Extreme weather events and tourism in Iceland

A vulnerability assessment of the Iceland tourism sector to extreme weather and related natural hazards

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Content

Abstract

With climate change accelerating, global extreme weather events are increasing in frequency and severity, posing a grave concern. For Iceland, where tourism is a linchpin of the economy, understanding the vulnerability of this sector to erratic weather patterns is crucial, yet research in this area is conspicuously lacking.

This study addresses the research gap by examining how extreme weather events affect Iceland's tourism industry. Using a vulnerability scoping diagram, data were collected through an online survey from 187 tourism companies. The results are telling: a staggering 82% of surveyed companies experienced direct impacts from extreme weather events over the past five years, with nearly half facing such events over ten times.

The most common extreme weather events included severe storms (93%), extreme snowfall (57%), and extreme rainfall/hail (49%). Alarmingly, severe storms increased both in frequency and intensity, while extreme snowfall remained relatively stable or declined.

From an economic standpoint, the sector's vulnerability was deemed moderate, with 62% of companies reporting damages below 1 million ISK. Damage primarily resulted from customer cancellations (50%), operational disruptions (22%), and supply chain or infrastructure damage (both at 19%).

While the overall vulnerability of the tourism sector was moderate, a nuanced analysis of vulnerability elements revealed significant disparities. Accommodations and restaurants/bars showed lower adaptive capacity, while tour operation/travel agencies and transportation faced notably higher exposure to extreme weather events.

This study provides important insights into the impact of extreme weather on Icelandic tourism and serves as a foundational resource for future research in the sector.

1 Introduction

Extreme weather events are no rarity in Iceland, but during recent years it seems that extreme weather brings a larger burden on Iceland´s economy and society. Extreme weather can simply be defined as an event that is rare at a particular place and time of year, and include temperature extremes, heavy precipitation, droughts, storms (including tropical cyclones), as well as compound events. Extreme weather events vary from place to place in an absolute sense but refer to a norm, average or standard in relative terms. It is often indicated as an anomaly or a deviation from its value averaged over a reference period. IPCC states in her latest report (IPCC, 2021, p. 7) that 'It is an established fact that human-induced greenhouse gas emissions have led to an increased frequency and/or intensity of some weather and climate extremes since pre-industrial time´ and that ´even relatively small incremental increases in global warming (+0.5°C) cause statistically significant changes in extremes on the global scale´.

Research in Iceland shows climate change will result in changes in extreme weather (Björnsson et al. 2018). During this century, precipitation intensity is likely to increase, the intensity and frequency of rain and meltwater induced floods will change, but the annual number of strong wind days in the country shows significant fluctuations between years and decades. This makes it difficult to discern a long-term trend and to predict how the frequency of strong winds in Iceland will change during this century (Björnsson et al. 2018).

1.1 Extreme weather events and tourism

Extreme weather events can have significant impacts on tourism. The severity of these impacts depends on the specific event and destination. Various studies (e.g., Becken, 2010; Hamzah et al. 2012; Giddy et al. 2017; Gómez-Martín et al. 2014; Smith and Fitchett, 2020; Susanto et al. 2020; Toubes et al. 2017) have shown that extreme weather events can have a variety of impacts on tourism, including:

- Physical damage: Extreme weather events can cause significant damage to tourism infrastructure such as hotels, airports, and transportation systems. This can make it difficult or impossible for tourists to reach certain destinations, or for businesses to accommodate them once they arrive.
- Disruption of transportation: Extreme weather events can disrupt transportation systems, making it difficult or impossible for tourists to reach their destinations. This can include cancelation or delays of flights, trains and buses, as well as road closures and power outages.
- Safety concerns: Extreme weather events can make certain destinations unsafe for tourists, particularly if there is a risk of injury or death. This can include destinations affected by hurricanes, floods, or wildfires.
- Economic losses: Extreme weather events can lead to economic losses for the tourism industry, including decreased revenues for businesses and lost jobs for workers.
- Perception of risk: Extreme weather events can change the perception of a destination as being unsafe or risky, which can lead to long-term declines in tourism even after the event has passed.

1.2 The tourism sector in Iceland

In Iceland, tourism is an important sector for its national economy. The sector is a major export earner in Iceland, accounting for ISK 520 billion in 2018 – equivalent to 39% of total export revenue and contributing 8.1% of GDP in 2019, and employed some 30 000 people – representing 15.7% of the workforce in Iceland (Statice, 2021). In 2021, there were over 3.000 companies registered as a tourism company in Iceland (Icelandic Tourism Board, 2022). The success of the tourism industry in Iceland is fundamentally connected to a wide array of nature-based leisure activities available on the island. However, the access to and the quality of the experience of Icelandic natural environment is frequently hampered by extreme weather events in the recent past.

Despite the importance of the tourism sector to Iceland´s national economy and the climate change induced increase in intensity and frequency of extreme weather events, research that studies the relation between tourism and extreme weather in Iceland is till now absent. Therefore, to further clarify the challenges that the Icelandic tourism sector may face in ongoing climate change, this study conducts a vulnerability assessment of the Icelandic tourism sector to extreme weather events and related natural hazards. Vulnerability is defined by the IPCC as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). Broadly defined, vulnerability is a characteristic of a system that makes it prone or non-resilient to change (Adger, 2006) and can be examined through three main dimensions. The first is exposure, which refers to the system's nature or degree of exposure to climate change. The second is sensitivity, which is the system's characteristics that determine how it may respond to change. The capacity of the system to successfully respond to changes in the climate is the third dimension (Polsky et al., 2007). On basis of this framework, this study conducted an assessment to analyze vulnerability of the Iceland tourism sector to extreme weather events.

2 Methodology

Vulnerability assessment

In order to analyze data that describes the three dimensions of vulnerability of the Icelandic tourism sector to extreme weather events, this study uses a vulnerability scoping diagram (VSD) described by Polsky et al. (2007). The VSD is a tool for comparing and visualizing various vulnerability assessments. There are three layers in the diagram (figure 1): the innermost layer relates to the three dimensions of vulnerability. The second layer specifies the components of each vulnerability dimension, i.e., the "abstract characteristics" that typify the dimensions (Polsky et al., 2007, p. 478). These depend on the particular vulnerability situation in question. Finally, the outermost layer shows the indicators that are used to measure the components. For evaluating the effects of climate change on tourism, such as extreme weather events, the VSD offers a comprehensive and holistic approach that takes into account aspects of social connections, biological responses, climatological drivers, and decision making. This research used both quantitative (literature search and statistics) and qualitative (interviews with stakeholders) methods to identify the key vulnerability components and their measurement indicators for the Icelandic tourism sector.

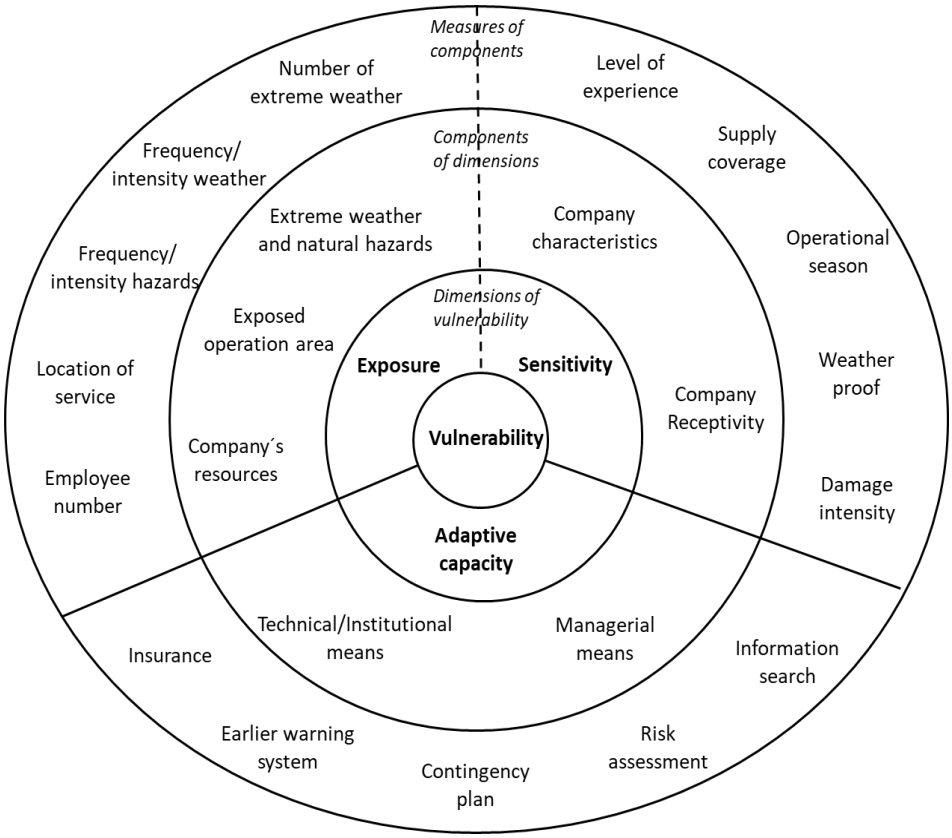

Figure 1: Extreme weather vulnerability scoping diagram of ´Icelandic tourism companies´ (adapted from Polsky et al. 2007).

2.1 Data collection

Data was collected by means of an online survey generated by SurveyMonkey©. The survey was delivered online and remained open for 1 month (from 15th of November to 15th of December 2022). Participation in the survey was restricted to owners or managers of tourism companies throughout Iceland. The participants were recruited and invited to participate by the Icelandic Travel Industry Association (SAF) using their members ´ e-mail listing and by means of an address database of the Icelandic Tourism Board.

2.1.1 Questionnaire

Our vulnerability assessment relied on participant responses to an online questionnaire we developed which comprised 27 questions (see Appendix 1)—divided into 15 measures, 2-3 measures for each of the six components that represent three dimensions of vulnerability—exposure, sensitivity and adaptive capacity (Table 1). We also queried stakeholders about the different types of extreme weather event and related natural hazards they experienced and the different types of losses their company bore because of extreme weather. Total vulnerability scores were derived from the 8 questions measuring exposure, 7 questions measuring sensitivity and 5 questions measuring adaptive capacity. The vulnerability components, measures and survey questions were tailored to the socio-economic and environmental conditions under which the Icelandic tourism sector is operating.

Table 1: Overview of the elements of the vulnarability analysis and the related question numbers of the survey.

Dimensions	Components	Measures	Survey question numbers
Exposure	Company´s resources	Exposed resources	Q3
		Exposed operation area	Q6/7/8/9
	Extreme weather and natural hazards	Number of experienced extreme weather	Q10/12
		Observed change in extreme weather	Q14
		Observed change in natural hazards	Q14
Sensitivity	Company´s characteristics	Level of experience	Q1/27
		Supply coverage	Q22
		Operation season	Q4
	Company´s receptivity	Level of extreme weatherproof	Q19/20
		Damage intensity	Q18
Adaptive capacity	Technical/Institutional means	Insurance coverage	Q21
		Earlier warning system access	Q23
	Managerial means	Information search frequency	Q24
		Risk assessment conduct	Q25
		Contingency plan	Q26

2.2 Data analysis

A procedure was developed to interpret and visualize the results of the VSD. Before the vulnerability analysis took place, the original value of data (scores) of the measures were

standardized. This was undertaken by means of dispersion normalization so that the results fell in the range of [0,1]. The equation is as follows:

$$x_{\text{norm}} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

where X is the initial value of the indicator for the respondent; Xmax and Xmin are the maximum and minimum value of each indicators, respectively. Then the scores of respective questions within each measure of the VSD were collated and recorded. Next to the overall vulnerability score of the total tourism sector also vulnerability scores per tourism subsector (accommodation, restaurant/bar, tour operator/travel agency, transportation and attraction) were measured. High scores (>5) indicate increasingly lower vulnerability, at both the overall and subsector level, and were represented in a 10-point radar plot diagram.

In the last part of the analysis, cross-tabulation with chi-square analysis was applied to explore the difference between the four general characteristics of the tourism companies: company´s age, size, operation season and subsector membership in terms of categorical variables of the vulnerability assessment.

3 Results

In total 218 companies participated in the online survey from which 187 (86%) filled out the questionnaire completely. These 187 companies constitute the sample used in the research analysis.

3.1 General demographic attributes

The study classified the responding companies by subsector, age, customer market, size in term of the number of employees and operation season (Table 2).

Table 2: Overview of respondents´ general information respondents (n=187)

Variables	Options	Frequency	%
Sub-sector (N=187, Sd=1,61)	Tour operating/ travel agency	90	48,1
	Accommodation	65	34,8
	Transportation	17	9,1
	Restaurant/Bar	8	4,3
	Attraction (museum/entertainment)	7	3,7
	Total	187	100
Company´s age (N=187, Sd=1,03)	3 years or less	21	11,2
	4-10 years	64	34,2
	11- 20 years	45	24,1
	More than 20 years	56	29,9
	Do not know	1	0,5
	Total	187	100
Customer market (N=187, Sd=0,58)	Mainly the international customer market	130	69,5
	More or less on the national and international customer market evenly	44	23,5
	Mainly the national customer market	7	3,7
	Do not know	6	3,2
	Total	187	100
Nr. of employees (N=187, Sd=1,23)	1-3 FTE	113	60,4
	4-10 FTE	27	14,4
	11-50 FTE	29	15,5
	51-100 FTE	7	3,7
	More than 100 FTE	8	4,3
	Do not know	3	1,6
	Total	187	100
Operating season	Whole year around	142	75,9
	Summer season	42	22,5
	Winter season	3	1,6
	Total	187	100

The largest part of the responding companies are tour operators/ travel agencies representing almost half of the respondents (48,1%) followed by companies working in the accommodation sub sector (34,8%) and transportation (9,1%). Restaurants and attractions such as museums or indoor entertainment places are in the minority. Particularly outside the capital area many hotels and bar are combined, which explains the relatively under representation of this subsector. The age categories of the responding companies are approximately evenly divided (between 24-34% of the respondents) except for the recently started companies (3 years or younger) who are a significantly smaller respondent group (11,2 %). The Covid pandemic of the last two years could be an explanation of the relative limited number of young companies participating in this survey. The majority of the responding companies are relatively small with regard to employees. More than 60% of the responding companies have less than 4 full-time employees. This resembles the general picture of the Icelandic tourism sector that is overrepresented by small scale enterprises. Furthermore, a large majority of the companies were operating the whole year around (75,9%) and serve mainly the international tourism customer market (69,5%).

3.2 Companies´ operation location

Considering the companies´ operation location, the results show (figure 2) that tourism companies which services are stationary – accommodation, bar/restaurant, and attraction - are in majority located in urban areas such as villages and towns (39%), followed by the locations grassland (18%) and mountain areas (18%). The operation locations of companies that provide mobile services (tour operators/ travel agencies) are in majority located in the lowlands (47%), mountain/glacier environments (18%) and diverse environment (16%). The large majority of companies in the transport sub sector (n=17) operate at a national level (76%).

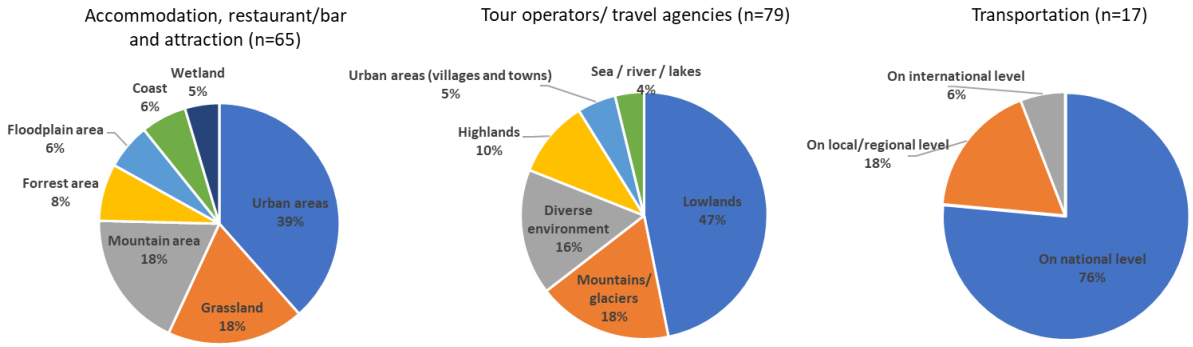

Figure 2: Overview of the percentage of responded companies´ operation location (n=187)

3.3 Experiences of extreme weather events and related natural hazards

A large majority (82%) of the responding companies have experienced an extreme weather event or natural hazard triggered by extreme weather during their operations within the last 5 years. With regard to the frequency of the experienced extreme weather events, almost half of the responding companies (42%) had experienced more than 10 extreme weather events in the last

5 years of which a majority (68%) had experienced more than 20 extreme weather events in the last 5 years (Figure 3).

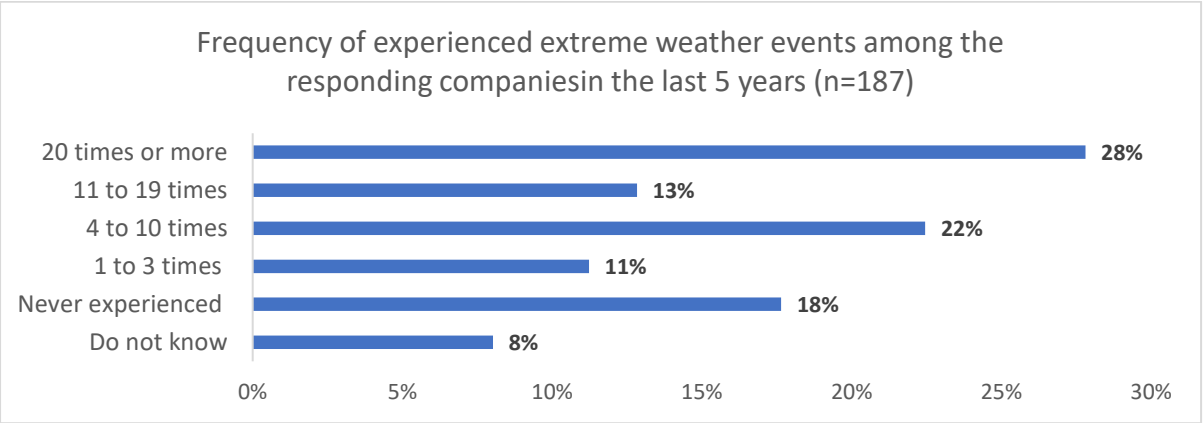

Figure 3: Frequency of experienced extreme weather events among the responding companiesin the last 5 years (n=187).

Furthermore, for the companies that experienced extreme weather events in the last 5 years (n=154), almost every respondent (93%) experienced severe storms/hurricanes, followed by extreme snowfall (57%), extreme rainfall/hail (49%), and cold waves (21%) (table 3).

In contrast with extreme weather events, a majority of the respondents (70%) did not experience any natural hazards connected to extreme weather within the last 5 years. From the 56 respondents that experienced natural hazards, a majority experienced flooding (70%) and to a lesser extent landslides (39%) and avalanches (25%).

Table 3: Percentage of respondents who experienced extreme weather events and related natural hazards.

Extreme weather events	**Frequency**	**Percentage of respondents who experienced extreme weather (N=154)**	**Percentage of total respondents (N=187)**
Severe storm/hurricane	143	93%	76%
Extreme snowfall	88	57%	47%
Extreme rainfall/hail	75	49%	40%
Cold wave	33	21%	18%
Heat wave	12	8%	6%
Drought	9	6%	5%
Other (please specify)	14	9%	7%
Did not experience extreme weather	33	Na	18%
Natural hazards			
Flooding	39	70%	21%
Landslides	22	39%	12%
Avalanches	14	25%	7%
Wildfire	2	4%	1%
Other	1	2%	1%
Did not experience natural hazards	131	Na	70%

3.4 Observed changes in extreme weather and related natural hazards

Respondents' perception of changes in extreme weather during the last 5 years differ significantly on the basis of extreme weather type (figure 4). The results show that a majority of the respondents perceived an increase in the number (63%) and intensity (72%) of extreme storms and the intensity of extreme rainfall events (50%), while a decrease or no change in the number and intensity of extreme snowfall was observed by a majority of the respondents (respectively 63% and 58%).

With regard to changes in natural hazards during the last 5 years, a third of the respondents perceived no changes in the number of floods while another third perceived an increase. Most of the respondents perceived an increase with regards to the number of landslides (45%) but wildfires and avalanches were perceived by most respondents (respectively 38% and 40%) with no change.

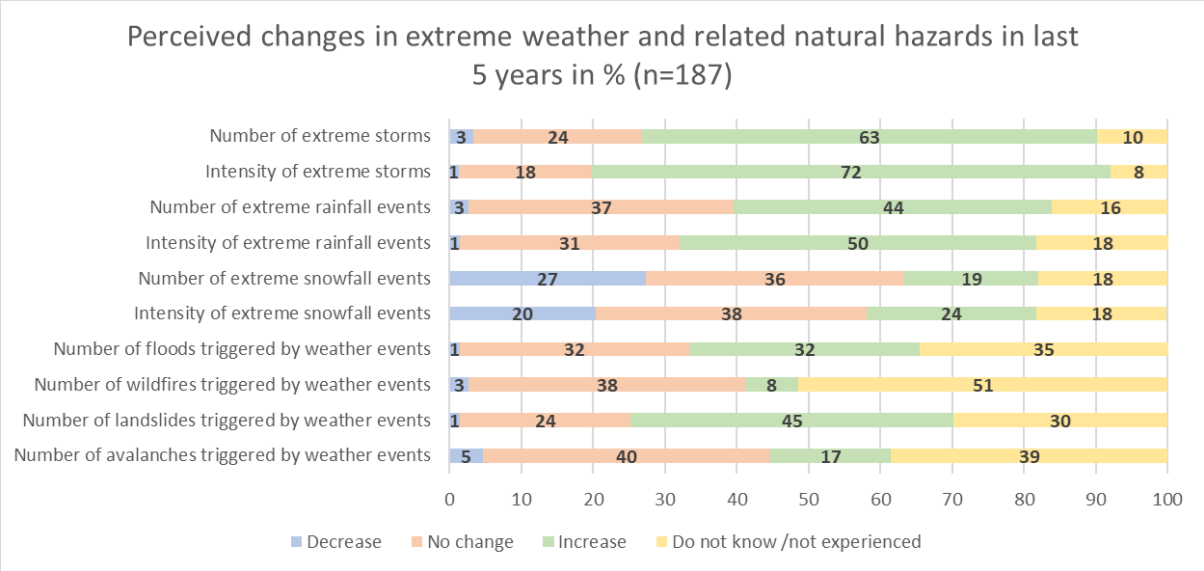

Figure 4: Overview perceived changes (decrease, stationary or increase) in extreme weather and related natural hazards by the responding companies in the last 5 years (n=187).

3.5 Damage

Seventy seven percent of all responding companies had damage or losses caused by extreme weather events or related natural hazards in the last 5 years. Results further show that half of the responding companies (94) had losses in form of cancelation by costumers (figure 5). A majority of these companies (67%) stated that the average estimated cancellation rate per extreme weather event was between 1-10%. A quarter of these respondents mentioned a cancellation rate between 11-90% and a minority (8%) of the responding companies had an average cancellation rate of 91% or more per extreme weather event. Crosstabulation with chi-square test showed that there were no significant differences between respondents' rate of cancellation on basis of the variables: company size, age, customer market, operation season or subsector.

Another type of damage caused by extreme weather or related natural hazards mentioned often by the respondents is cessation of business operations. Almost a quarter (23%) of the responding companies had to cease operation in the last 5 years. A minority (9%) of these companies ceased

operations for less than a day, but 44% of these companies had to cease operations between 1-10 days and 47% of the responding companies for more than 10 days in the past 5 years. Crosstabulation with chi-square test shows that responding companies in the sub sector accommodation (9%) had significantly (p=0.000) fewer cessations than the respondents from the other sectors.

Other types of damage that companies encountered were supply interruption (19% of the respondents), damage to infrastructure (19% of the respondents), vehicle and building damage (both 17% of the respondents), and damage to equipment or facilities (11% of the respondents). Crosstabulation with chi-square test (p=0.000) shows that responding companies with the least employees (1-3 FTE) have significantly more no damage (30%) in relation to companies with more employees (0-14% with no damage). Furthermore, larger companies (>50 FTE) have significantly more vehicle damage than smaller companies (< 50 FTE) while smaller companies (<10 FTE) have significantly lesser supply interruptions (18% of total) than larger companies (45-63% of total).

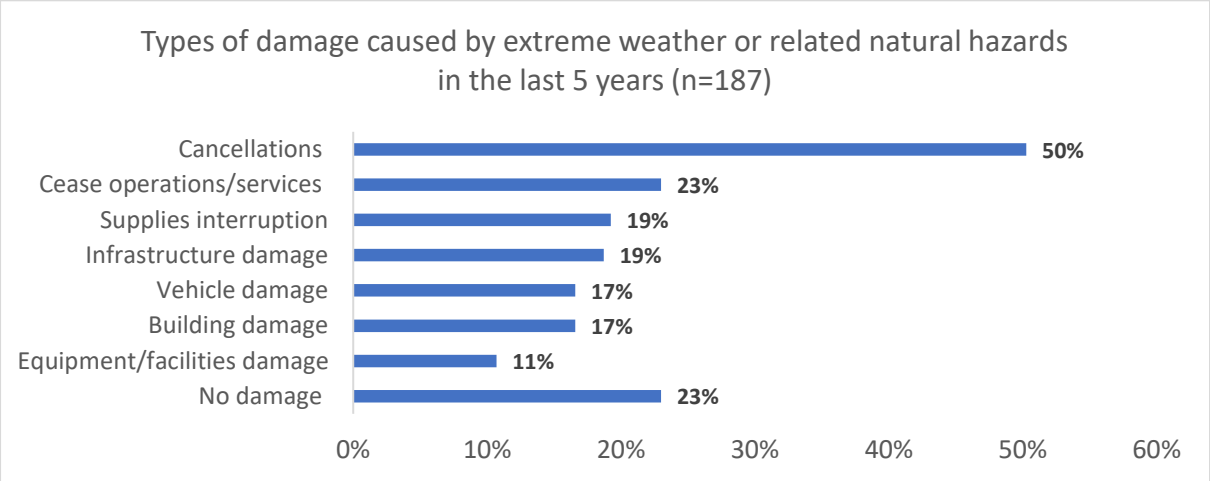

Figure 5: Percentage of damage types caused by extreme weather or related natural hazards that the respondents encountered in the past 5 years (n=187).

The estimated losses due to extreme weather and/or related natural hazards differ significantly between the responding companies. The results presented in figure 6 show that around 23% of the responding companies did not have any damage in the past 5 years. A similar number of respondents (22%) had just a minimal amount of damage (1-500.000 ISK), 30% of the responding companies mentioned moderate damage (500.001-5.000.000 ISK), and 9% of the mentioned considerable damage (5.000.000 ISK or more). Crosstabulation with chi-square test (p=0.000) reveals a significant lower percentage (1%) of the smallest companies (1-3 FTE) having the highest estimated costs (>5.000.000 ISK) in comparison with the percentages of other companies (17-43%).

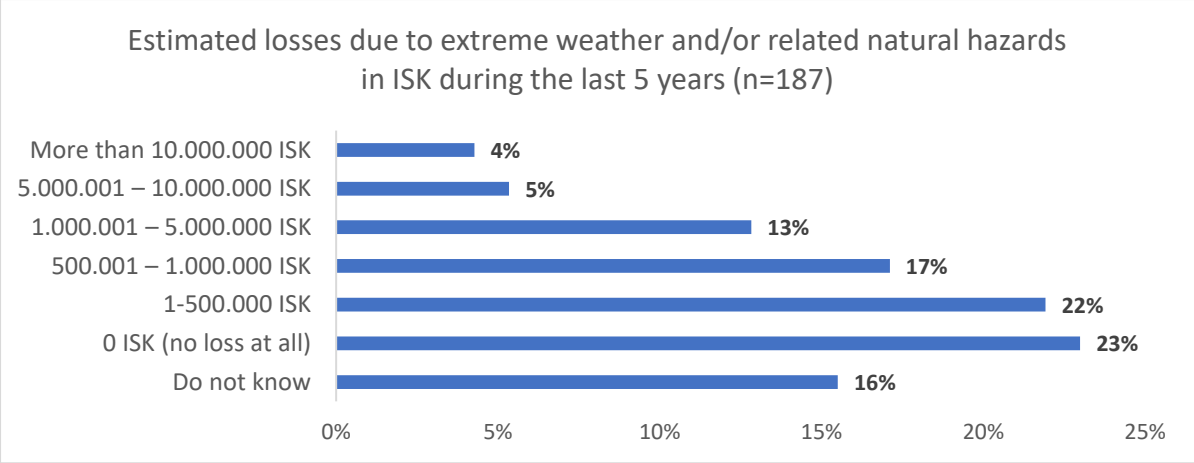

Figure 6: Overview of percentage of respondents´ estimated losses due to extreme weather and/or related natural hazards in ISK during the last 5 years (n=187).

3.6 Adaptation

3.6.1 Extreme weatherproof

A considerable percentage of the responding companies´ assets are for 91-100% storm (34%) or rain/snow (44%) proof (figure 7). However, a quarter of the companies (25%) have only half or less of their asset extreme storm proof (< 50% proof) while a considerable part of the responding companies (19%) is only half or less extreme rain/snow proof (< 50% proof). Crosstabulation with chi-square test (p=0.005) shows that a significant higher percentage of companies in the accommodation subsector (51%) are for 90-100% extreme weatherproof than the responding companies in the other subsectors.

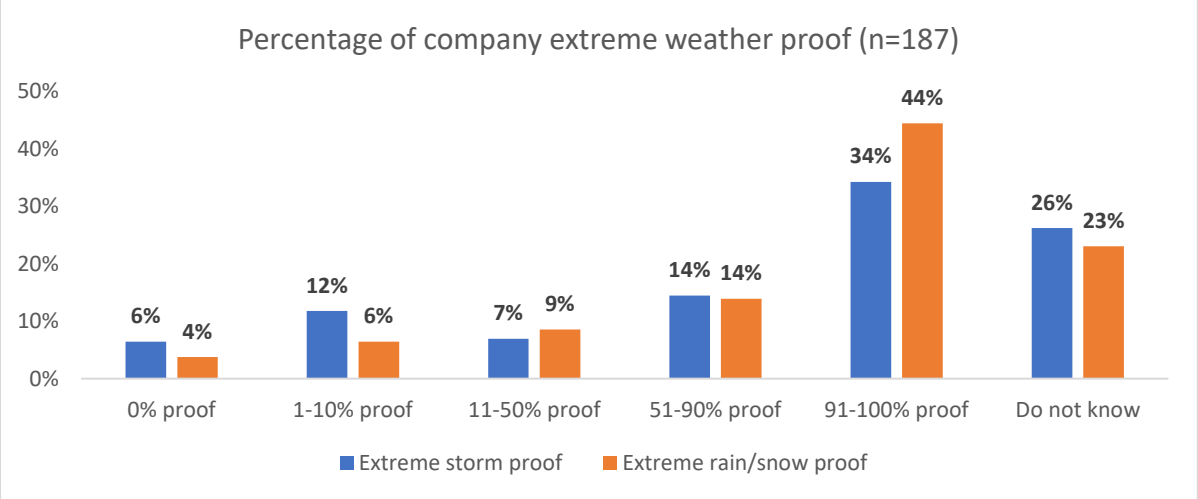

Figure 7: Overview of percentage of companies´ degree of extreme weatherproof (n=187)

3.6.2 Insurance

Results in figure 8 show that a minority of the responding companies is completely (13%) or for most part (36%) insured against damage caused by extreme weather and/or related natural

hazards. A relatively small part of the responding companies is for a small part (11%) or totally not insured (12%). A relatively large part of the respondents (28%) did not know to what extent their company was insured. Crosstabulation with chi-square test showed no significant differences between respondents' insurance extent on basis of the variables: company size, age, customer market, operation season or subsector.

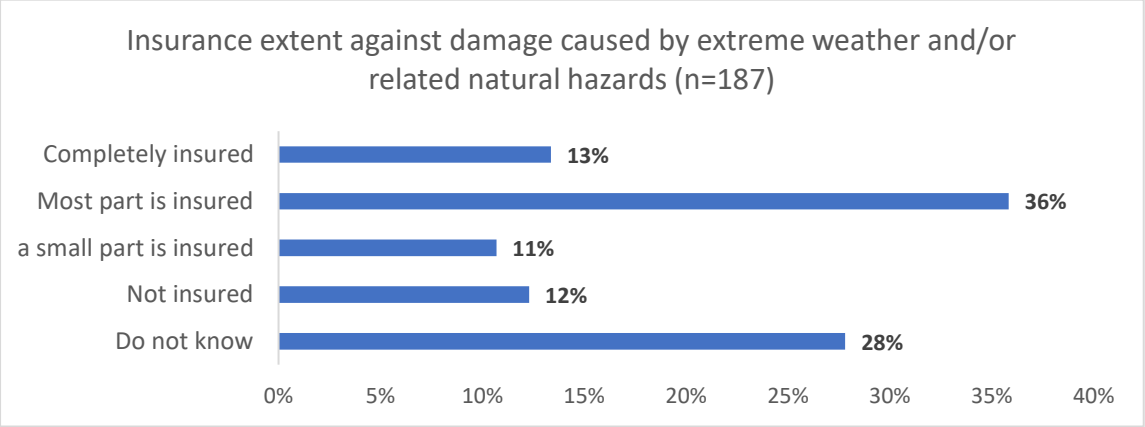

Figure 8: Overview of percentage respondents insurance extent against damage caused by extreme weather and/or related natural hazards (n=187).

3.6.3 Access to an extreme weather early warning system

A considerable percentage (43%) of the responding companies do not have an extreme weather early warning system (figure 9). Less than half of the respondents replied that their company has an early warning system for extreme weather. Furthermore, crosstabulation with chi-square test shows that a significantly higher percentage of companies operating in the summer season have no earlier warning system (55%) in comparison to companies which operating all year around (39%). There are no other significant differences in the implementation of an early warning system among participating companies on the basis of companies ´ size, age, customer market or subsector.

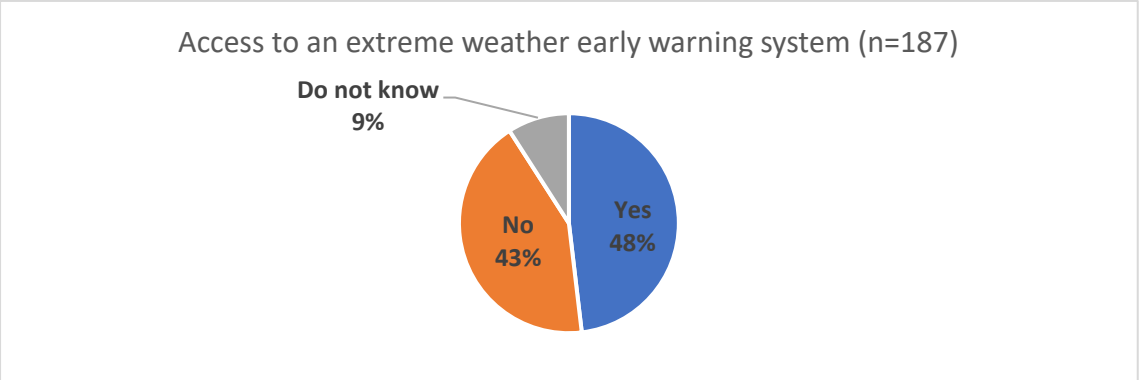

Figure 9: Percentage of respondents who have access to an extreme weather early warning system (n=187).

3.6.4 Risk assessment conduct

The result shown in figure 10 reveal that a large majority of the responding companies did not conduct a risk assessment regarding the impacts of extreme weather and connected hazards such as floods, landslides and avalanches in the last 5 years. Crosstabulation with chi-square test shows that a significantly higher percentage (p=0.000) of companies in the subsector accommodation (90%) have not conducted a risk assessment in comparison with other sectors, and that companies in the subsector transportation have significant high percentage companies that conducted a risk assessment (41%). Furthermore, larger companies (>51 FTE) have conducted significantly more frequent an extreme weather risk assessment (43-63%) in the last 5 years than the smaller companies (<51 FTE) (15-24%).

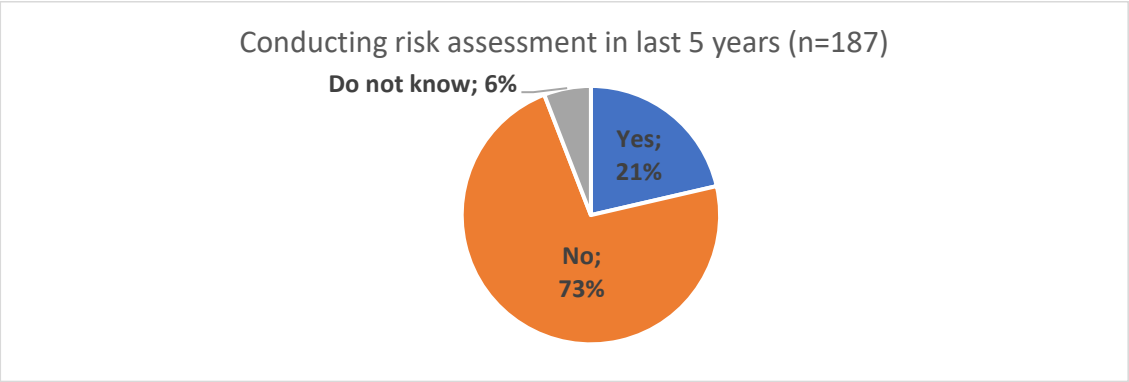

Figure 10: Percentage of respondents who conducted an extreme event risk assessment in the past 5 years (n=187).

3.6.5 Extreme weather contingency plan

A third of the responding companies have an extreme weather contingency plan and 23% of the responding companies are developing such a plan (figure 11).

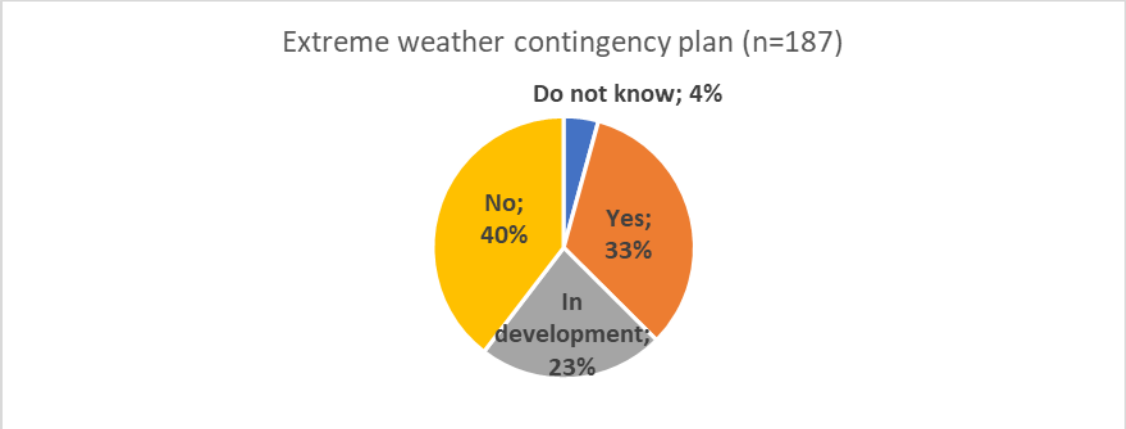

Figure 11: Percentage of respondents that are in the possession of an extreme weather contingency plan (n=187).

However, 40% of the responding companies have neither implemented a contingency plan nor a plan in development. Crosstabulation with chi-square test shows that a significant lower

percentage (p=0.000) of companies in the subsector accommodation (11%) do not have a contingency plan in comparison to other companies of other subsectors (41-57%). Furthermore, a significant (p=0.001) higher percentage (46-57%) of the smaller companies (<11 FTE) have no contingency plan in comparison to larger companies (>11 FTE) (0-17%). Also, a significantly higher number of companies that operate all year around have installed a contingency plan (39%) than companies operating only in the summer season (12%).

3.6.6 Extreme weather information search

Results show (figure 12) that a majority (61%) of the responding companies search on a daily basis for information about extreme weather events that benefit their companies. A quarter of the companies search for extreme weather information on a weekly to monthly basis, while just 13% of the responding companies(almost) never search for information about extreme weather. Crosstabulation with chi-square test (p=0.000) shows that there is no significant difference among the participating companies regarding their extreme weather information search frequency on the basis of the variables: company size, age, customer market, operation season or subsector.

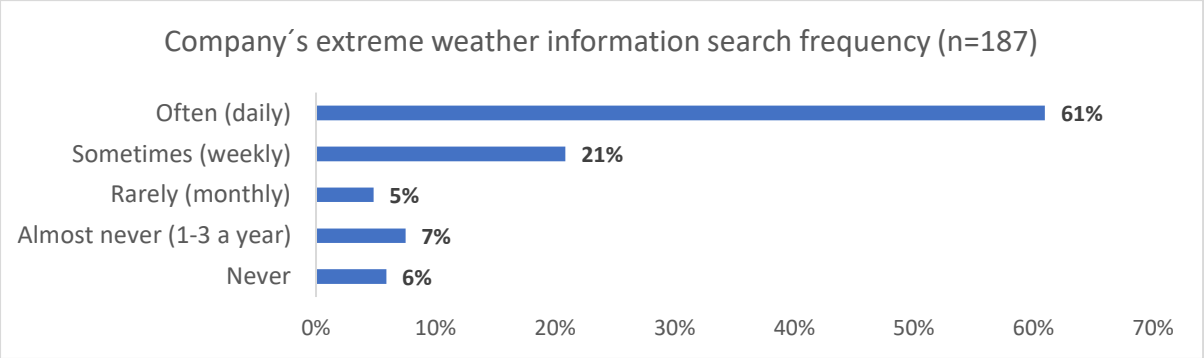

Figure 12: Percentage of company´s extreme weather information search frequency (n=187).

3.6.7 Staff experience with extreme weather events

The results presented in figure 13 show that a majority of the responding companies stated that all or most of their staff has experiences with extreme weather events during their work. However, almost a fifth (18%) of the responding companies only a few or none of their staff members have experience with extreme weather during their work. Crosstabulation analysis shows further that 35% of the responding companies without staff (14% of the total sample) had never experienced extreme weather events with their company.

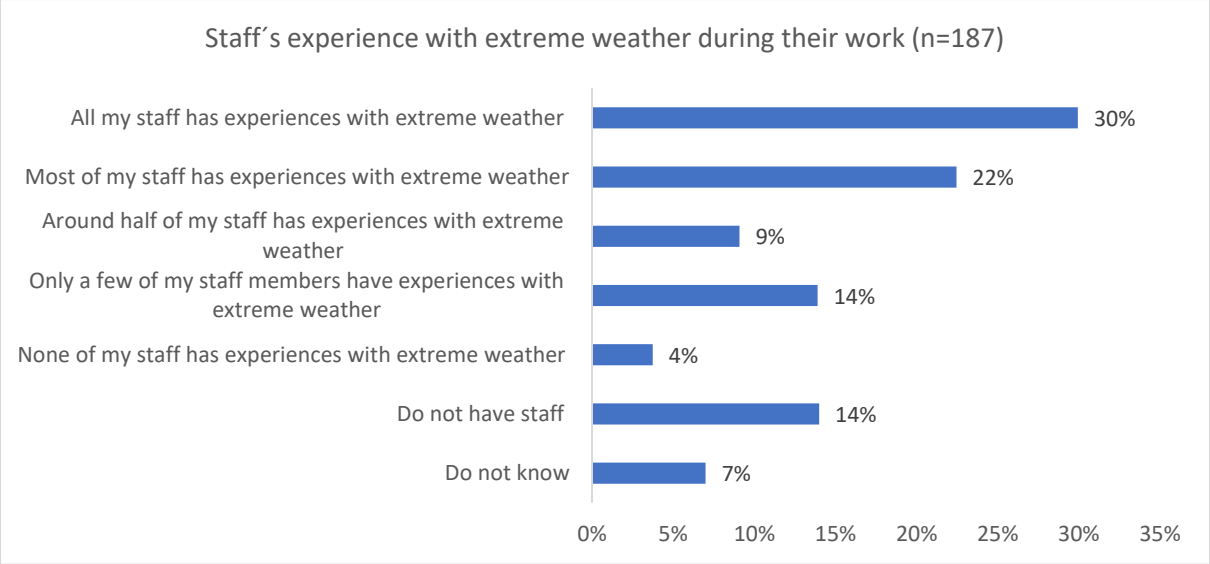

Figure 13: Overview of companies´ staff´s experience with extreme weather during their work (n=187).

Furthermore, crosstabulation with chi-square test showed that relatively young companies (<10 years old) have a significant higher percentage (p=0.001) of all staff members with extreme weather experience (42-43%) than the older companies (>10 years old) (16-24%). Responding companies of the accommodation subsector have significantly (p=0.004) more staff without or less experience with extreme weather during their work than the companies of the other subsectors. In addition, a significant (p=0.000) higher percentage (42%) of the smallest companies (< 4 FTE) has all staff members with experience with extreme weather in comparison to other companies' percentage (0-15%).

3.7 Vulnerability assessment

The total vulnerability of the responding companies has been calculated on the basis of the vulnerability scores for the three dimensions of exposure, sensitivity and adaptive capacity that tourism companies face regarding extreme weather events and related natural hazards. A decimal scale from 0 to 1 – 1 being the most vulnerable shows that the average total vulnerability of the 187 participating tourism companies was 0.43 (moderately vulnerable) overall (figure 14). However, mean scores across the entire spectrum of vulnerability range from 0.19 (very low vulnerability) to 0.77 (high vulnerability). The different tourism subsectors have similar total vulnerability values. The subsector attractions has the lowest vulnerability with 0.38, followed by the tour operators/travel agencies and transportation, both with a score of 0.42. The subsectors restaurant/bar and accommodation have a slightly higher vulnerability than the overall average; 0.44 and 0.45 respectively. The overlaying a radar plot on the vulnerability scoping diagram visualizes differences among sub sector groups in each of the three dimensions of vulnerability. For each measure, the distance from the centre to the outer circle represents increasing vulnerability (e.g., from 0.1 to 1). Additionally, measures of a significant difference between subgroups are indicated with an asterisk (*) and measurement scores with a high vulnerable score (i.e., ≥ 0.6) are indicated with a hash (#).

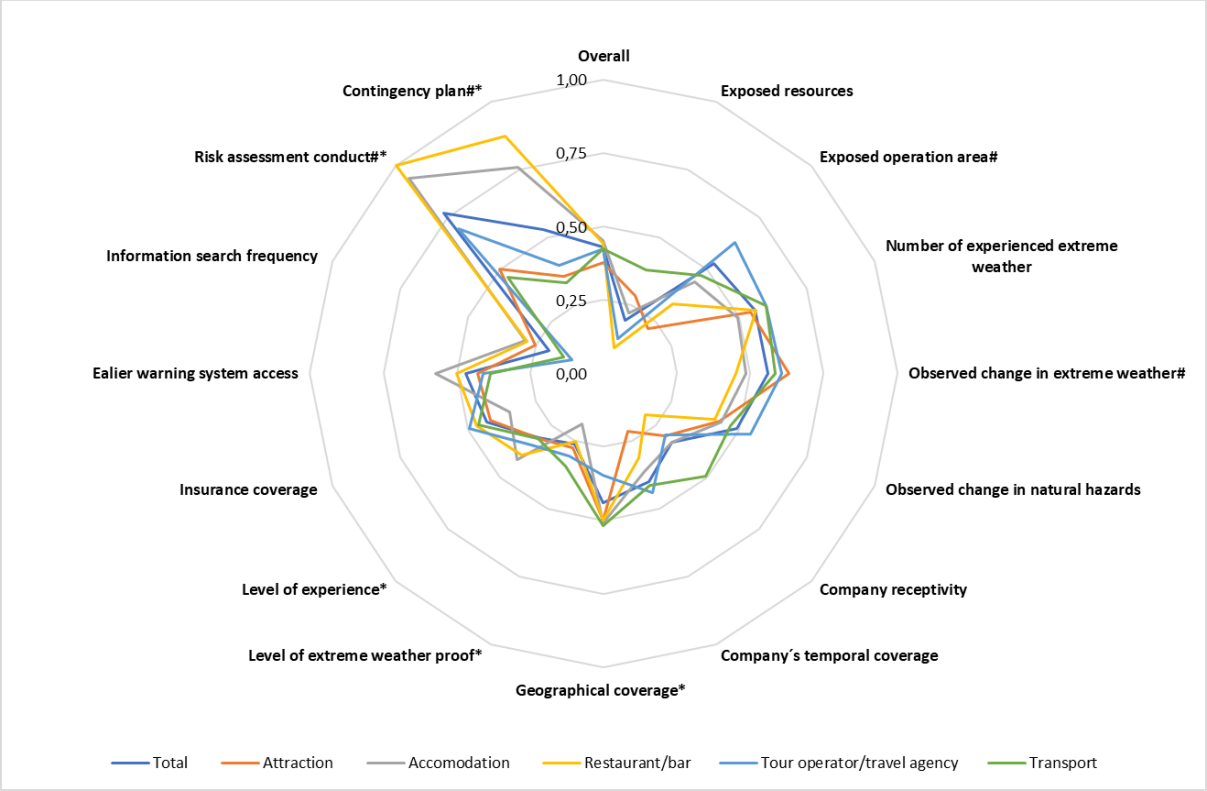

Figure 14: Radar plot of vulnerability scores derived from a vulnerability scoping diagram for total and individual tourism subsectors.

Scores greater than six (≥0.6) for these measures indicate that vulnerability of the overall sector or total sector to extreme weather would be considered 'high'. Regarding the overall vulnerability, only the variable risk assessment has a high vulnerability score (0.77). All the other scores are moderate till very low vulnerability. The different subsectors have more variable scores that indicate a high vulnerability. The subsector attraction has a high vulnerability score on the variable observed changes in extreme weather (0.63). The subsectors accommodation and restaurants/bars have high to very high (>0.8) on the variables risk assessment conduct (0.94 and 1.00) and contingency plan (0.76 and 0.88 respectively). The subsector tour operators/travel agency has high vulnerability scores of the variables exposed operation area (0.63), number of experienced extreme weather event (0.60), observed changes in extreme weather (0.61) and risk assessment conduct (0.70). Finally, the subsector transport has a high vulnerability score on the variable number of experienced extreme weather event (0.60).

Table 4 provides an overview of the different scores per vulnerability dimension and per subsector.

Table 4: Overview vulnerability assessment scores divided per dimension and per subsector.

Total	Total	Attraction	Accommodation	Restaurant/bar	Tour operator/ travel agency	Transport
Exposure	0,47	0,50	0,51	0,46	0,59	0,59
Sensitivity	0,35	0,32	0,36	0,33	0,35	0,42
Adaptive capacity	0,48	0,39	0,58	0,62	0,42	0,36
Overall	0,43	0,38	0,45	0,44	0,42	0,42

The results indicate that particularly the subsectors accommodation and restaurants/bar have a relatively low adaptive capacity towards extreme weather events in comparison to the other sectors while the subsectors tour operation/travel agency and transportation have a significantly higher exposure to extreme weather events than the other subsectors.

4 Conclusion

Future projections indicate that climate change will increase the intensity and frequency of extreme weather globally. However, the effects of extreme weather events on tourism can be complex and varied, depending on the specific event and destination. In Iceland, the tourism sector constitutes one of the most important economic sectors of the country, but knowledge regarding the impacts of extreme weather on this sector is still lacking. Therefore, this study provides some insight into the Icelandic tourism sector´s perception of and experiences with extreme weather during the last 5 years and assessed the sector´s vulnerability to extreme weather. The conducted vulnerability assessment used a vulnerability scoping diagram as a framework to develop an online survey to collect data from tourism companies located in Iceland (n=187).

The study revealed that a large majority (82%) of the tourism companies in Iceland experienced extreme weather or natural hazard triggered by extreme weather during their operation within the last 5 years and almost half of the responding companies have experienced extreme weather more than 10 times in the last 5 years. The experienced extreme weather events were in most cases severe storm (93%), extreme snowfall (57%) and extreme rainfall/hail (49%). The majority of companies observed an increase in frequency and intensity of severe storms, but observed a decrease or no change in extreme snowfall intensity and frequency in the last 5 years as well.

The damage caused by extreme weather or related natural hazards was considered relatively moderate by the responding companies. A majority of the companies (62%) had damage to less than 1 million, while just a minority (9%) of the respondents had damage of over 5 million ISK during the last 5 years. Most damage comprises cancelation by customers (50%), cessation of operations (22%), supply interruption and infrastructure damage (both 19%).

Furthermore, the assessment shows that the overall vulnerability of the tourism sector to extreme weather is moderate and there are no significant differences between the tourism subsector with regard to the overall vulnerability. However, considering the different vulnerability elements (exposure, sensitivity and adaptive capacity), there are significant differences between the companies' exposure and adaptive capacity on one site and sensitivity on the other. In particular, the subsectors accommodations and restaurants/bar show a relatively low adaptive capacity towards extreme weather in comparison to the other sectors, while the sub sectors tour operation/travel agency and transportation have a significantly higher exposure to extreme weather events.

A considerable part of the collected data is based on the entrepreneurs´ own (subjective) perceptions and experiences and can therefore deviate significantly from weather data collected with robust objective methodology. Nevertheless, these experiences and perceptions of extreme weather provide a value contribution to the dearth of knowledge of the relationship between tourism and extreme weather and provides a valuable benchmark for further research.

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Appendix 1

Dear participant,

The University of Iceland is conducting a study about the vulnerability of tourism companies to extreme weather events in Iceland. Extreme weather events are occurrences of unusually weather or climate conditions that can cause severe impacts on companies, communities, infrastructure, and natural environments, such as severe storms, heavy rain/snowfall, drought, cold waves or sandstorms.

To develop effective adaptation approaches to cope with extreme weather events in the future, it is necessary to get insight into current extreme weather events impacts on the Icelandic tourism sector and how vulnerable the sector is to such extreme weather events in Iceland.

This online study should take you around 10 minutes to complete. All your information will be handled confidentially, and your answers will be anonymous and reported in a generalized format (averages and standard deviations) that will conceal individual information. Thank you for your participation, your input is very valuable for this project. For further information about this study, you can contact the principal investigator of this study, dr. Johannes Welling: hwelling@hi.is.

Question 1. For how long is your company operating in the tourism sector?

1. 3 years or less
2. 4-10 years
3. 11- 20 years
4. More than 20 years
5. Do not know

Question 2. Which costumer market does your company focus on?

1. Mainly the national costumer market
2. More or less on the national and international costumer market evenly
3. Mainly the international costumer market
4. Do not know

Question 3. How many employees does your company have measured in full-time equivalent (FTE)?

1. 1-3 FTE

2. 4-10 FTE
3. 11-50 FTE
4. 51-100 FTE
5. More than 100 FTE
6. Do not know

Question 4. In which season does you company operate (mainly)?

1. the summer seasons
2. the winter seasons
3. the whole year around

Question 5. In which sub-sector is your company operating? (Select most applicable answer)

1. Accommodation
2. Restaurant/Bar
3. Souvenir/gear store
4. Tour operating/ travel agency
5. Transportation

If answered options 1-3 above

Question 5a. Where is your company located?

1. In urban areas (villages, town, city)
2. In countryside

If answered option 2 above

Question 5a1. In which environment in the countryside is your company located? (Select most applicable answer)

- Mountain area
- Floodplain area
- Forrest area
- Wetland
- Grassland
- Other

If answered option 4 above

Question 5b. In which environment does your company mostly operate its tours? (Select most applicable answer)

- Mountains/glaciers
- Sea / river / lakes
- Woods / forests
- Highlands
- Lowlands
- Urban areas (villages and towns)
- Other

If answered option 5 above

Question 5c. On which scale does your company´s service take place?

1. On local/regional level
2. On national level
3. On international level
4. Do not know

Question 6. What extreme weather events did you experience with your company in the last 5 years? (Select all that apply)

- Severe storm/hurricane
- Extreme rainfall/hail
- Extreme snowfall
- Cold wave
- Heat wave
- Drought
- Other

Question 7. In total, how many extreme weather events (e.g., severe storms, very heavy rain or snowfall, hailstorm, cold wave, etc.) have you experienced in the last 5 years?

1. 20+
2. 11 - 19
3. 4 - 10
4. 1 - 3
5. 0
6. Do not know

Question 8. What natural hazard triggered by extreme weather did you experiences with your company in the last 5 year? (Select all that apply)

- I did not experience any natural hazard in the last 5 years
- Flooding
- Wildfire
- Landslides
- Avalanche
- Other types of natural hazards

Question 9. In the last 5 years, have you observed directional changes to the following?

	1. Decrease	2. No change	3. Increase	4. Do not know
a. Number of severe storms				
b. Intensity of severe storms				
c. Number of extreme rainfall events				
d. Intensity of extreme rainfall events				
e. Number of extreme snowfall events				
f. Intensity of extreme snowfall events				
g. Number of floods triggered by weather events				
h. Number of wildfires triggered by weather events				
i. Number of landslides triggered by weather events				
j. Number of avalanches triggered by weather events				

Question 10. What damage did your company had in the last 5 years that was caused by extreme weather events or connected hazards such as floods, landslides and avalanches? (Select all that apply)

- Buildings damage
- Vehicles damage
- Equipment /facilities damage
- Infrastructure (water, power, trails, roads) damage
- Cancellations by costumers
- Cease business operations or services temporarily
- Supplies interruption
- Other

If answered option was cancellation

Question 10a What is the average estimated cancelation rate (by costumers) per extreme weather event?

1. 0% (no cancelations)
2. 1-10%

3. 11-50%
4. 50-90%
5. 91-100%
6. Do not know

Question 10b What is approximately the number of days your company had to cease business operations or services due to extreme weather events or connected hazards such as floods, landslides, and avalanches in the last 5 years?

1. Less than a day
2. 1-3 days
3. 4-10 days
4. More than 10 days
5. Do not know

Question 11 What are the estimated losses your company had due to extreme weather events or connected hazards such as floods, landslides and avalanches during the last 5 years in ISK?

1. 0 ISK (no loss at all)
2. 1-500.000 ISK
3. 500.001 – 1.000.000 ISK
4. 1.000.001 – 5.000.000 ISK
5. 5.000.001 – 10.000.000 ISK
6. More than 10.000.000 ISK
7. Do not know

Question 12 What percentage of your company´s total assets (real estate, vehicles, facilities, equipment) is extreme stormproof?

1. 0%
2. 1-10%
3. 11-50%
4. 51-90%
5. 91 - 100%
6. Do not know

Question 13. What percentage of your company´s total assets (real estate, vehicles, facilities, equipment) is extreme rain/snowfall proof?

1. 0%
2. 1-10%
3. 11-50%
4. 51-90%
5. 91 - 100%
6. Do not know

Question 14. To what extent is your company insured against losses caused by extreme weather events or connect hazards such as floods, landslides and avalanches?

1. Completely insured
2. Most part is insured
3. A small part is insured
4. Not insured
5. Do not know

Question 15. What percentage (%) of your company´s supplies are from inside your region?

1. 0-10%
2. 11-25%
3. 26-50%
4. 51-90%
5. 91-100%
6. Do not know

Question 16. Does your company have access to an extreme weather early warning system?

1. Yes
2. No
3. Do not know

Question 17. How often do you seek information about extreme weather events in Iceland that can benefit your company?

1. Often (daily)
2. Sometimes (weekly)
3. Rarely (monthly)
4. Almost never (1-3 times a year)
5. Never

Question 18. Did your company conduct a risk assessment regarding the impacts of extreme weather and connected hazards such as floods, landslides and avalanches in the last 5 years?

1. Yes
2. No
3. Do not know

Question 19. Does your company have an extreme weather contingency plan?

1. No
2. In development
3. Yes
4. Do not know

Question 20. To what extent does your staff have experiences with extreme weather events during their work?

1. All my staff has experiences with extreme weather events
2. Most of my staff has experiences with extreme weather events
3. Around half of my staff has experiences with extreme weather events
4. Only few of my staff members have experiences with extreme weather events
5. None of my staff has experiences with extreme weather events
6. I do not have a staff
7. I do not know

Question 21. Is there anything you would like us to know? Please provide your comments below.