016; Sharma, 2017). This technique relies on the researcher choosing the respondents (Etikan, Musa and Alkassim., 2016; Sharma, 2017), so for this study only tourists that had visited or had strong plans to visit Santorini over the age of 18 were asked to participate in the questionnaire. Within this, an aspect of convenience sampling was added into this method; allowing those that are planning on visiting Santorini to be included, thus increasing the uptake in the questionnaire as they meet a piece of practical criteria (Etikan, Mussa and Alkassim., 2016). This is beneficial to the study as the number of people travelling to Santorini currently was lessened due to the effect of the Covid-19 outbreak (Medova, Mackova and Harmacek, 2021) and therefore, if it was only available to those visiting currently or previously, the number available to take part would be significantly reduced.

One specific strength that comes with using this method of sampling is that it provides justification to generalise (Sharma, 2017) about the sample of participants in relation to their perceived risk on Santorini. These generalisations are more justified through such a method as the group is very select. For example, Bird, Gisladottir and Dominey-Howes (2010) could make generalisations from their results of the questionnaire as they used the same select type of sampling.

For this study, due to difficult global travel issues, all distribution of the questionnaire was performed online showing a major difference in comparison to Bird, Gisladottir and Dominey-Howes (2010). This distribution online still allowed for the questionnaire to get the required number of responses for this study, and this is partly because of the power of social media to distribute information. Through the use of the internet and social media, the study can be posted on the relevant pages within places such as Facebook and Twitter (Kayam and Hirsch, 2012). For example, the public Facebook pages, Santorini, and Greek Islands, have been used to post about this questionnaire. The Santorini page has around ninety-two thousand members on the page whilst the Greek Islands page has about one hundred and twenty-four thousand members. Selected examples of the posts, regarding the questionnaire, are shown in figure 2.3. This demonstrates the ability to spread this questionnaire to a large number of people using social media. Also, what can be seen in figure 2.3 is that the posts are in line with the ethical criteria set out. Each participant had to like or interact with a researcher before needing to commit to doing the questionnaire. Furthermore, by putting it online it allows for the questionnaire to be out and available for a longer time, again reducing the chance of a lack of participants (Kayam and Hirsch, 2012).

The questionnaire was made through the online survey development software SurveyMonkey. This allowed for easy construction of the questionnaire as well as easier collection of the data. SurveyMonkey's ease of use is a reason that it is one of the most popular online survey development software (Marra and Bogue, 2006). Furthermore, putting it online and using SurveyMonkey permits the collapse of physical space between participant and interviewer (Huffman, 2006). Through this specific method, the questionnaire has been able to reach people much further away than those that would only be available at the time of an on-site visit approach.

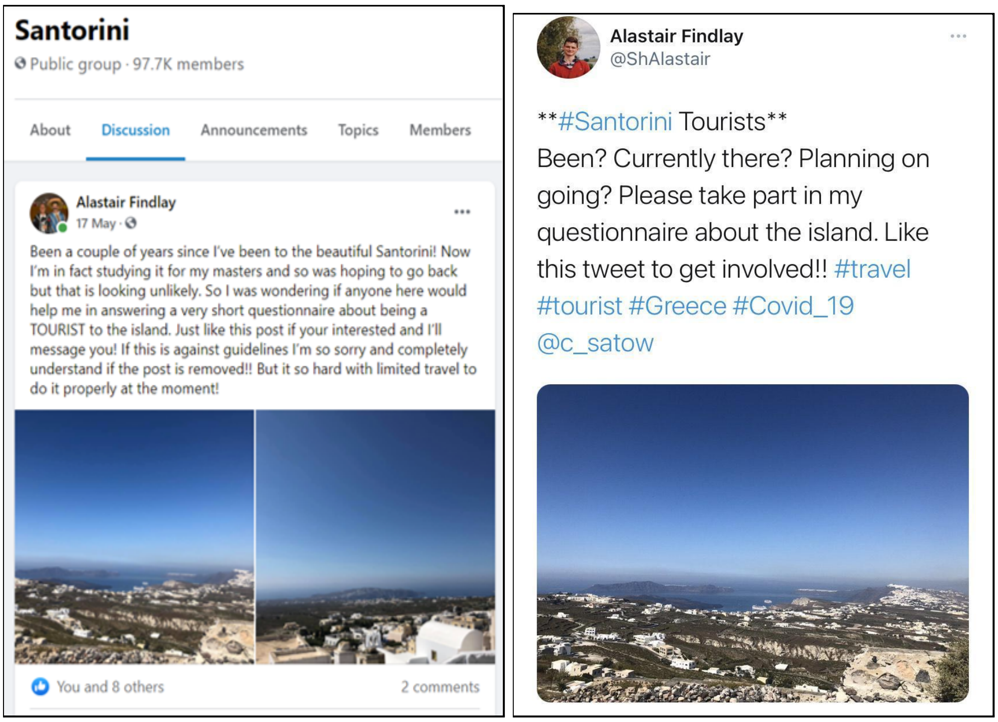

Figure 2.3 Two social media posts advertising the questionnaire and how to take part. On the left is via Facebook whilst on the right is Twitter.

2.2 Spatial Distribution of tourists on Santorini

2.2.1 Function of collecting tourist distribution data

One of the key aims was to collect a dataset that showed where in the nine centres mentioned by Jenkins et al (2015) are the most popular areas to stay. In the questionnaire design, section (2.1.3), it highlighted that a specific question led participants to answer where of the nine centres they plan or have visited. However, the dataset also requires the numbers in terms of places to stay and number of beds available in each centre for tourists to use. Through gaining this dataset, it is possible to highlight which areas are most likely to have a high number of visitors at a time of any future volcanic activity.

To be able to map out the volcanic risk over the area where tourists are more likely to stay/visit on the island, there is a requirement to survey the island so as to determine the area(s) most populated by tourists. This can be achieved through primary research such as a survey whilst also using data already produced by the Ministry of Tourism for Greece to gain a true understanding specifically as to which areas are the most popular. This study was designed to use the number of rooms and beds available to tourists at hotels in

Santorini as data to see which areas are most popular. It was decided for this methodology to only count rooms and beds in hotels on the island. Sarantakou and Terkenli (2019) showed that there is a large spread of types of places where tourists stay, with an increasing number of private houses (Airbnb) being available. Data on the number of these places to stay is much harder to gain, whether online or in on-site fieldwork, and so therefore the survey was limited to just hotel rooms and beds. This is because, for institutionalised tourist accommodation, there are specific planning and development regulations in place, whereas for housing used in Airbnb there is not (Sarantakou and Terkenli, 2019). Therefore, hotels are only going to build up in certain permitted areas that can lead to overcrowding, which in turn can be an even larger issue in terms of future risk.

2.2.3 Collating a dataset of hotel accommodation

The survey of the number of rooms and beds from hotels available will focus on the nine key centres highlighted by Jenkins et al. (2015) due to being key population areas as well as areas of critical infrastructure. They are as follows: Thera, Oia, Akrotiri, Pyrgos, Perissa, Kamari, Therassia, the Port and the Airport as shown in figure 2.2. These same nine centres are a constant focus through the methodology as the knowledge of how each area would be affected by a future eruption is shown through previous research and so relates to the number of tourists in each area. This makes mapping and highlighting the risks to tourists clearer.

The number of rooms and beds in each of the areas was calculated through: (a) purely online research, and (b) data sent by the Greek Authorities due to travel restrictions at the time of this project. Data given by authorities was sourced from the Ministry of Tourism for Greece. The data provided included the exact number of hotels and beds available to tourists on the island of Santorini from 2015 up until 2020 according to the Hellenic Chamber of Hotels. These numbers give a strong idea of the amount in terms of standard institutionalised tourist accommodation available, however, it is not specific in terms of where in Santorini and also includes hotels found outside of the nine areas focused on within this study. These data, therefore, do not have the spatial information necessary and are shown in Appendix 2.

As for the primary data collected, this was performed using two different websites. Data was extracted and collected to create the data set of the number of rooms and beds available in hotels from the nine centres mentioned. The websites used were the Hellenic Chamber of Hotels (HCH) and LastMinute.com. The HCH website was the only website found that would give both the number of beds and the number of rooms available at the hotels as shown in figure 2.5, whereas Lastminute.com gave the number of rooms available, not the number of beds as shown in figure 2.4. However, all other travel websites only gave the number of rooms available to book at that moment. Therefore, only these two websites were used in the survey of hotels.

Consequently, the method of collecting the data from these two websites was as follows:

First, data was collected from Lastminute.com and comprised the number of hotels in a centre and the number of rooms each of these hotels had. Using the filtering tab on the website meant that the search was only for hotels in one of nine centres, for example, only hotels in the area of Oia, shown in figure 2.4 below. Having filtered this search, the results provided a list of hotels available on a selected date (30th September, for up to 4 nights). To avoid missing hotels that had already been fully booked up, and so would not show up when searching, a date was selected a good distance from the day of the search and the search was repeated a week or so later so that any cancellations would now show any previously fully booked hotels. Having collated a list of hotels in the area, the next step was to click on each hotel listed which would lead to the page shown in figure 2.4 that gives the number of rooms available. This process was done for each hotel that came up in each of the centres that were searched for. Two of the centres are not defined areas on any websites. These two centres are: the airport and the port and therefore in that search only hotels within a 1km of these centres were counted.

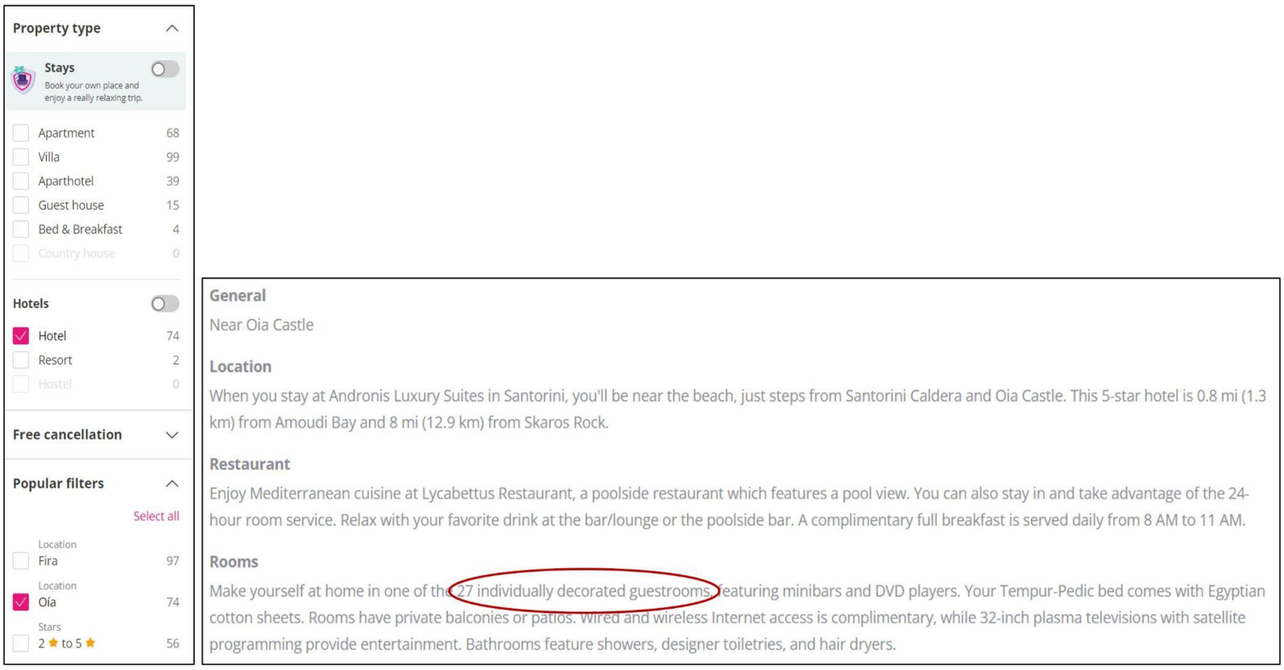

Figure 2.4 Left: shows the filter menu found on the left side of the web page of Lastminute.com when searching for hotels. Right: The description page of a hotel that comes up once selecting a specific hotel.

Second, having collected all the data available from last minute.com, the search then moved to the HCH website. This permitted the data collected from Last minute.com could be cross referenced with data derived from the official website for Hotels by the Ministry of Tourism for Greece. Also, it meant that if any hotels had been missed through Last minute.com, these could be highlighted in the search results of HCH. Consequently, the method for the HCH website was as follows:

Using the Search and filter tab on the HCH website, as shown in figure 2.5, an area and only hotels were selected and searched as well as a name of a hotel that had come up from the Last minute.com search. Then if found on the HCH website, the hotel was clicked on, which led to a page that gave information about the number of beds and rooms available shown in figure 2.5. The number of beds was noted down and the number of rooms was noted next to the number of rooms given in the previous search to allow for comparisons in the number both websites gave. This process was repeated for each of the hotels that had previously appeared on the last minute.com search. Having done this, so as to avoid missing any hotels on the HCH website, the search was performed but without the name of the hotel and so produced a list of hotels in each centre. This list was compared to the data already collected. Any hotel that showed up that had not previously been found would have the data extracted and so allowing for no hotels to be missed.

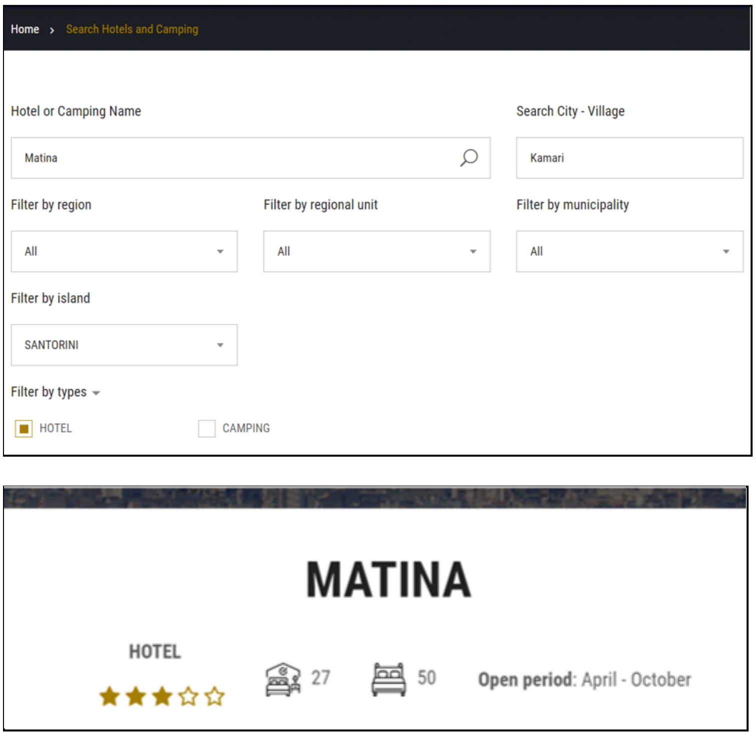

Figure 2.5 top: Filter section of HCH website. Bottom: The key aspects of data given about each hotel, including the number of beds and number of rooms

Having done this, it is also important to get even more precise spatial information about each hotel and therefore each hotel was searched for on Google Earth, and the coordinates for the hotel taken down. The coordinates were taken for input mapping on ArcGIS.

2.3 Use of GIS to integrate data

2.3.1 Previous GIS work on volcanic risk on islands

GIS is used as a key component in many different decision- making processes and is specifically central to the decision-making process when looking at volcanic risk management (Pareschi et al., 2000). Previous work has highlighted the improvement in risk assessment that has occurred alongside the development of GIS (Felpeto, Marti and Ortiz., 2007). In terms of previous work that links closest to this current project, the work of Scaini et al. (2014) titled ‘A GIS-based methodology for the estimation of potential volcanic damage and its application to Tenerife Island, Spain' is one of the closest. Scaini et al. (2014) used GIS to be able to estimate potential damage from a future volcanic eruption. They did this by going through four sections, first. defining and simulating any future eruption scenario; second, by looking at the exposure analysis for each of those scenarios; third, looking at the general vulnerability on Tenerife Island; and finally, estimating the expected damage from any future eruption scenario.

GIS was used as a tool to produce maps of the expected damage, which is a similar use to what is required in this project. Lowe et al. (2007) highlights the ability to map risk, hazards or vulnerability as a key reason for the use of GIS. They also mention the ability of overlaying different datasets, which is a particularly beneficial analysis tool available when using ArcGIS. This is utilised in this current project when overlaying the tourist data, such as hotel location, with the likely hazards such as ash accumulation.

2.3.2 Spatial data gathered from questionnaires

The questionnaire's main objective for this study was to gain a better understanding of the tourists' perspective of volcanic risk on the island of Santorini; however, it also had a secondary objective of gaining further spatial data in terms of where tourists most commonly visit and stay. This was addressed in one specific question that has been shown in figure 2.2. In asking where each participant intended or had visited, the study gained an idea in terms of those who were questioned on how many went to certain areas.

2.3.3 Spatial data gathered from hotels survey

The hotel survey not only gained an insight into how many bed places and rooms were available to tourists, but also through knowing the locations of all of the hotels looked at, it also provided spatial data on where the majority of places to stay are located. When gaining data on the hotels for the centres of the Airport and Port, the search only focused on hotels within 1km. Coordinate data collected from the survey was tabulated and formatted correctly for import into ArcGIS and onto the map. With this layer of information, which along with the hazard information on the map, can be used to visually show the risk tourists are at when visiting Santorini. In GIS, by superimposing the coordinate data layer with the risk data layer, this creates a spatial overlay (https://support.esri.com, 2021), which helps visually show the relationship between them.

2.3.4 Spatial data on volcanic hazards from Jenkins et al. 2015

For this study to fully show the spatial distribution of volcanic risk in comparison to the most popular tourist areas, it is necessary to know what the actual risk is with the most likely possible future eruption scenario. Many studies investigate the types of possible future eruptions and the risks and hazards that could come with them. However, specifically for Santorini, one of the most up to date studies is that of Jenkins et al (2015). This was produced based on the volcanic unrest that occurred during 2011 and 2012. Within this study, data produced was used to realise the hazards and risks associated with the most likely scenario of a future eruption. Jenkins et al (2015) looked specifically at two hazards that come from potential eruptions, namely ash and gas. For both of these hazards, a key factor is wind conditions in relation to Santorini. Their study highlighted the dominant direction of the wind and modelled distributions for hazardous ash and gas emissions.

For this project, it is planned to adapt the data produced in the Jenkins et al. (2015) study. This was made possible thanks to the kind cooperation of the lead author Susanna Jenkins who provided raw data from that paper. This was deemed beneficial when trying to map out the hazards, which may impact tourists visiting the island. These data and figures provided can be found unedited in Appendix 3, with the edited versions of the data being produced in the results and discussion sections of this study.

For this study to be able to truly show the volcanic risks present for the tourists visiting the island of Santorini, it is necessary to map out the risks over the areas that are most frequently visited by the tourists. To do this most efficiently, ArcGIS was used to produce these maps. To do this, a base map was required along with georeferenced versions of the figures produced and supplied by Jenkins et al (2015) along with spatial data relating to hotel locations.

The first step in the ArcGIS component of this study was to georeference the images and figures produced by Jenkins et al (2015). The idea of georeferencing an image is so that it becomes a form of spatial data as it is aligned within a coordinate system (Herbei et al, 2010). This means that the image can be used as an overlay on top of any other map using the coordinate systems. There are two ways in which an image can be georeferenced in ArcGIS, either automatically or manually. For this project, due to the type of images used control points were georeferenced manually. A control point is a point on the raster image

(Undefined image) and the reference image (Defined image) that corresponds. The points position on the referenced image is known with great precision (Herbei et al, 2010).

2.3.5 GIS Setup and parameters for creating maps.

In producing the maps required for this project, ArcMap 10.7.1 was used. To produce the maps needed in this study, i.e. to include the data produced by Jenkins et al (2015), there was a requirement to georeference that data as explained in section 2.3.4. The systems and set up of ArcMap is described below:

For the georeferencing of Jenkins et al (2015) data as well as for the digital elevation model (DEM) from Karátson et al., 2020, the coordinate system used was WGS_1984_Web_Mercator_Auxiliary_Sphere, with the World Topographic Map base map selected. Additionally, a different coordinate system was required when inputting the spatial coordinates collected from the hotel survey so as to create a spatial overlay highlighting hotel locations. The system selected here was GCS_Greek.

3.0 Results

The following chapter lays out the primary data collected using the methods presented in the previous chapter. These data are presented through a series of figures that outline tourists' volcanic risk perception, the capacity and distribution of the hotels on the island as well as the actual risk (adapted from Jenkins et al., 2015). Data collected from the questionnaire is displayed first, followed by the hotel survey data and finally the edited data provided by Jenkins et al (2015).

3.1 Questionnaire Results

The first section of the results chapter focuses on data collected from the questionnaire. The results from the questionnaire have been divided into three sections, with the first looking at the demographic characteristics of the survey respondents, this then allows analysis later in the study as to the characteristics which affect a tourists volcanic knowledge and perception of volcanic risk. The second section covers volcanic knowledge of the survey participants and the final section explores their risk perception.

In total there were 81 fully completed responses to the questionnaire, from a total of 117 having clicked on the online link (a completion rate of 69%), with the average time for completion being 7 minutes 30 seconds.

3.1.1 Characteristics of Participants

Table 3.1 (below) shows the demographic variables that arose from the questionnaire. It breaks down these variables into their constituent categories, for example age being broken down into groups of 18 to 30 year olds, 31 to 60 year olds and 61+. It is important to understand which demographic variables are found within the responses of the questionnaire, as this permits the study to place each participant into categories, as well as giving insight in terms of perception and knowledge (Bird, 2009). Furthermore, later on in the discussion section of this study, these variables will be investigated to see if they affect the tourists' risk perceptions.

An in depth look at table 3.1 (below) shows there to be a higher number of female respondents (n=51) in comparison to male (n=29), with the greatest difference being in the 31–60-year-old group. In terms of the age ranges of respondents, the greatest number of respondents came from the 18-30 age range, with there being 36 completed responses coming from this range, and the least came from the oldest range (61+) with only 16 completed responses. The majority of respondents were English (n=66), however the table shows there to be a few from other nations including Spanish (n=5) and German (n=4). Collating all of these parts of demographic variables together it can be seen that the most common type of respondent was an English-speaking female. This matches somewhat with the general tourist statistics for Greece, with the UK being the largest visitor to Greece in June 2016 (latest data) with 472,601 arrivals, with Germany being the second largest (398,774 arrivals) (Hellenic Statistical Authority, 2016).

The types of groups visiting Santorini are generally seen to be groups of adults with no dependent children (45), with those that answered ‘other’ seen to be couples visiting the island (n=11). Further down the table, it shows that the most popular type of accommodation is a hotel with 28 of the respondents using a hotel, the least popular accommodation was equally B&B, hostel and other. The answers of ‘other’ included camping or using a self-catered apartment (Airbnb). Finally for the length of stay it was seen that 8+ nights were the most popular (n=17), with the least popular option being a 1 night stay.

Table 3.1: Characteristics of the survey respondents including age, gender, nationality and nature of their stay n=81

Variable	Categories of Variable	No. Responses
Age		
	18<30yrs	34
	31<60yrs	31
	61+yrs	16
Gender		
	Prefer Not to Say	1

	Male	29
	Female	51
Nationality		
	English	66
	Spanish	5
	German	4
	French	2
	Greek	2
	Italian	1
	Bulgarian	1
Travelling Group		
	Just yourself	6
	A group, all over 18	45
	A group, at least 1 under 18	14
	Other	13
	Prefer not to say	1
Accommodation type		

	Hotel	28
	Villa	22
	cruise ship	12
	B&B/Inn	6
	Hostel	6
	Other	6
Length of Stay		
	Day Trip	13
	1 night	1
	2 nights	2
	3 nights	14
	4 nights	7
	5 nights	8
	6 nights	5
	7 nights	11
	8+ nights	17
	Skipped	3

A key question within the questionnaire was asking the respondents whether they had previously visited, were currently visiting or planning to visit Santorini. Table 3.2 shows the breakdown of the responses to this question, with just over two thirds of the respondents having previously visited (n=55) and only 1 respondent answering the questionnaire as a current tourist to Santorini. This result is not a surprise due to the restricted conditions surrounding travel at the time of the questionnaire being live. The percentages add up to higher than 100% due to the fact that respondents who had previously visited and were planning on visiting again were asked to select both responses. This information is beneficial in analysing what has affected the risk perception of each tourist. If they have previously visited, has that experience benefitted their perception (Jochen et al., 2012)?

Table 3.2 shows the breakdown of respondents' situation in terms of whether they have already, or plan to visit Santorini. The response is shown both a percentage on the left and as the number of participants on the right.

Please select the options that apply to your situation in terms of visiting Santorini. (e.g. if you are currently visiting and have previously visited please select both)		
Answer Choices	**Responses**	
Previously Visited	**68%**	**55**
Currently Visiting	**1%**	**1**
Plan to Visit	**42%**	**34**
	Answered	**81**

The final part of the classification of the participants is understanding their reason for visiting Santorini. For this, participants were asked in question 5, to provide a worded response, which was then coded. Table 3.3 (below) shows the codes produced from the participants' written responses. The table is in order of the most popular code at the top to the least popular code at the bottom. This shows the main reason for the majority of participants to visit is due to the picturesque nature of Santorini, with one response showing this exactly with “The Beautiful scenery”. 8 of the participants mentioned the volcanic nature of the island as a reason for them to visit. The culture and romantic connection were equal in terms of the number of responses that used these reasons. The code ‘holiday’ covers those that explained that they chose Santorini purely as a place to get away on holiday and there was no other more specific reason.

Table 3.3, the coded breakdown of why people have or want to visit Santorini. The code is in the left-hand column, with the definition found in the right-hand column.

Code	Definition
Picturesque	Visiting Santorini due to is scenery and beauty
Holiday	The basis of visiting is for a holiday
Convenience	Where its situated makes it a convenient destination, whether that be for a cruise or in relation to where one is situated prior
Volcanic attraction	Visiting due to the volcanic nature and history of the island
Reputation	A place to go based on the word of others and from pictures online
Romantic Connection	An area for a romantic trip (Wedding or Honeymoon) while being many people's favourite or most loved place.
Greek Culture	The interest in the local culture including the Greek food

3.1.2 Volcanic Knowledge

Recognising each tourist's basic volcanic knowledge allows a better understanding of what they already know, before trying to understand their perception of risk. Table 3.4 below shows the response to the key knowledge question, ‘are you aware that Santorini is a volcanically active area?’ The large majority of respondents are aware that it is volcanically active (62), however with 19 being unaware, this highlights that it cannot be assumed that tourists turning up to Santorini have any basic knowledge.

Table 3.4, A table showing the response as to whether respondents knew that Santorini is a volcanically active area (n=81)

Are you aware that Santorini is a volcanically active area?		
Answer Choices	**Responses**	
Yes	**77%**	**62**
No	**23%**	**19**

Figure 3.1 shows participants' knowledge regarding the last time the volcano erupted. 49 of respondents stated that they had no previous knowledge and a further 11 answered that they did not know when the last eruption occurred. The results relating to those who answered yes, have been broken down further, into those that answered yes and correctly knew the date and those that answered yes but were incorrect on the date. There is a slight majority in those that were incorrect in their answer. Those that answered 1950s and not specifically 1950 were noted as incorrect. The key data point to take away from figure 3.1 is that the majority of tourists visiting the island know little about its volcanic history.

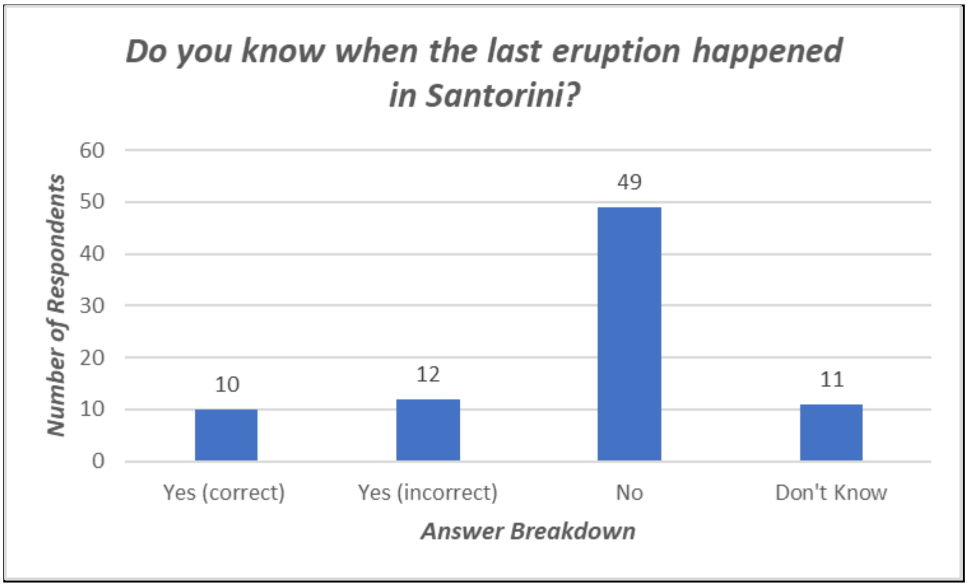

Figure 3.1, Graph showing the response as to whether tourists know when the last eruption happened in Santorini. (n=82)

Figure 3.2 below, represents the response to whether tourists know that a volcanic monitoring system exists for Santorini. The majority answered that they did not know (55 respondents), no one answered that they believed there isn't one, and 26 answered that it does exist.

Table 3.5 (below figure 3.2) looks at the response to whether any of the participants would look to see what the latest hazard and emergency information is for Santorini before travelling. This provides the study an understanding of their awareness of any systems on the island that are there for their protection and so to mitigate risk. The response was overwhelming, with 90% answering 'no' they have not looked. This highlights a lack of hazard awareness when visiting the island. Only one respondent mentioned looking at a specific website (the ISMOSAV website 'Institute for the Study and Monitoring of the Santorini Volcano'). This along with one other participant mentioning that they looked at seismographic data, shows a few tourists visiting know the science behind the potential risk.

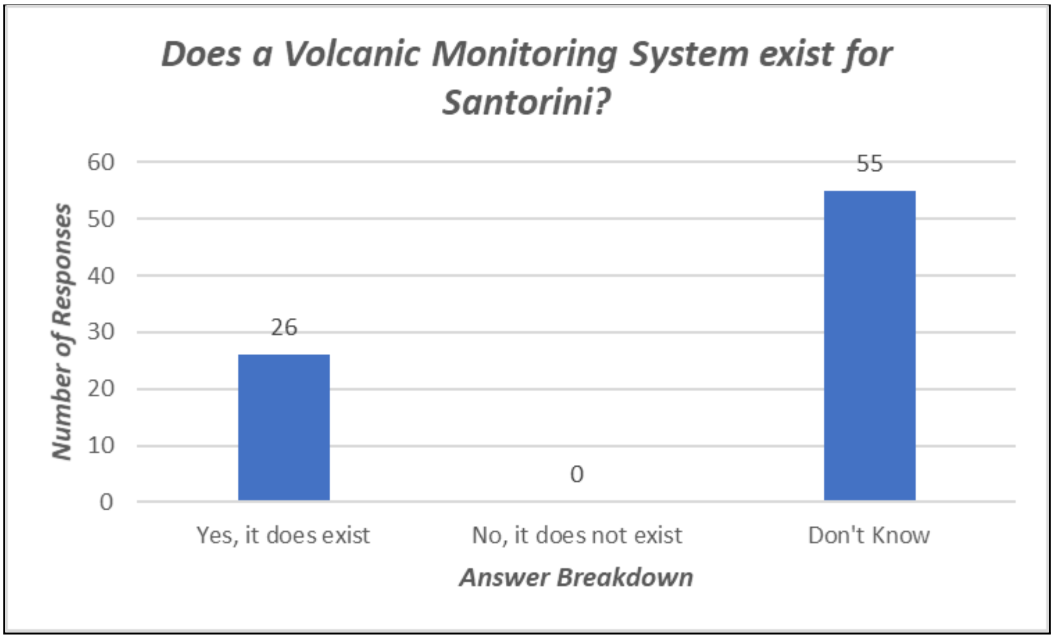

Figure 3.2 Graph showing the results of whether tourists know if a Volcanic Monitoring system exists for Santorini (n=81)

Table 3.5, The response breakdown of whether the respondents had looked to see the latest hazard and emergency response information

Before travelling to Santorini have/had you looked to see the latest hazard and emergency response information?		
Answer Choices	**Responses**	
Yes	**10%**	**8**
No	**90%**	**73**

Figure 3.3 below shows an edited map from Jenkins et al (2015), which has been modified to show the percentage of respondents that visited each of the nine centres highlighted as key areas in both Jenkins et al (2015) and this current project. It highlights that Thera (67%) is the most popular place to visit, while Therassia is the least visited (25%). Furthermore, aside from the two transport hubs (the airport and the port) the second most visited place is Oia in the north of the island, with just over half (52%) of the respondents visiting. It must be noted that for this question people that had previously visited and were also planning on visiting again were asked to answer only with the places that they had already visited.

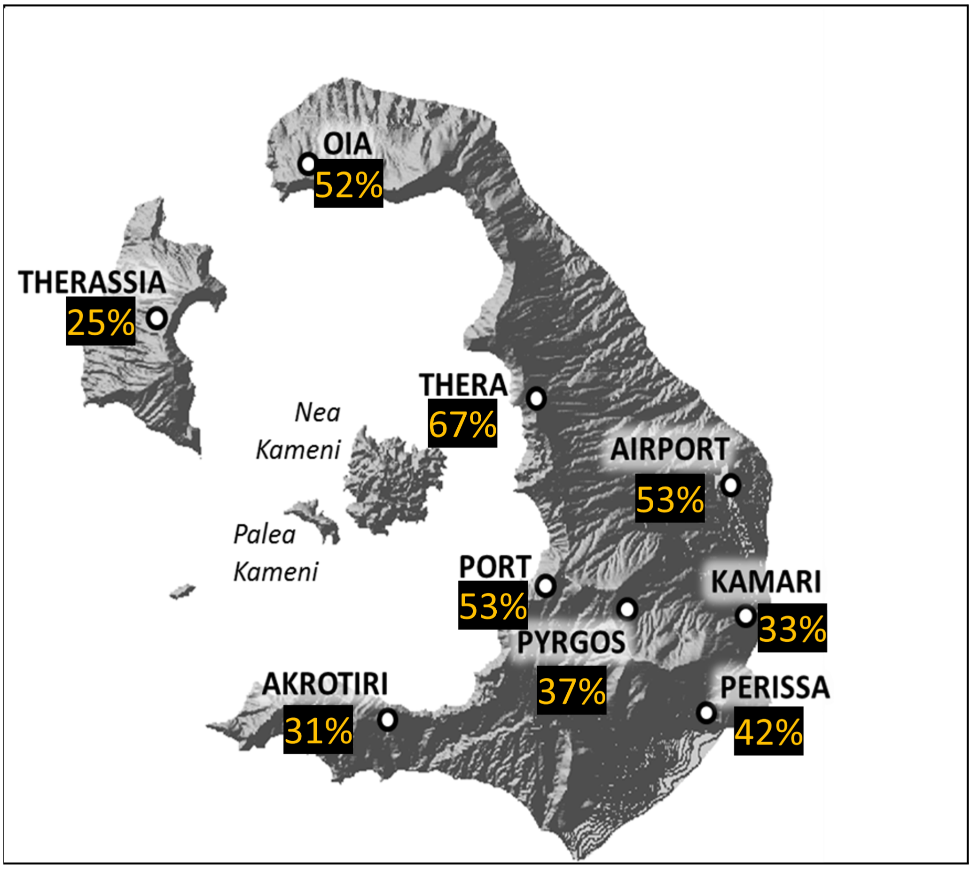

Figure 3.3, Map showing areas visited by the survey participants as a percentage of all respondents.

3.1.3 Volcanic Perception

The questions that address volcanic perception are crucial in gaining an understanding of the tourists' perception of the genuine risk that is present on Santorini. The results from this section allow for a much greater understanding of the vulnerability of tourists, with less perception of risk implying greater vulnerability.

Figure 3.4 highlights what the participants said they would use for information whilst staying in Santorini. The most popular response was 'smartphone' which is unsurprising given the findings that highlight smartphones as having the potential to significantly influence the touristic experience (Wang, Park and Fesenmaier, 2012). The two lowest responses were that of 'Guide' and 'Other'. Under the written responses given for 'Other', a number noted that they would use locals, such as Airbnb hosts or friends from the area for knowledge. Furthermore, some 'Other' responses mentioned that on the cruise ship information sheets and talks were given that produced information about the island.

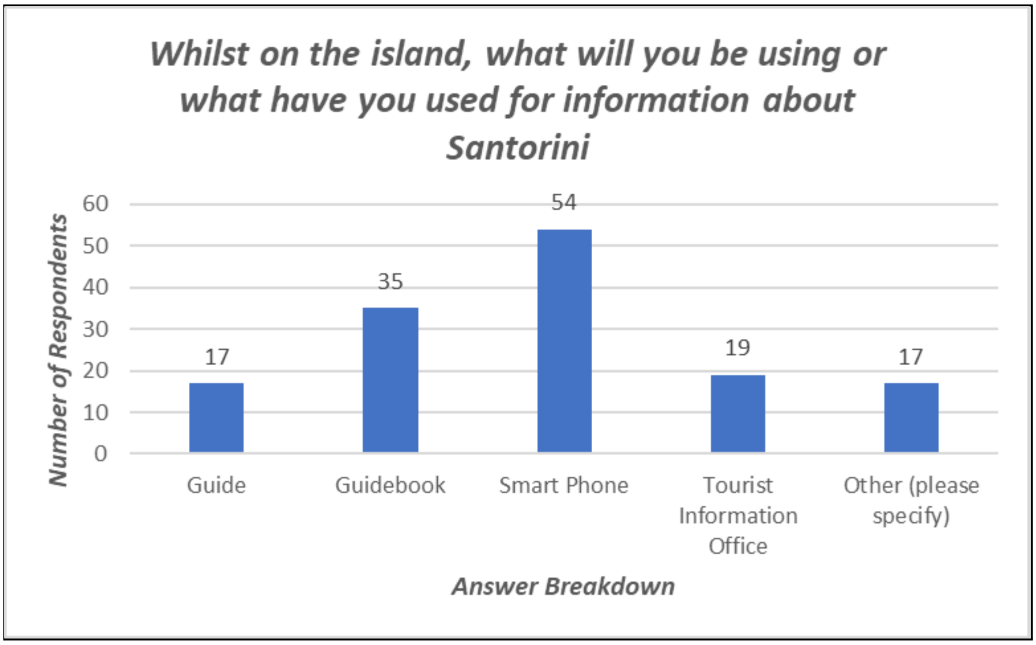

Figure 3.4, shows options as to what participants would use for information about Santorini whilst visiting. With the number of responses given (n=81)

Shown in figure 3.5 are responses to a question related to what participants believe to be hazards associated with volcanic activity on Santorini. It shows that most believed Volcanic Ash is associated with any volcanic activity (63 participants). The least popular response listed was that of lightning (15 participants). 3 stated that none of the listed hazards were associated with volcanic activity on Santorini. Volcanic Ballistics (n=53), Lava (n=52), Poisonous Gases (n=48) and Earthquakes (n=46), were all selected by over half of the participants. For the 7 that selected 'other', their written responses included risks such as landslides and mudslides as well as acid rain. A couple of the 'other' responses mentioned that they did not realise it was an active volcano or that they did not know which of the risks would be associated with volcanic activity.

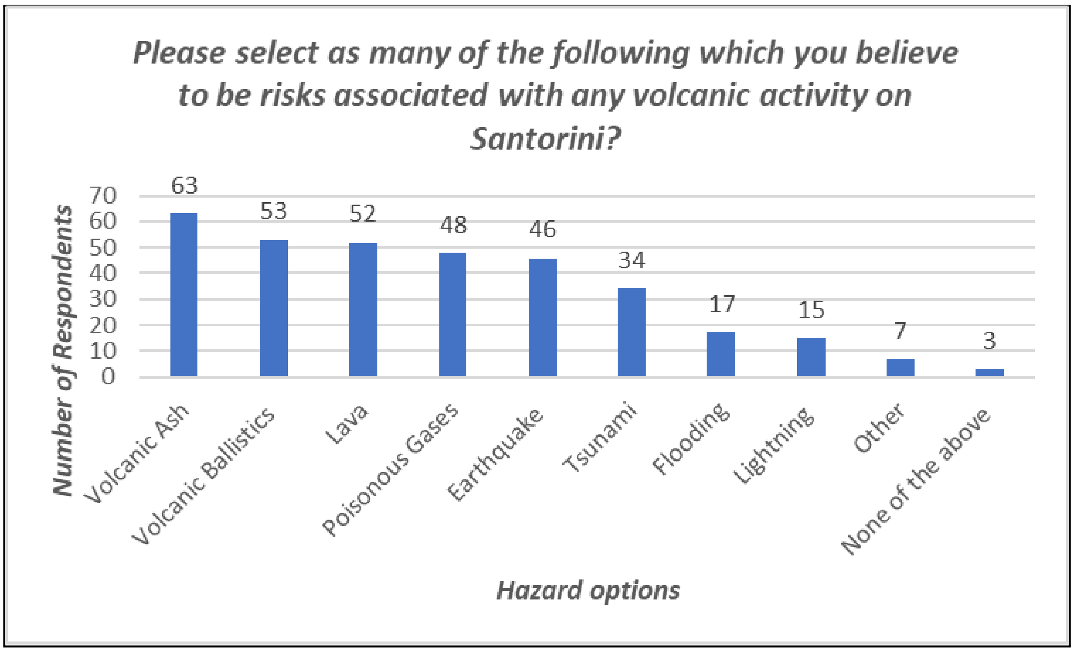

Figure 3.5 shows the many different hazards that participants believed to be associated with volcanic activity. Data is ordered with the most selected on the left and the least selected on the right.

Two questions in the questionnaire addressed participants' awareness of the possible hazards associated with volcanic eruption. The first of the two asked which hazards from a list would have the greatest impact on the island and why? Written responses have been coded, with codes shown in Table 3.6. Alongside the codes are the hazards that were associated with these codes, with most popular being put first in each case. Therefore, it can be seen that for the destruction of both homes, businesses, and infrastructure, earthquakes are seen to have the greatest impact, with lava being the second highest response. However, when looking at disruption to infrastructure, such as closing airports and contaminating water supplies etc, it can be seen that volcanic ash is, with earthquakes second, volcanic ballistics third and lava and flooding also having a slight impact. The codes are also in order of order of occurrence, meaning that the one at the top of the table i.e., 'Disruption and destruction of infrastructure' is the most used code with nearly half of those that answered why giving this as their reasoning. For example, participant 52 said "*Earthquake - Loss of infrastructure*". The code 'Danger to health' was the least used. Finally, it can be shown that earthquakes are seen as the cause of the greatest impact due to their possible effects of destroying homes, business, and infrastructure.

Table 3.6 shows the codes extracted from the written responses given in response to which hazard would have the greatest impact in the left hand column. On the right is the hazard associated with that code, with the most mentioned written first and the least written last.

Code	**Hazards associated with it (Most popular first)**
Disruption and destruction of infrastructure (e.g., Disruption to air travel)	Volcanic ash, Earthquakes, Volcanic Ballistics, lava and flooding
Destruction of Homes and business buildings	Earthquake and lava
Damage to the natural environment (Vegetation etc.)	Volcanic Ash, Lava, Earthquake
Loss of life	Volcanic Ash, earthquake, Poisonous Gases
Danger to health	Volcanic Ash and Poisonous Gases

The second question focuses on which risk was most likely to occur in the participants opinion and why? Table 3.7 below shows the codes created from the worded answers, along with the definition of the code and the risks associated with each code. The most mentioned risk for each code is put first, and the most used code is at the top of the table. Therefore, it is seen that the risk that is expected with every period of volcanic activity, volcanic ash, is the most likely risk to occur, with lava, earthquakes, poisonous gas, and tsunamis also being associated with that code. Earthquakes are seen to be mentioned in connection with being a common precursor to a volcanic eruption and therefore seem to be fairly likely. Whereas the table shows that lightning and flooding are much less likely although they could happen easily outside a period of volcanic activity.

Table 3.7 shows the codes extracted from the written responses given to which risk was most likely to occur in the participants opinion in the left hand column, with the definition of each code given in the middle column. On the right is the risk associated with that code, with the most mentioned written first and the least written last.

Code	Definition	Risks associated with it (Most popular risk first)
Present with volcanic activity	The risk is expected with any volcanic activity so therefore likely to happen	Volcanic Ash, Lava, Earthquake, Poisonous gas, and Tsunami
Precursor to volcanic eruption	The risk is expected prior to the beginning of a volcano erupting so therefore likely to happen	Earthquake, Volcanic Ballistics and Volcanic Ash
High frequency risk	The risk is common and frequent so therefore likely to happen	Earthquake, Volcanic Ash and Volcanic Ballistics
History of risk	Due to knowing that it’s happened in the past, expected to happen again	Volcanic ash and Earthquakes
Separate risk	It can occur separately, without volcanic activity	Lightning, flooding and tsunami

Another question asked participants what they would do if they were told through local media announcements of the beginnings of volcanic activity but within the announcements there was no mention of the need to evacuate. Figure 3.6 below, shows that the majority selected the option of ‘asking a local authority figure for more information’ (n=35, 43.21%), with the second most popular option being to ‘return to their accommodation’ and then ‘continue to follow the news from there’ (n= 16, 19.75%). The other three options; ‘carry on as normal’, ‘look to get on the next flight/boat home’ and ‘other’ all received the same percentage of response (n= 10, 12.34%). Of those that answered ‘other’, many mentioned in their written responses that they would look online at the latest information and then take action from there. A couple of responses mentioned the idea of trying to observe whatever volcanic activity was going on if they believed it to be safe to do so.

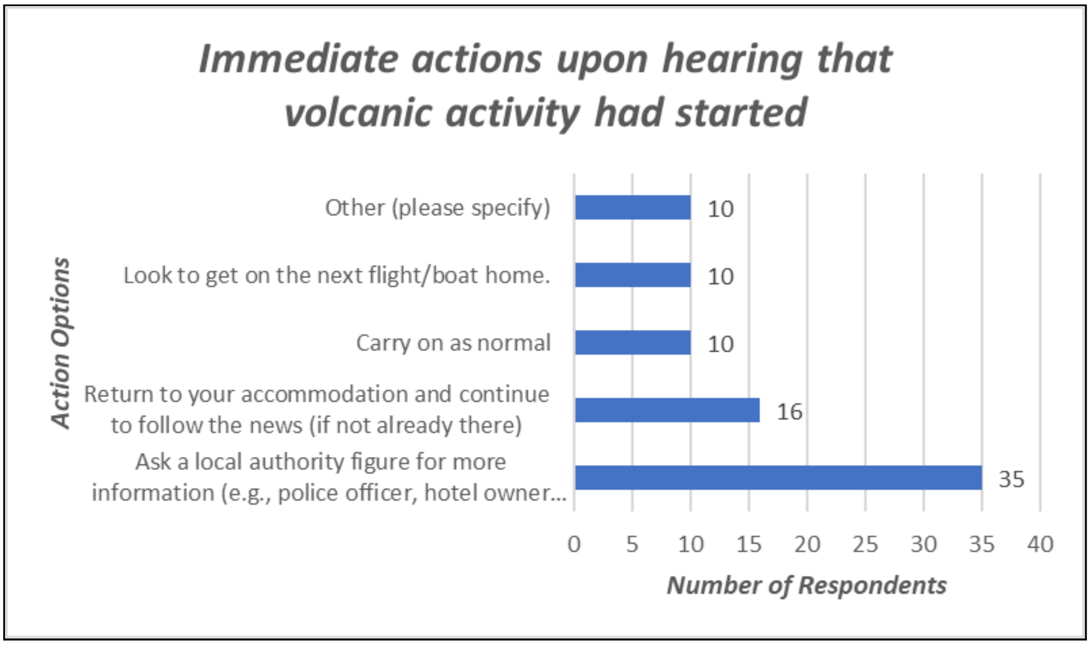

Figure 3.6 breaks down what action each participant said they would do on hearing that volcanic activity had started. It has been ordered so that the most popular answer is at the bottom with the least given at the top. Each selection has a data label to show the exact number of responses for that option(n=81).

In the case of an emergency on the island, the participants were asked to choose from a selection of different types of authority figures which they would like to hear from when conveying emergency information. Figure 3.7 below shows how each person scored, with a high number representing someone who was seen to be higher on a participant's preference when ordering the selection. Therefore, the chief officer of the fire brigade with a score of 3.49 was in general the one most wanted on average to convey any emergency information. The least popular was a leader from mainland Greece, with their score being 2.04 and their percentage as the bottom rank being 52.50% meaning that just over half of the participants (42 out of 100) ranked them as the last of the selection that they would want to convey emergency information. The difference in score between Chief Officer of the Fire Brigade, Chief Officer of the Police and the local media news is just under 0.25, which highlights them to be very close in the tourists preferences, but as mentioned the Chief Officer of the Fire Brigade being the top response.

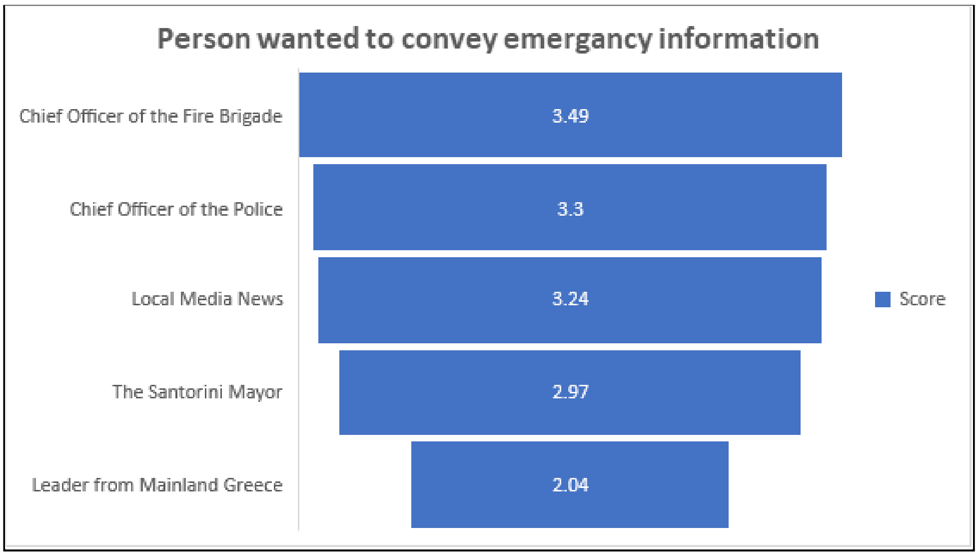

Figure 3.7 shows the score given to each person of the authority, which has been worked out by how each was ranked by the participants from top to bottom. The top being the highest priority and bottom being the lowest.

Although it is understood that the Chief Fire Officer is the preference out of a selection of authority figures, the next question asked participants as to what form they would most prefer to receive emergency information. The overwhelming majority (45 respondents) stated that they would prefer to receive it through a text message to their phone, with the second preference being through a public media broadcast (23 respondents). No participants selected a public poster or distributed leaflet. Knowing the responses to the previous question (figure 3.7), only 10 respondents wanted it to come in person from an authority figure. The one participant that selected the 'other' option, said in the written response that it should be a message sent to all electronic devices instead of a text message just to your phone.

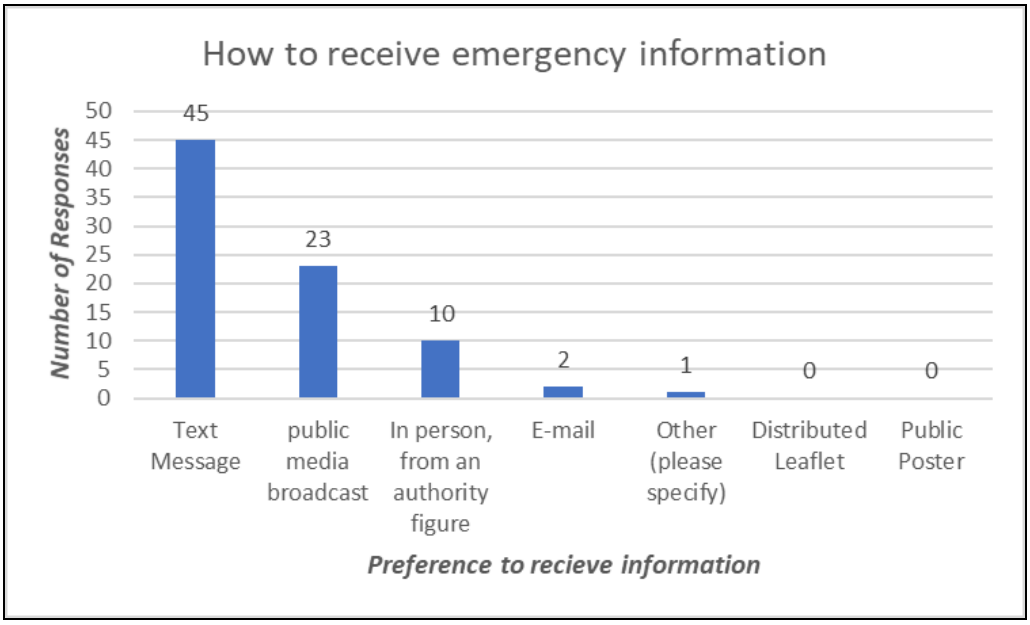

Figure 3.8 shows in which way participants want to receive their emergency information. This was asked as a checklist question. n=81

One of the final perception questions looked into whether tourists had a strong understanding of volcanic risk to suggest if an area of Santorini is at least at risk at the time of a future eruption. As shown in figure 3.9, they were given a map of Santorini split into 5 different areas, and were then asked to select which area, if any, is least at risk during an eruption. They were also given the options of choosing a combination of areas or to select that all the areas are at the same amount of risk. Figure 3.9 has the percentages showing which selection was picked by the participants, with the largest option being that all areas are at risk (43%)

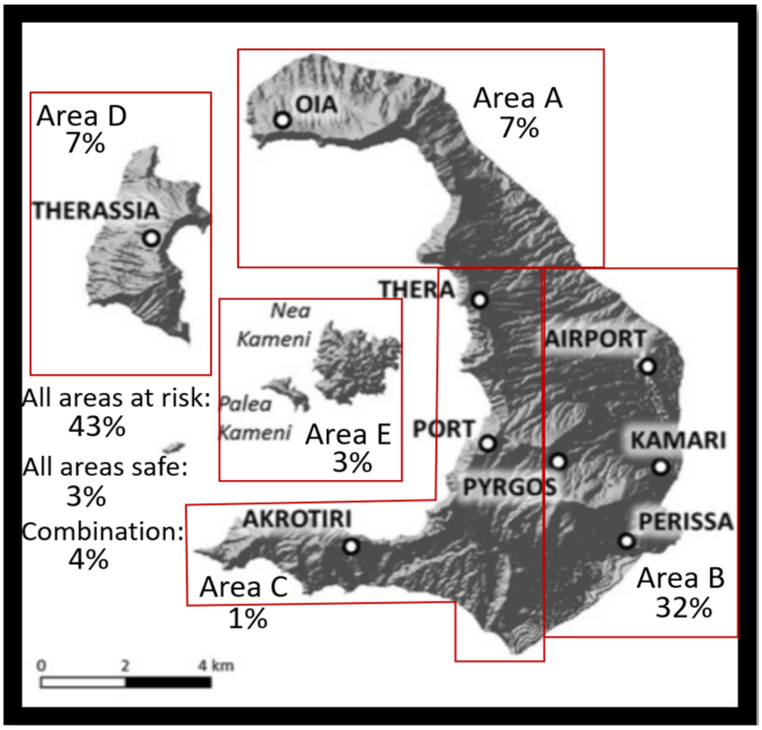

Figure 3.9 showing the percentage of which area was chosen as at least risk during an eruption by the participants of the questionnaire. The basemap is taken from Jenkins et al (2015)

Having seen which areas were selected by the participants, the next question asked them to give their reasoning behind their answer. Table 11 shows the codes created from their written responses with the definition for each code. The code at the top of the table is the most popular code from the written responses. Therefore, it can be seen that the most common reasoning behind why participants chose their area was because they believed that a future eruption would be of a scale exceeding the size of the island. Specifically, this reason was given for those that answered that all areas were at risk in the previous question.

Table 3.8, Codes created from the answers as to why the participants chose a specific area as the least at risk area in the event of volcanic activity. The code at the top of the table is the most popular code from the written responses.

Code	Definition
Scale of Island versus eruption	It's believed the size of a future eruption would exceed the size of such a small island

Protected infrastructure	The thought process is that the location of the airport indicates an area of safety as critical infrastructure should be in a protected area
Distance from Volcanic Centre	The greater distance from the perceived volcanic centre, increases the safety of the area

3.2 Spatial Distribution of Accommodation and Volcanic Risk

To fully be able to show the risk present to tourists visiting Santorini, it is important to show the results that highlight where tourists most likely stay whilst also showing what the largest risk is and which areas of the island it will most affect.

3.2.1 Distribution of Accommodation

Through the survey undertaken in this project, as explained in section 2.2, the locations of the hotels found in the nine centres are shown in Figure 3.10 where the locations are shown on a topographic basemap using ArcGIS. The number of rooms available at each hotel is also shown. The higher number of rooms available the larger the dot that represents that hotel, as well as the colour of the changes. This is shown in the legend below the map, showing the ranges selected to separate the hotels. The map shows the exact georeferenced locations of 255 hotels. It should be noted, however, that the Hellenic Chamber of Hotels lists over 300 hotels for Santorini, which includes those located outside of the main centres looked at in this study.

This shows that the towns of Thera, Kamari and Oia are those most densely populated with hotels and have the highest number of beds available to tourists. In terms of size of hotels Karmari is seen to have the most hotels in the top two ranges (41-64 and 64-124 rooms). The least popular areas shown are the two transport hubs, the port and the airport as well as the island of Therasia. The island of Therasia only has two hotels, both of which found to be in the smallest range when looking at rooms available. The two transport hubs did not have clearly defined areas to go by when looking for hotels nearby, therefore hotels within 1 km according to last minute.com were added.

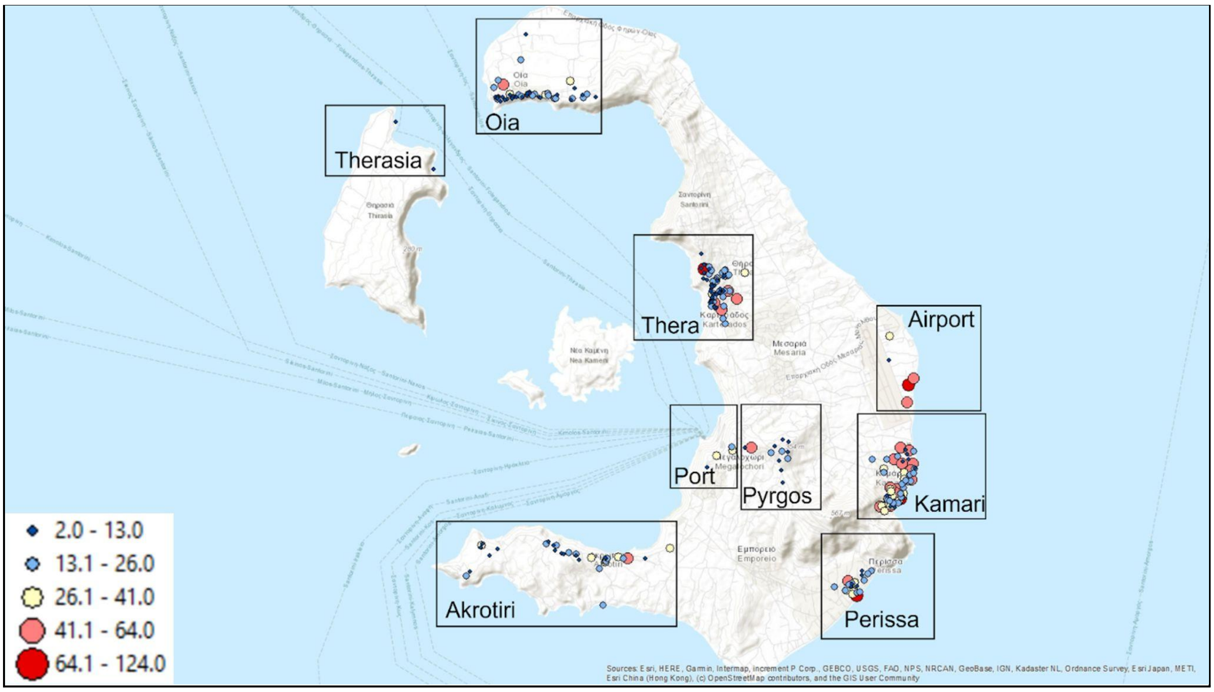

Figure 3.10 Map generated from ArcGIS, with labels and boxes added to show the areas where hotels are located. The hotels themselves are shown by a size and colour dots depending on the number of rooms available at that hotel as denoted in the legend on the lower right hand side scale 1:150,000)

3.2.2 ArcGIS - Volcanic Risk

Jenkins et al (2015) modelled the probability for total ash accumulation on the ground as determined by the most likely eruption scenario. Figure 3.11 shows an edited georeferenced version of the probable ash accumulation values superimposed as a separate vector layer onto a topographic basemap produced from the online ArcGIS Desktop database. The numbers associated with each line show the cumulative deposit in kg/m². The black star shown is the assumed vent location of the future eruption used by Jenkins et al (2015) in their modelling process. On the left hand side of Figure 3.11 are wind rose diagrams, also taken from Jenkins et al (2015), for wind direction at surface level. They show the wind direction to be predominantly northerly, as they show the direction the wind is blowing from, not where it is blowing to.

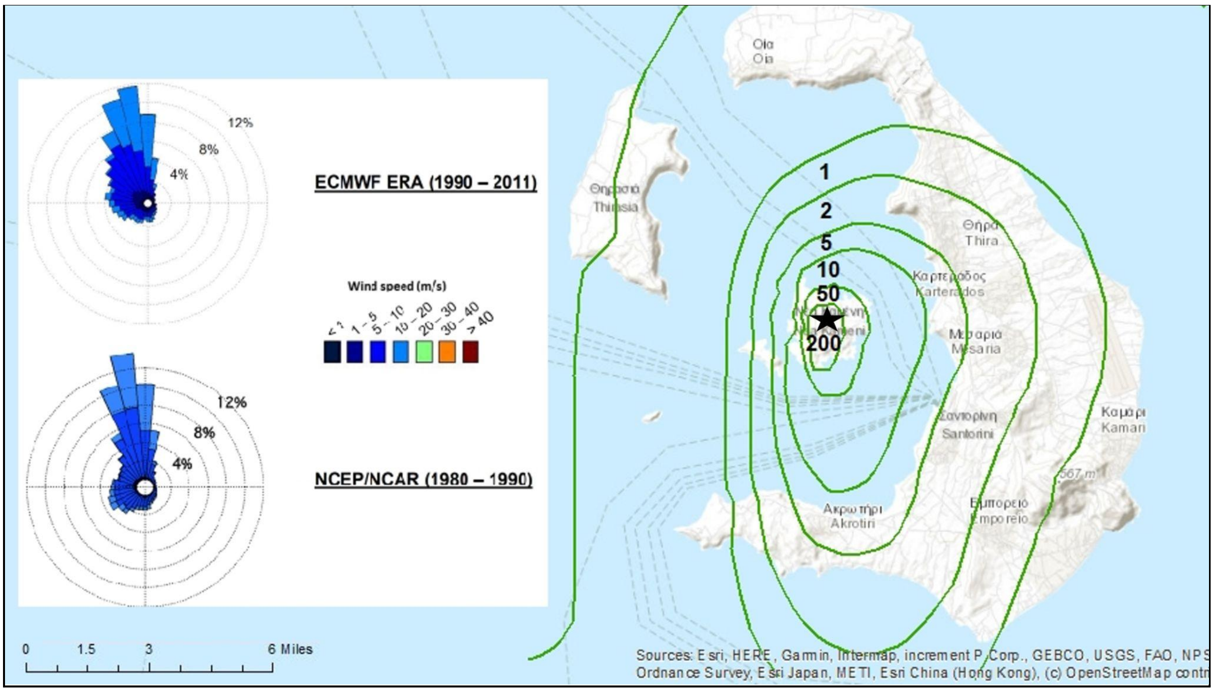

Figure 3.11, On the right, represents the model generated in Jenkins et al (2015), but imported into ArcGIS desktop, using a topographic base map layer. The map is showing the total ground ash accumulation expected in the most likely scenario measuring in kg/m². On the left, are wind rose diagrams produced by Jenkins et al (2015), showing the wind direction at surface level. It is shown to be northerly as they show where the wind is blowing from not to.

4.0 Discussion

Through this discussion chapter the aims of this study will be laid out along with how they have been achieved. The chapter will analyse the results, highlighting significant results that particularly respond to the aims set out. These aims are:

1) What is the spatial distribution of volcanic risk for tourists on Santorini?
2) What the perceived volcanic risk is for tourists visiting the island of Santorini.

Furthermore, to establish the tourist's perceived risk, some initial speculation is made on how the characteristics tourists had affects their perception.

4.1 Spatial distribution of Volcanic Risk

Through the previous works of Dominey-Howes and Minos-Minopoulos (2005), Jenkins et al. (2015) and Vougioukalkis et al. (2016), this study was able to understand better what the exact risks are in a future eruption. Previous studies have highlighted multiple different scenarios that could occur in a future period of activity (Vougioukalkis et al., 2016). For this study, however, the focus has only been on that of the most likely scenario to occur, which is an intra caldera volcanic eruption of the Kameni centres following that of historical eruptions (Fytikas et al., 1990; Vougioukalakis 1994; Vougioukalakis & Fytikas 2005; Pyle and Elliott, 2006; Jenkins et al., 2015; Vougioukalakis et al., 2016). This is shown in figure 4.1, which shows a ArcGIS adaption of the figure first produced in Jenkins et al (2015). This ArcGIS version, however, not only shows the risk of ash accumulation but also shows the locations of hotels (this study) found in the nine area hubs of Jenkins et al (2015). This figure therefore shows the amount of risk that all of these areas are potentially at during a future eruption. The key hazard, highlighted in figure 4.1, is ground ash accumulation with each band showing a number representing the kg/m² of ash accumulating. Each of these numbers have been calculated with a 50% chance of exceedance.

The nine area hubs from Jenkins et al (2015) are; Oia, Therassia, Thera, Kamari, Pyrgos, Perissa, Akrotiri, the port and the airport. Using figure 4.1, the risk from ash fall to hotels in these areas can be looked at specifically. The reasons for each area being of interest for tourists are shown in figure 4.2. This shows the original figures for ash accumulation from Jenkins et al (2015) but with the addition of information as to why each area is significant to tourists visiting Santorini. Knowing this information, the specific link of where tourists are found on Santorini and where the genuine risk is expected to be in a future eruption can be explored.

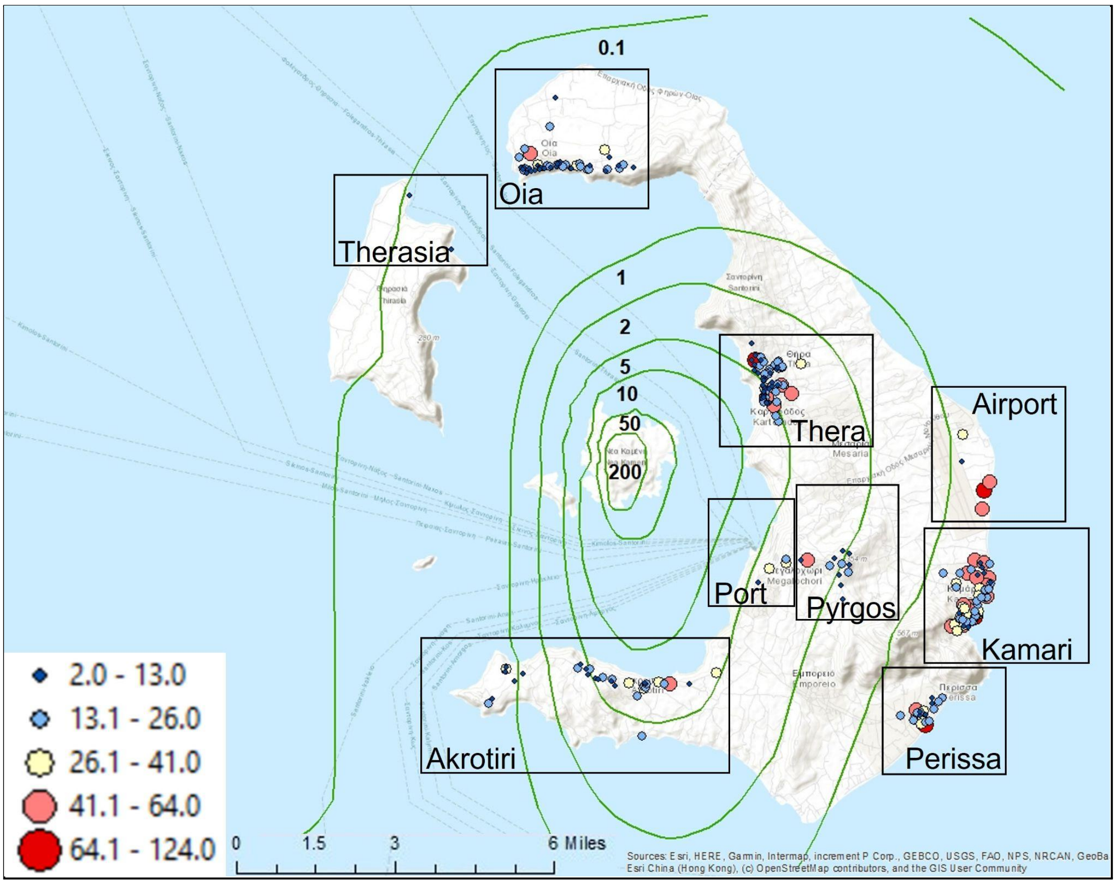

Figure 4.1 ArcGIS map showing the varying amounts of ground ash accumulation in the most likely eruption scenario. Also shown are the locations of hotels found in nine area hubs previously highlighted in Jenkins et al (2015). Hotels segregated by number of rooms available, with legend showing the symbol breakdown.

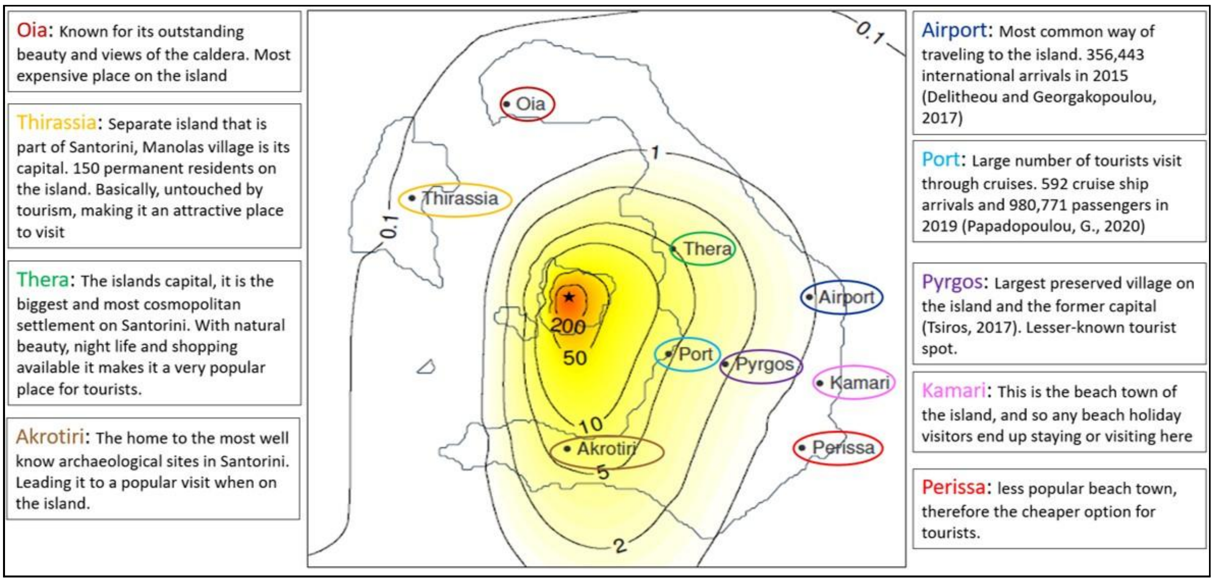

Figure 4.2 Adapted from Jenkins et al (2015), this shows the predicted ground ash accumulation in the most likely eruption event. Black star represents the expected eruption centre. It highlights nine area hubs, colour coded with each having information given as to why it is of interest to tourists visiting the island of Santorini.

4.1.1 Link of Expected Volcanic Risk to Tourist Area Hubs

Thera is the most popular town in Santorini. This is shown by multiple data sets collected within this project. First, figure 4.2 describes Thera as the largest and most cosmopolitan settlement on Santorini and this is supported by the number of hotels situated in the town shown in figure 4.1. Second, the town of Kamari has the next highest number of hotels situated within it. The hotels seem to vary in size from 2-13 rooms up to hotels with 41-64 rooms. This shows there to be a high chance that there are a large number of tourists staying in the area at any one time. Additionally, the town is the most visited area according to the questionnaire undertaken in this study, with 67% of participants visiting or planning to visit Thera (Figure 4.3).

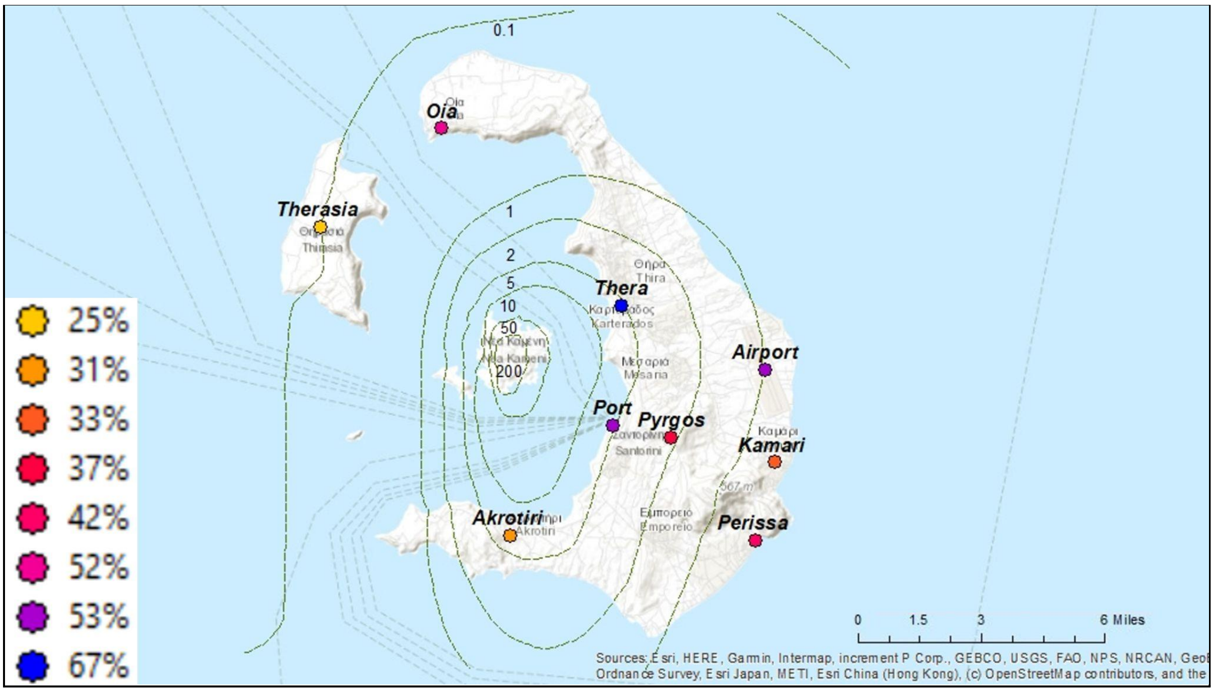

Figure 4.3 represents the percentages of where participants of the questionnaire had visited or planned on visiting and the expected risk (ground ash accumulation (kg/m²)) from a future eruption in the most likely scenario.

What can be seen in all three figures (4.1,4.2,4.3) is that the town of Thera falls into the ash accumulation band of 5 kg/m². This is a large amount of ground coverage and presents a sizable risk to the town of Thera. Adding this to the data, suggesting that it is one of if not the most popular destination on the island of Santorini (fig. 4.1, 4.3), it is fair to suggest the level of risk aimed at tourists visiting Thera is high when compared to other parts of the island.

In terms of the safer area hubs, the town of Oia, is thought to be one of the safer places in the event of a future eruption, situated in the lower 0.1 kg/m² ash accumulation zone (fig.4.3). The main wind direction for Santorini is northerly (blowing from), which therefore benefits the town of Oia in times of volcanic activity, as ash and gas would be expected to be blown away from the town. Furthermore in responding to an informal interview G. Vougioukalakis mentioned when looking at which areas would be at least risk that in the same scenario modelled by Jenkins et al (2015) (most likely scenario) “the north part of Thera island and Thirasia have been identified, because of the prevalent wind direction” (*Pers. Comm. G. Vougiokalakis, Sept 2021)*. Therefore in risk alone Oia is seen to be at much less risk than places such as Thera. With the exception of the two transport hubs, it is seen that Oia is the second most visited area on the island, with 52% having visited or intending to visit (figure 4.3). It is known for its amazing view of the beautiful caldera, whilst also being the most expensive area of the island (figure 4.2). The number of hotels is less than that of Thera and Kamari, however, it is by no means the smallest. Although the size of hotels are mainly found to be in the 2-13 room bracket, with only one hotel in each of the 26-41 and 41-64 room brackets, it is clearly an area with a large number of tourists, which in turn increases its overall risk. However, due to the previously mentioned reduced risk in terms of ash and other hazards, Oia is thought here to be the one of the safest area hubs in Santorini (in agreement with the proposals in the emergency Plan Talos- *pers. comm. G. Vougioukalakis*).

The other area hub thought to be safest in the event of the most likely eruption scenario, is that of the island of Therasia. G. Vougioukalakis (*pers. comm.*) states that this is due to the prevalent wind direction for Santorini (fig. 3.11), meaning the main hazards of ash and gas are less likely to affect this island as much. This is highlighted in figures 4.1,4.2 and 4.3 where it is seen that Therasia is located on the 0.1 kg/m² ash deposition boundary. Except for Therasia, nowhere else in Santorini is found outside of the 0.1 kg/m² band. Furthermore, it is seen that the island of Therasia is one of the least popular places to visit, with only two hotels shown in figure 4.1 and the percentage of participants that visited or planned to was low at 25%. All of these data combined highlights Therasia as one of the lowest risk areas due to the low numbers of tourists as well as the physical aspects with reduced risk to the area.

Another area to be considered is Kamari. It can be seen in figure 4.1 that Kamari is the area on the island with the most number of the top two categories in terms of size of hotels, i.e hotels with 41-64 rooms and 64-124 rooms available. During peak tourist season it is an area that has a high capacity of tourists, which immediately increases its risk. With the increasing number of permanent residents in Kamari (Delitheou and Georgakopoulou, 2017) and suffering from the highest population density in Santorini (433 residents/km^2) (Batzakis et al., 2020) leads it to being an area of high risk. However, two data sets that reduce this slightly are (a)the band it fits into for the ash accumulation,0.1kg/m² (Figure 4.1, 4.2 and 4,3), which is the lowest band produced although again there is a 50% probability that this is exceeded; and (b) when looking at the responses of the questionnaire only 33% respondents intended to visit this area (Figure 4.3), showing far fewer tourists than for Thera.

Whilst Kamari seemingly has a reduced proportion of tourists and it also falls in the smallest band of ash accumulation, there is another hazard highlighted to be a risk in previous assessments for the area of Kamari, namely the threat of a tsunami. As seen in figure 4.4 (below) Kamari, with a maximum elevation of 50m, is situated on much lower ground than other parts of the island (Batzakis et al., 2020). Figure 4.2 mentions that it is the beach town of the island for tourists, giving a key reason as to why tourists may visit the area. With the aforementioned high population density, along with a potentially high visiting rate of tourists shown by the amount and scale of the hotels, the threat of a tsunami causes its risk to be higher than shown through the ash accumulation data and questionnaire data. A tsunami is a much greater risk in the event of a submarine eruption of the Kolumbo Volcano situated north east of the main Santorini complex. This risk is not thought about as much when looking at the most likely scenario, which is in fact an intra caldera volcanic eruption of the Kameni centres following that of historical eruptions (Fytikas et al., 1990; Vougioukalakis 1994; Vougioukalakis and Fytikas 2005; Pyle and Elliott, 2006; Jenkins et al., 2015; Vougioukalakis et al., 2016). Batzakis et al, (2020) shows that 57% (82 out of 146) of the hotels in Kamari fall into the high and very high brackets of relative vulnerability, with scores of 62% and 90% for stores and food outlets. These scores are thought to be due to the substantial touristic growth there. To be in the high or very high bracket it means the buildings have scored a score of 3.4 or higher with the highest being 5 based on the Relative Vulnerability Index (RVI). This calculation takes into account a variety of vulnerabilities such as water, the surroundings exposure and the building's vulnerability (Batzakis et al., 2020). These data highlight the area of Kamari to still be a high risk area for tourists visiting. Less because of the hazards expected in other areas (ash and gas) but increased instead because of a hazard localised to this coastline (tsunami) of the island of Santorini.

The other area seen to be at risk from a tsunami in a future eruption is the area found just south of Kamari, Perissa. Perissa, shown in figure 4.4 (below), is located on very low ground on the south-easterd coast of the island, as is a beach location similar to Kamari. The area is located in the 0.1kg/m² modelled band of ash accumulation. In terms of hotels it has fewer than the larger towns. It does, however, have some of the largest (64-124 rooms) and so does have the capacity to hold a high number of tourists especially during high season. From the questionnaire, 42% planned to or had visited this location. Showing this to be a fairly popular place for tourists, especially if they want less crowded beaches as expected in the town of Kamari.

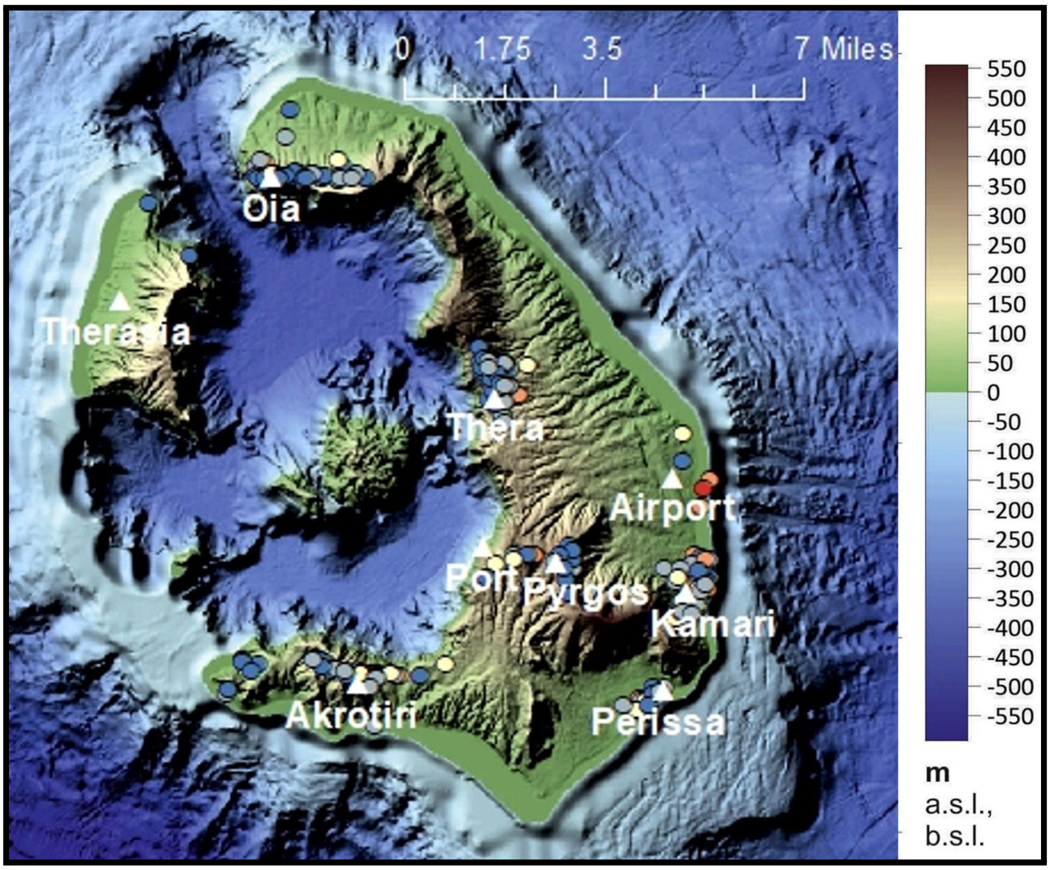

Figure 4.4 A digital elevation model (DEM) of Santorini (adapted from Karátson et al., 2020) showing the locations of hotels situated in the nine area hubs focused on in this study

Lastly, it is important to look at the two key transport hubs, the airport and the port. In terms of tourists visiting each, they had exactly equal percentages (53%), however, they fall in different bands of ash accumulation. The airport is situated in the 0.1kg/m² band while the port is much higher between 2 and 5kg/m². This a large difference, although the smallest amount of ash is still a significant issue for the airport and the potential impacts on air travel. The accumulation of only a few millimetres is sufficient to force airport closures (Guffanti et al., 2009). The possibility of the closure of the Santorini Airport during a future eruption scenario increases the risks further to tourists as the key evacuation transport would be disabled. The possibility of an airport closure is well known and is mentioned in the recently produce 'Talos', which states that "due to inability to operate or access to the port of Athinios or the airport, the removal will be carried out with the contribution of means of the Navy and the Coast Guard"(General Secretariat For Civil Protection, 2020 p.133). Whether this plan is sufficiently able to cope with the possible millions of tourists needing to be evacuated is unknown.

The port in Santorini is situated in the much higher 5kg/m² band in terms of ash accumulation. Along with the hazards of ash and gas, 'Talos' had produced a hazard map for the most likely scenario and this highlights the port as being in an area that is at high risk of landslides increasing the risk to those in that area, especially those visiting by sea (General Secretariat For Civil Protection, 2020). As a result of these factors, the risk to tourists within the Port area hub is much higher than other parts of the island such as Therasia.

4.1.2 Link between of Expected Volcanic Risk to Tourists Perceptions

Having looked at the expected volcanic risk, and the known and expected distribution of tourists on the island, it is now necessary to look at the relationship between what the expected volcanic risk is and what the tourists visiting the island perceive it to be. Data for the tourists' perceptions came mainly from the questionnaire carried out in the study. A tourists perception of volcanic risk has not been widely studied and therefore this study provides a first step to stimulate further research. Therefore it is important to highlight some of the key theoretical background behind risk and public perceptions before suggesting links that have been found in this project's research. Kasperson et al. (1988) suggest that through an interaction with the psychological, social, institutional and cultural processes, hazards amplify public responses to risks or risks events. They state that one of the key stages that create amplification of risk is in the communication stage. This is an area that will need to be considered and assessed closely during any future research such as those outlined in section 4.3 Risk Mitigation Recommendations.

One of the first questions posed in the questionnaire was 'why were they visiting the island of Santorini?' In addressing their reasoning for travel, it can be established as to whether it is connected to their perception of risk. For example, if they were travelling due to the fact that Santorini is volcanic it would be expected that they have a greater perception than those that are purely travelling due to its ease as a holiday destination. The responses were coded as shown in the results section (3.1.1), with the most popular code shown at the top and least popular at the bottom.

The code 'Volcanic Attraction' was found in only 8 responses with this code (approx. 8%). This low percentage is a surprise, with G. Vougioukalakis saying that the volcano is one of the key reasons for visitors (*Pers. Comm. G. Vougiokalakis, Sept 2021)*. Furthermore, he mentioned the reason of Santorini's fame as a tourist destination, however, it can be seen again that the code ‘reputation’ is found low on the table as it is one of least popular codes mentioned in responses. This highlights a possible difference in the views of the experts and those actually visiting.

To continue, a key part of a tourist's perception is looking at what they know and think regarding possible hazards related to a volcanic eruption. Within the questionnaire, participants were asked to select as many hazards from a list that they thought were associated with any future eruption on Santorini. As shown in figure 3.5 (results chapter) the most frequently mentioned hazard selected was that of Volcanic Ash (63 participants selected this). This shows that at first glance the majority of tourists have a perception in line with what the experts know to be the key hazards associated with future volcanic eruptions on Santorini. However the questions that followed this in the questionnaire, looked further into the perception of the participants, asking them to say which they thought would have the greatest impact in a future eruption and which is the most likely in a future eruption.
Figure 4.5 is a world cloud created using the response to what participants believed to be the hazard that would cause the greatest impact. The bigger the word shown in the figure the larger the number of tourists that mentioned it. Therefore, it can be seen that Lava and Earthquakes are thought of as to have the greatest impact in a future eruption, with their reasoning for this shown in table 3.6 (results section). For the majority to select lava, shows a lack of knowledge when it comes to hazards of any future eruption, as this hazard is not expected to affect either of Thera or Therisia island, with only the eruption centres (Nea and Palea Kameni) going to have lava flow issues. This is highlighted by the hazard maps produced by Vougioukalakis and also by ‘Talos’ (General Secretariat For Civil Protection, 2020). Furthermore, ash and more so gas is seen to be thought about far less by participants with gases being seen as the smallest word on the word cloud. It is known through the work of Jenkins et al (2015) that these two hazards are to be of concern if an eruption were to occur on Santorini.

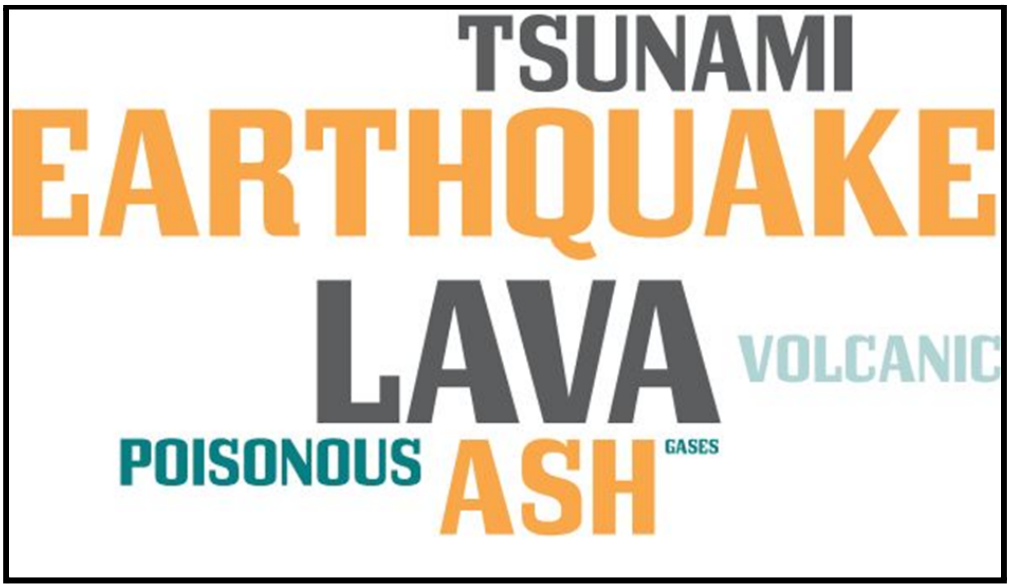

Figure 4.5 Word cloud representing the most impactful hazards perceived by participants (n=81)

Below is a second word cloud (Figure 4.6), which highlights the responses to the question that focused on the most likely hazard in a future eruption. Similarly to previous examples focused on greatest impact, participants have again highlighted earthquakes as the most likely, with ash and then lava being second and third on the list. Again the reasons behind why each participant selected a certain hazard is highlighted in table 3.7 (results section). The increase in perception of ash being one of the most likely shows a slightly increased perception of hazards, however, with earthquakes and lava still being the dominant hazards mentioned. Again this shows that in comparison to the experts, and the most up to date research, it is not correct. Furthermore, gas as a hazard is seen to be the least thought about, however, when asking G.Vougioukalakis which hazards are authorities most worried about for future activity, he stated “Ash fallout and volcanic gases from the plume” (*Pers. Comm. G. Vougiokalakis, Sept 2021)*. What is clear, through the data produced so far in terms of tourist perception, is that the hazard of gas is underestimated, whereas hazards such as lava are found at the forefront of tourists' risk perception.

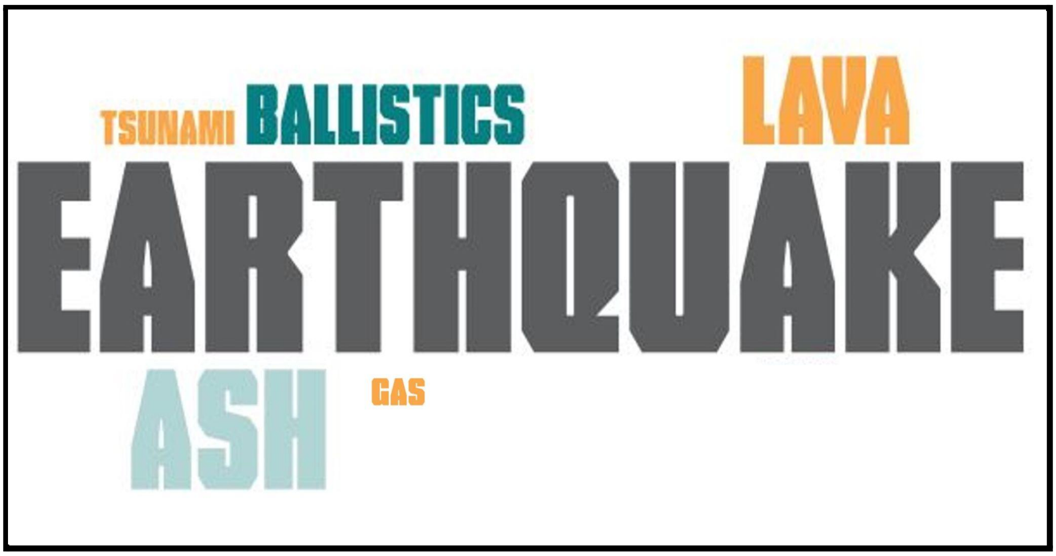

Figure 4.6 Word cloud representing the most likely hazard perceived by participants (n= 81)

The final part of the perception, looked into through the questionnaire, is spatial risk perception, i.e. where on the island tourists believe to be least at risk in the event of a volcanic eruption. Figure 4.7 below shows a map that incorporates all the key data sets that highlight tourist perception as well as genuine volcanic risk.

The map highlights that Thera is the most popular tourist destination on Santorini and that tourists themselves do not believe it to be in an area of safety, with the genuine risk supporting their perception. This showsThera to be situated in an area expected to receive up to 5kg/m² of ground ash accumulation. This raises the point as to whether highlighting this risk to all visiting tourists will change their behaviour? Noting, however, that tourists' perceptions are seemingly in line with the genuine risk of Thera.

The map also highlights that a large number of tourists (participants) believe the airport to be located in an area of less risk (32%). It also shows that 53% of the participants visited that area hub so there is the potential for high risk, if it were to be badly affected by hazards. The hazards that would most likely affect the airport is ash with values between 0.1 and 1kg/m² of ground ash accumulation. As mentioned above (section 4.1.1) the slightest amount of ash can cause an airport to close (Guffanti et al., 2009) and Jenkins et al (2015) concluded that "*it seems probable that the Airport will be affected for some ash events" (p.20).* This highlights an area at risk that is not at the forefront of tourists' perceptions, largely due to their belief that infrastructure such as an airport would be built in an area of safety.

Additionally, 53% of tourists (participants) visit the port, and similar to Thera falls into two bands of ash accumulation (5 and 2kg/m²) representing a potential high level of risk. In addition, a hazard not focused on within this study, landslides, is mentioned in 'Talos' as a risk to the port (General Secretariat For Civil Protection, 2020). With these two hazards, focused on areas with a potential for a high amount of tourists similar to that of Thera, the clear high risk of the area does not dissuade tourists from visiting the area. However, if they had greater knowledge and awareness would this change? Here is where mitigation and management of risk perception needs to be looked into further. The suggestions from this study for mitigation and management will be suggested in section 4.3.

The final key point to make from figure 4.7 relates to the island of Therasia, where only 7% of participants suggested it to be an area of least risk and only a quarter of them have or intend to visit there. Whereas, the genuine risk in that area is seen to be the lowest of any area in Santorini, with only half the island found in the 0.1kg/m² band and the rest being seen to be outside of this. This is supported by G. Vougiokalakis, who said "*Northern part of Thera island and Therasia have been identified*" (*Pers. Comm. G. Vougiokalakis, Sept 2021)* when responding to being asked which areas had been identified by the authorities as the safest areas in the time of an eruption.

Therefore what figure 4.7 shows is the difference between tourists perceptions of risk, the actual risk and experts perception of that risk. As well as highlighting that in cases where the tourists' risk perception is more in line with that of the experts, the travelling behaviours do not change.

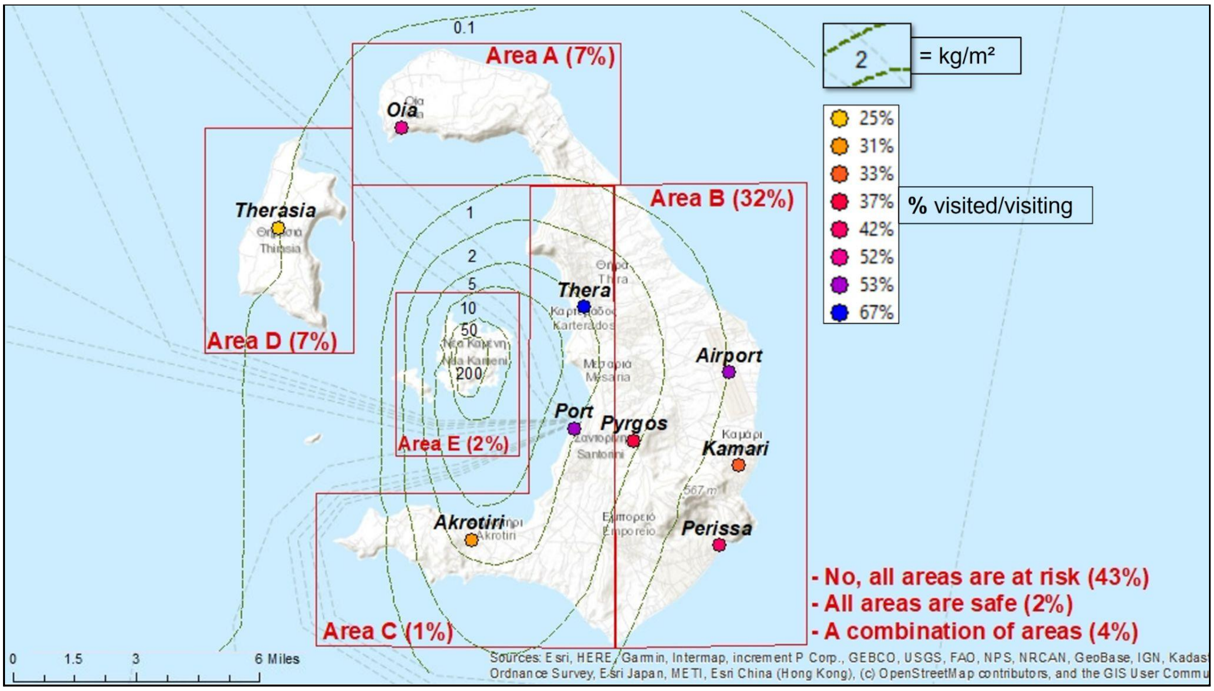

Figure 4.7 Highlighting perceived and actual risk for the islands of Santorini. ***The potential hazard is shown by the ground ash accumulation that is represented by the green dashed***

lines, with the numbers under each dashed line showing the amount of ash accumulation in kg/m². The risk for tourists, as shown by where tourists are seen to commonly visit on the island,Each colour represents the percentage of participants (see legend) that had either visited or planned to visit that area. Perception is shown in the red boxes and text on the map, showing where participants (tourists) believed to be least at risk in Santorini. The combination of all these sets of data provides a visual understanding of perception versus the genuine risk.

4.2 Tourist characteristics and perception of risk

The final part that needs to be looked into in terms of links between tourists and their perceptions of risk, is the characteristics behind the tourists themselves. Does the experience of past trips to Santorini have an effect on the risk perception of a tourist? In the Handbook for Volcanic Risk Management Jochen et al., (2012) along with other studies including Wachinger et al. (2013) states that it does. Does a person's age or gender also possibly affect one's risk perception? This has been found to be the case in numerous studies looking at natural hazards (Karanci, Aksit and Dirik, 2005; Armas, 2008; Barberi et al., 2008; Armas and Avram, 2009 and Kellens et al., 2011). This can be looked into through the questionnaire aspect of the methodology. First, this will examine the difference between the male and female participants, followed by differences found depending on age group and finally, looking at whether they are participants that had previously/planned to visit and whether that experience does in fact make a difference in their perception. Although, it must be noted that with the number of participants in this study, there is further scope for further research beyond this study (section 5.1) to look more deeply at the characteristics of tourists and how this may affect their volcanic risk perceptions

4.2.1 Female vs Male characteristic

"*Worldwide studies show that gender is an important variable affecting disaster risk perception and that women have high levels of disaster risk perception." (*Mizrak, Ozdemir and Aslan, 2021, p.2241)

For this study, the above quote highlights the need to look into whether there is a considerable difference in the volcanic risk perceptions between the male and female participants. When looking at the perceptions, in terms of which area of the island they believed to be least at risk in the event of an eruption, the male and female responses were very similar. Just under half of each gender highlighted the fact that the whole island would be at risk, with the second highest option for both genders being area B. The difference between the genders on the areas of least risk was instead found in the reason they gave for each area being at least risk.

For the female participants that selected area B, they used the code (Section 3.1.3) “Protected infrastructure”, therefore believed that infrastructure such as the airport had been built in an area of safety. This is further supported by figure 4.7 that highlights the high percentage of participants selecting area B. As for the male participants, they fell into the code of “distance from volcanic centre” meaning they believed that this area was far enough away from the eruption centre that it would reduce its risk in comparison to the other areas of the island. Thes shows contrasting differences between these two groups, that being their reasoning behind such perceptions. The reason for these differences would need further research to work out exactly why, but this study has started to highlight a difference of reasoning for a certain perception that has occurred between the male and female genders.

The next thing to look at is what each gender chooses when asked to pick the hazard they believe would have the greatest impact in a future eruption and which they believed to be the most likely. The breakdown of these responses is shown in tables 4.1 and 4.2 below. Table 4.1 focuses on the responses for greatest impact, and immediately what can be seen is that the top hazard for each gender is different, with females answering lava and males answering earthquakes. 12 out of the 16 responses that answered lava were female, whilst 10 out of the 21 responses for earthquakes were male. Now although in total more females answered earthquakes than men, the percentage breakdown has earthquakes as the biggest hazard for men, whilst lava does for females. This finding is supported by the word cloud (figure 4.5), where it is shown that earthquakes were the most mentioned hazard with lava being a close second. In terms of what this shows, as to which gender has a stronger perception, both hazards found to be top by the majority of each gender are not in line with previous research, showing both genders to have a poor perception. Although for a greater look at this, further research with a more equal split of male and female participants, along with a generally bigger sample size, would help better understand these differences.
When looking at the most likely hazard (table 4.2) the two genders are more aligned in their perceptions, with both having earthquakes as the most likely. Again this is supported by the word cloud (figure 4.6) where again it was shown that earthquakes came out as the biggest, and therefore most mentioned hazard in response to the question.

When examining these perceptions, in comparison to the expert opinions, there is a clear difference, with experts being more worried about gases and ash in any future eruption (*Pers. Comm. G. Vougiokalakis, Sept 2021).* Therefore, unlike the greatest impact perception, there is no need to look further into the difference in perception but more into why both have a perception that is incorrect according to recent research.

Table 4.1, The breakdown of responses for male and female participants as to which hazard would have the greatest impact in the event of volcanic activity

Greatest Impact			
Hazards (Female order)	*No. Female Mentions (total for that hazard)*	**Hazards (Male order)**	*No. Male Mentions (total for that hazard)*
Lava	12 (16)	Earthquake	10 (21)
Gases	12 (18)	Ash	8 (17)
Earthquake	11 (21)	Tsunami	6 (11)
Ash	9 (17)	Gases	6 (18)
Tsunami	5 (11)	lava	4 (16)
Ballistics	1 (2)	Ballistics	1 (2)

Table 4.2, The breakdown of responses for male and female participants as to which hazard is most likely in the event of volcanic activity

Most Likely			
Hazards (Female order)	*No. Female Mentions (total for that hazard)*	**Hazards (Male order)**	*No. Male Mentions (total for that hazard)*

Earthquake	13 (21)	Earthquake	8 (21)
Ash	9 (13)	Gases	5 (8)
Ballistics	8 (9)	Ash	4 (13)
lava	6 (8)	Tsunami	3 (4)
Gases	3 (8)	Lava	1 (8)
Tsunami	1 (4)	Ballistics	1 (9)

The final data collected on the questionnaire shows an interesting difference between the male and female genders. This relates to what would each gender do on hearing that there was the beginnings of volcanic activity, followed by from whom do each gender want to receive important information about what to do.

Looking at what each gender (male and female) would do, it can be seen that the majority of females would look to ask a local authority figure for more information (25 out of 51 respondents). Male respondents were more equal between asking a local authority figure and returning back to their accommodation to follow the news from there. In terms of the most drastic action, there were more females (n=8) looking to get the next flight home than males (n=2). Although a small sample size, this follows previous research that suggests that females worry more about a possible eruption and that the potential effects of an eruption will be more serious than males (Barberi et al., 2008).

As for who each gender would expect important information from, it was seen that the male participants were in favour of receiving news from the head of the fire brigade and then police with the news outlets being third, whilst the female participants had the local news outlets at the top of the rankings with again police second and the head of the fire department third. Both genders agreed with the Santorini mayor fourth and last being a leader from mainland Greece. From having seen the majority of females select to ask local authorities for further information, it is surprising that they would rather further important information come from the local media news. It has been found;

"that journalists may attend to risky situations in ways that are quite different from scientists and risk managers" (Dunwoody and Peters, 1992 p.208).

This leads to the question at the onset of volcanic activity, 'is it sensible to expect the media to put across possible vital information'. Furthermore, trust in science experts and local authorities is one of the key factors that can lead to a better personal risk perception (Wachinger et al., 2013). Therefore, is it the case that female tourists lack full trust in the local authorities of the areas they travel to? Answering this question in future research could be key in further developing female risk perception, due to this trust being so vital (Wachinger et al., 2013).

4.2.2 Age Groups

The second characteristic of the participants t is that of age as this has also been seen to contribute to people's risk perception (Kellens et al., 2011). For this study the participants were split into three age ranges; 18<30 yrs old, 30-60 yrs old and lastly 60+ yrs old. Commonly it is seen that middle aged people have a more accurate perception than that of younger people (Carlino, Somma and Mayberry, 2008), however, that is when comparing those still in education (younger people) in comparison to those not (middle aged). Whereas in this study those in the youngest age group will have at least finished secondary school education, with some being at university or another form of higher education. Therefore it is still appropriate to see the differences in perception between the age groups.

A clear change throughout the age groups can be seen firstly in how each looks to find information whilst travelling around Santorini. The 18<30 yrs old group are heavily reliant on their smartphones for information (29 out 34), whilst the middle range (30<60 yrs old) were slightly more even although again the majority were in favour of smartphones (21 smartphones, 16 guidebooks). These two findings are unsurprising with the challenge that has come to the use of guidbookes through the development of digital information technology (Mieli and Zillinger, 2020). However, it was seen in the oldest group (60+ yrs old) that they would in fact be slightly more reliant on a guidebook or guide (10 responses) than a smartphone (4 responses). What this shows is that for the oldest tourists visiting Santorini it is important that guidebooks are kept up to date, so as to keep the perceptions of those tourists up with the latest risk even with the constant progression on digital information (Mieli and Zillinger, 2020). Whilst it is also important to manage what information is available online, so that those using smartphones are not misinformed with incorrect information.

The next thing to be seen when comparing the age groups, is their general awareness of Santorini being a volcanically active area. The most unaware was seen to be the youngest age group, with 11 out the 34 respondents answering that they were unaware that it was a volcanically active area. In comparison, the middle age range (30<60 yrs old) were the most aware with 27 out of 31 respondents answering yes they were aware. As for the oldest range the majority of these respondents were also aware (12 out of 16 respondents). This highlights the point made at the beginning of this section that commonly middle aged people have a more accurate risk perception than that of younger people (Carlino, Somma and Mayberry, 2008).

All participants were asked to select as many hazards from a list they believed to be risks associated with any volcanic activity on Santorini. For all three age groups it was seen that ash was top in terms of the amount of selections, with the oldest range having it alongside lava, the middle range with ballistics and the youngest group also having gas at the top. This shows that at first look they have a similar perception of the hazards, however, when looking at this further such as which they believe to have the greatest impact or be the most likely, the differences appear. The youngest age group (18<30 yrs old) have ash at the top of both greatest impact as well the most likely, here being in line with what is expected by the experts (Jenkins et al, 2015 and Vougioukalakis et al., 2016). Whereas the middle aged group (30<60 yrs old) was seen to have earthquakes at the top of both lists and although they had ash as the second most mentioned, it shows the majority's perception for this age group to be wrong in comparison to what is expected. Lastly the oldest age range (60+ yrs old) was seen to have two different hazards for greatest impact and then for most likely. For the greatest impact the majority had chosen Lava, which is not expected to have a significant impact due to it being expected to only be confined to the Kameni islands. As for the most likely hazard, the majority followed that of the middle aged group and selected earthquakes. What can be seen here is that the top two age ranges have risk perception different to the expected risk, whilst the youngest do in fact have a perception following the expected risk. This shows that those that are aware that it is volcanically active in the first place tend to have the correct perception.

The final aspect of the perception of the different age groups is which area they selected as the area of least risk. The oldest (7 all area responses and 5 Area B responses) and youngest (13 all area responses and 12 Area B responses) age ranges were seen to be near even in splitting between all areas being at risk and Area B being the area of least risk. Whilst just under half of the 30<60 yrs olds selected all areas to be at risk. All of the age groups had few or no participants select areas A and D expected to be safest as mentioned by *G. Vougiokalakis, Pers. Comm.Sept 2021.* It was seen in the oldest age group that a few participants (3) selected area A, and in the youngest group, Area D got 5 responses, showing very slight signs of a better risk perception.

4.2.3 Previously visited versus Planning to visit (experience comparison)

The final characteristic looked at is that of experience. It has been seen that personal experience of natural hazards has the most substantial impact on a person's risk perception (Jochen et al., 2012; Wachinger et al., 2013). Therefore the ability to split the participants of this study into those who have previously visited versus those who plan to visit allows the study to begin to look into this theory.

Of those that participated in this study, there were nine of whom had previously visited Santorini and plan to visit again. The information they gave, provides some insight into how experience does affect one's perception going forward. Of the nine, only three mentioned ash or gas as the most likely hazard in a future eruption. With such a small sample size not much can be drawn from this, however, with all having been and still intend to visit again, should it be expected that such tourists have a better perception and knowledge of the risk? (Section 4.3)

Looking at the wider number of those that had previously visited, the majority of the fifty-five said that earthquakes were the most likely hazard in future volcanic activity. Whereas, those that only plan to visit, had the majority say that ash was the most likely to occur, which is more inline with the expert opinion. This shows a difference when compared to what is expected when looking at experience of natural hazards (Jochen et al., 2012; Wachinger et al., 2013), those with experience seem not to have the perception expected whilst those without do have the correct knowledge and therefore perception.

Although those that plan to visit had the majority mentioning the correct hazard, those that had previously visited produced more options of hazards, with some mentioning ballistics and gas, where those that plan to visit did not. Whether this greater variety came from their experience of visiting is a question that could be investigated further, with a more focused study into why tourists have their certain perceptions and knowledge.

When looking at which areas of the island would be least at risk in the event of volcanic activity, both had a majority that said that all areas are at risk with both using the reason ‘scale of island versus eruption’ (Table 3.8, results section). However, although the second most chosen area for both groups was Area B, the reasoning behind the selection was different. Those that had previously visited, mainly said this due to ‘distance from volcanic centre’ (table 3.8), whilst those that had planned to visit were because of the reason, ‘protected infrastructure’ i.e. the airport would be built in an area of safety. An example of this is shown here “The airport would be in the safest spot” (respondent #9). This difference in reasoning is an interesting one, having never visited the island the sense of size may not be so apparent and so when seeing the map they were given on the questionnaire, the clearest thing to go by is that within area B the airport is situated and therefore logically could be a safer area. Here showing certain perspectives that could possibly be gained through experience versus misleading information.

4.3 Risk Mitigation Recommendations

What has been apparent throughout this chapter is that there is plenty of room for further research in volcanic risk mitigation for tourists, both specifically for the island of Santorini as well as for tourists globally visiting areas with volcanic risk. As mentioned in 4.1.2, there is a necessity before carrying out mitigation to understand the theoretical basis behind risk perception and specifically the communication of this risk. Factors such as the social amplification of risk framework (SARF) (Appendix 5) (Pidgeon, Kasperson and Slovic, 2003) are important for consideration as it brings to light important factors such as communication. In addition to this, Alexander (2016, p. 183-185) points out that to be more effective, emergency planning for tourism requires collaboration between representatives of the industry (tour operators, hoteliers, etc.), consular officials and national civil protection services. Developing such a collaborative approach, which considers the implications of risk perceptions for emergency planning in an integrated manner is recommended for Santorini though noting that the situation is likely to be more fluid for vulnerability and risk (Alexander, 2002). The following section will suggest further mitigation strategies that could be incorporated into such a collaborative approach.

The first point to highlight is expectations of tourists visiting an area. It has been shown through this study that tourists that have visited a place, such as Santorini, have not gained an increase in risk perception, even though they also have the intention to visit again. To help with this issue, and in so doing mitigate future risks, a combination of actions should occur. First and foremost is to try increasing the knowledge of tourists visiting places such as Santorini as it is understood an irregular visitor to an area, such as Santorini, is likely to have less knowledge of local hazards (Alexander, 2002). This would ensure that returning tourists have retained knowledge from a previous visit. The key way to do this is to ensure that the information provided to tourists visiting Santorini is always up to date with the latest hazard and risk information. Alexander (2002), suggests that communication of such information must be simple and effective to make the messaging of the information acceptable. Highlighted in this study (section 4.2.2), although the younger generation are reliant on technology (smartphones) for information, the older generation still use guidebooks, and so reproducing updated versions of guidebooks is important, as well as keeping websites up to date. As presented in section 1.2.1, some of the top tourist websites for Santorini currently have information not easily understandable for tourists, and secondly the information provided is from research undertaken in 1996. This backed up by the point G.Vougioukalakis mentioned, that this sort of information is not yet well organised and available (*Pers. Comm. G. Vougiokalakis, Sept 2021).* This study would suggest that this needs updating with information from 'Talos'(General Secretariat For Civil Protection, 2020). Making key parts of this plan known to the public, such as the expected risks from any future eruption, would immediately help increase tourists' knowledge and risk perception.This way, information can be addressed further in any future research, for example, including suggestions made by Alexander (2002) such as distributing material to hotel rooms or having it on signs in key places.

Secondly, making tourists perform an action following the example of the 'Icelandic Pledge' (Take the Icelandic pledge - Inspired by Iceland (visiticeland.com)) (section 1.3.3.1) would immediately make them more aware of the risk on the first visit to Santorini so that their perception is instantly higher, and for those returning it would reaffirm their perception. The 'Icelandic Pledge' asks those travelling to sign a pledge that means they accept to respect nature and avoid risk-taking behaviours.Through this action tourists are automatically more aware of their behaviours and therefore bettering their risk perception. For Santoini, as the landscape is not as high risk as that of Iceland, the pledge would clearly take a different approach, instead maybe asking tourists to keep themselves aware of the latest hazard and risk information at that current time. Therefore, if activity were to start they are immediately up to date with what they should do, thuseducing work on spreading information at the time of emergency and in general keeping tourists more informed and increasing the perception.

Additionally for Santorini specifically, more planning is needed in the organising of its emergency plans, such as the distribution of emergency information in multiple languages in times of emergency. Due to the high numbers of tourists, the number of different languages that need to be accommodated for is very high. It was suggested that this still needs to be organised better *Pers. Comm. G. Vougiokalakis, Sept 2021.* This study suggests that this is an easy way to ensure that emergency action occurs with less issue due to misunderstandings.

It is also imperative to ensure that the authorities in charge have the trust of not only the locals but also the tourists visiting. It is noted in Pidgeon, Kasperson and Slovic (2003) that it is common to see risk control efforts fail due to the lack of openness and trust between the authorities and the other interested parties, therefore showing it to be critical to build and keep this trust. Throughout the whole document of ‘Talos’(General Secretariat For Civil Protection, 2020) the word ‘Tourists’ is only mentioned twice. This immediately shows a lack of thought into the tourists that could be situated on Santorini at the time of volcanic activity. If this were to be common knowledge, to all those that visited Santorini, the trust that is necessary to help in emergency situations would certainly not be there. Therefore, this study suggests first to amend ‘Talos’ so that there are more plans to deal with tourists that could be in danger in the event of future volcanic activity. From this, plans and details should be presented to tourists so as to ensure they trust the authorities to be prepared in the event of volcanic activity.

5.0 Conclusion

Much research has been undertaken on the volcanism of Santorini and also on Santorini as a major tourist destination. However, the two areas have not been researched together. This is the first study to examine the risk to tourists from volcanic eruptions on Santorini. This was achieved by first setting out clear aims and objectives, looking at the relationship between tourists and the volcanic risk on Santorini.

The aims set out at the beginning of this study (Section 1.5) were as follows; '*What is the spatial distribution of volcanic risk for tourists on the island of Santorini?',* with a secondary aim of '*establishing the perceived eruption risk for tourists on the island'*. The following objectives enabled achievement of these aims:

1. to compile a database of spatial distribution of tourist accommodation (number of beds/rooms for Hotels) for nine key centres of population and critical infrastructure (Jenkins et al., 2015) on Santorini.
2. to compile a primary database of the spatial distribution of perceived volcanic risk for tourists (through a questionnaire on the perceptions of volcanic risk from tourists on the island)
3. To extract data from Jenkins et al., 2015 to produce maps of actual volcanic risk using ArcGIS.
4. Finally to integrate these maps (from objective 3) with the spatial data from objectives 1 and 2 to assess the spatial relationships between tourists, perceived risk and actual eruption risk.

Similar research in Iceland highlighted that a mixed-methods approach is most appropriate for examining the relationship between volcanic hazards and tourism (Bird et al., 2010). Therefore this study used a mixed methodology (Figure 2.1) to achieve the aims and objectives. A tourist-targeting questionnaire collected data on the risk perception of tourists visiting Santorini as well as data on the spatial distribution of tourists. This spatial data was complemented by an online survey of Santorini's hotels to establish the distribution of tourist accommodation on the island. Lastly, data on the spatial distribution of risk (in terms of ash fall expected from the most likely future eruption) was extracted from Jenkins et al. (2015) to be integrated (using ArcGIS) with the spatial data gathered in this study. The links between tourism and volcanic risk and activity have therefore been mapped out (figs. 4.1, 4.2 and

4.3), enabling us to begin to answer spatial questions such as; how do the areas tourists are most likely to visit relate to the risk from the most likely volcanic scenario? What is the relationship between the hotel accommodation capacity across Santorini and risk from the volcano, or are the areas tourists believe to be less at risk, actually those least at risk?

The key conclusions of this study are:

1. Hotel accommodation and locations where tourists are most likely to visit on Santorini are coincident with the areas of highest risk (of ash fall in the most likely eruptions scenario). For example, the capital Thera is the most visited area, has the most hotels, and is also within the area of highest risk (Fig. 4.1). The opposite can also be said to be true: the location tourists are least likely to visit (and with the least accommodation) is Therasia, the location at least risk (Fig. 4.1).
2. The majority of respondents think that the area of least risk (if any) is the eastern part of the islands (area B in this study- Kamari and Perissa), whereas the areas of least risk is actually the Western and Northern parts of the islands (areas A and D; Therasia and Oia).
3. Tourists lack an accurate perception of the potential volcanic hazards on Santorini, thinking that lava and earthquakes would be the major hazards (Figs. 4.5, 4.6.) when ash and gas are considered to be both the most likely and most likely to cause the highest risk (Jenkins et al., 2015; Vougioukalakis et al., 2016). Furthermore, the results show a lack of preparedness by tourists visiting Santorini. Most tourist respondents (90%) do not check the latest hazard and emergency response information for the islands before visiting (table 3.5) and 23% were not aware that the islands were volcanically active at all (table 3.4).

Given these results, that tourism is the main economic activity on the island (90% GDP, Stanchev, 2018) and that the existing emergency plan (Plan Talos) does not account for tourists at all, this study recommends further research into the risk to tourists on the island of Santorini and also for other volcanic islands worldwide.

5.1 Future work recommendations

Throughout this study, it can be seen that further research could be undertaken into how best to mitigate the volcanic risk present to tourists visiting the island of Santorini.
The first area is that of the advertising and online presence of risk awareness when visiting a tourist destination. Section 1.2.1 briefly looked into this and showed for Santorini that

highlighting of risk is minimal. Research into whether increasing this would in turn make tourists have a better risk perception, whilst also looking at whether this would have a detrimental effect to the tourism numbers, would help to see whether simple updated information would reduce future risks.

A second area highlighted for further research, and not a focus of this study, are the risks and hazards to tourists, as well as locals, in the event of a submarine eruption of the Kolumbo Volcano. With the current situation surrounding Tonga, and a submarine eruption causing massive disruption and destruction to the island, it is necessary to evaluate exactly the issues that could arise for Santorini and the surrounding areas in the case of a Kolumbo eruption.

Additionally further research could be performed on the characteristics that can affect a tourists perception, as mentioned in section 4.2 the sample size of this study was sufficient enough to begin to look into this, however for a greater understanding a study with an increased sample size would be better placed to understand these characteristics.

Finally, the limited sample size (n=81) and scope (English speaking tourists) of the questionnaire respondents in this study means that much more comprehensive sampling, particularly of non-english speaking tourists, remains to be done.

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Appendix

Appendix 1 - Participant Information Sheet:

https://drive.google.com/file/d/1X3yBpUSPqa9BHWKwn3AfiTGw6xxfYEyg/view?usp=sharing

Appendix 2 - Full questionnaire

- Santorini Tourist Volcanic Risk Questionnaire PDF.pdf

Appendix 3 - Ministry of Tourism Data

Hotel Capacity 2015							
		5*	4*	3*	2*	1*	Total
Santorini	Units	26	81	62	75	37	281
	Rooms	926	2,131	1,196	1,850	583	6,686
	Beds	1,910	4,051	2,344	3,527	1,167	12,999

Hotel Capacity 2016							
		5*	4*	3*	2*	1*	Total
Santorini	Units	27	81	64	71	37	280
	Rooms	984	2,191	1,253	1,745	577	6,750
	Beds	2,028	4,188	2,458	3,326	1,160	13,160

Hotel Capacity 2017							
		5*	4*	3*	2*	1*	Total

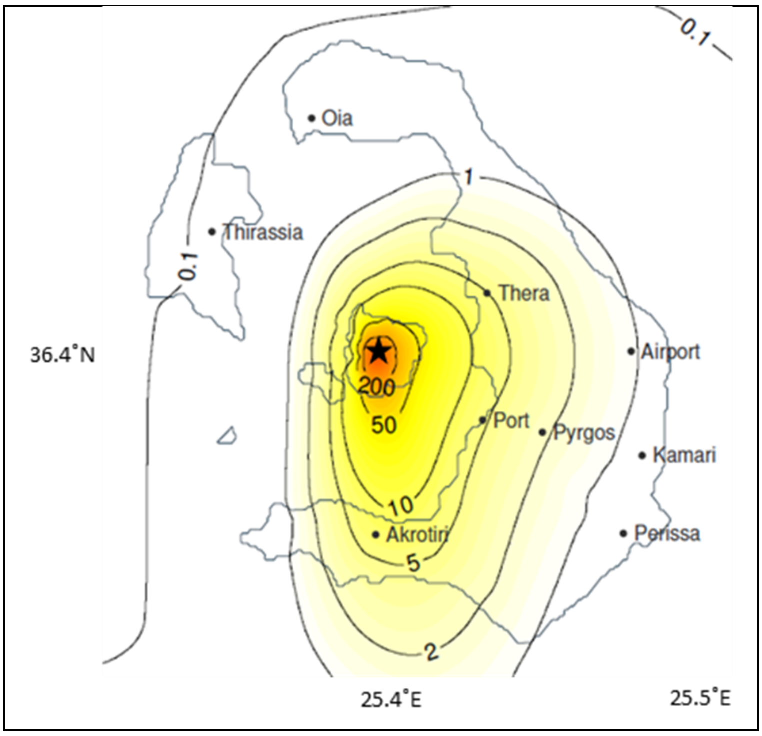
Santorini	Units	33	85	62	65	35	280
	Rooms	1,192	2,324	1,215	1,599	555	6,885
	Beds	2,445	4,497	2,397	3,048	1,115	13,502

Hotel Capacity 2018							
		5*	4*	3*	2*	1*	Total
Santorini	Units	35	87	70	60	33	285
	Rooms	1,319	2,369	1,443	1,467	514	7,112
	Beds	2,653	4,623	2,879	2,780	1,028	13,963

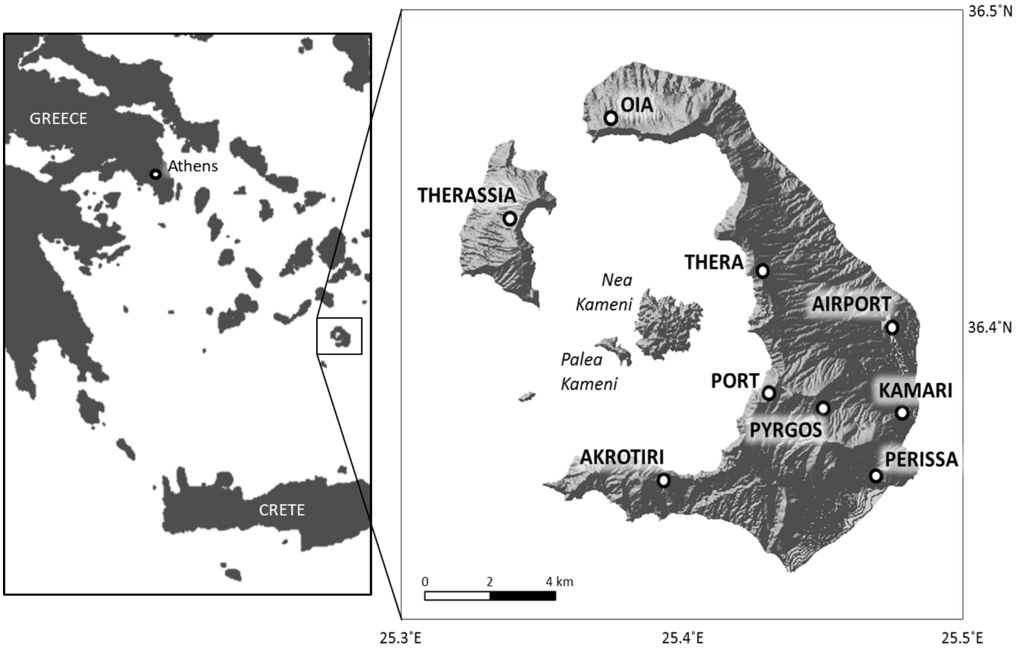
Hotel Capacity 2019							
		5*	4*	3*	2*	1*	Total
Santorini	Units	47	91	74	55	33	300
	Rooms	1,743	2,433	1,561	1,342	515	7,594
	Beds	3,483	4,798	3,136	2,532	1,037	14,986

Hotel Capacity 2020							
		5*	4*	3*	2*	1*	Total
Santorini	Units	53	93	83	53	31	313
	Rooms	1,891	2,451	1,825	1,317	454	7,938
	Beds	3,802	4,853	3,692	2,481	924	15,752

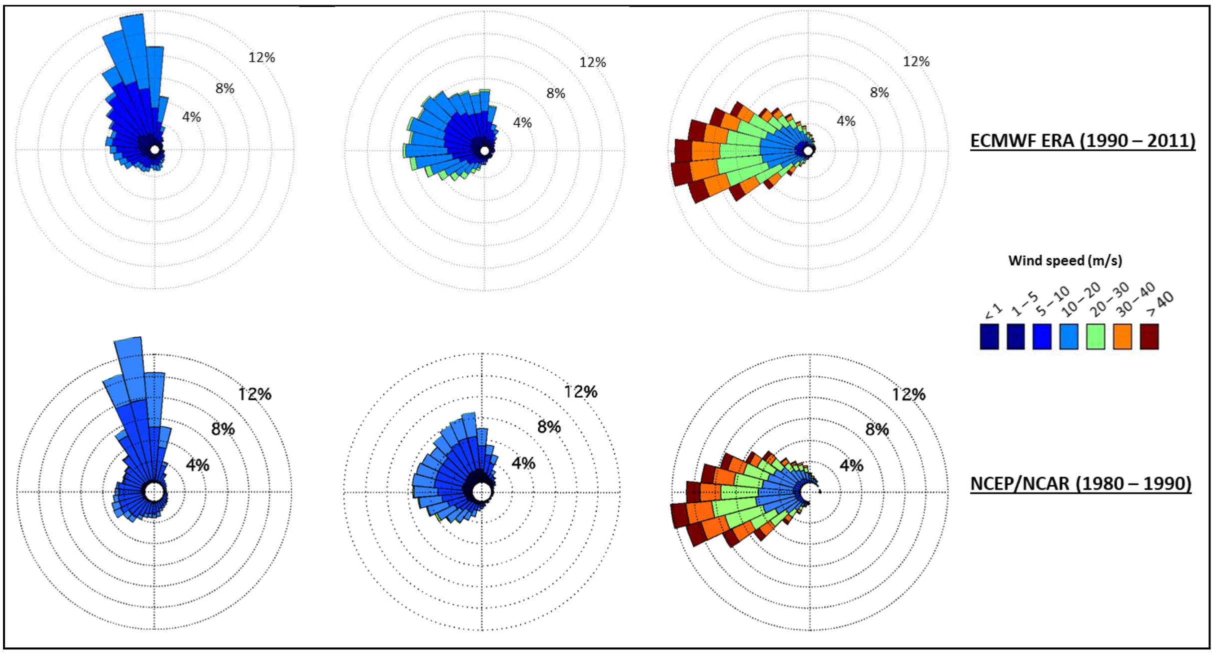
Appendix 4 - Unedited data from Jenkins et al (2015)



'represents total ash accumulation on the ground over a most likely eruption scenario as computed by the TEPHRA2 model. The 0.5 exceedance probability (50 % probability of being exceeded) cumulative deposit (in kg/m2) in each grid cell'



'Map of Santorini caldera, and its location within Greece, the recent volcanic islands of Nea Kameni and Palea Kameni and nine key locations considered in our assessment of the potential ash and gas impacts from a future eruption at Santorini volcano'



'Wind rose diagrams that show wind speeds and directions as a function of altitude (approximately surface, 3 km and 9.5 km), based on statistical analyses of daily regional winds provided by the ECMWF ERA-Interim (upper) and NCEP/NCAR (lower) re-analysis data over extended periods. Note that wind rose diagrams follow standard meteorological definition and show the direction the wind is blowing from rather than to'

Appendix 5 - Social Amplification of Risk Framework From Pidgeon et al., 2002