Plumes and paths: The Eyjafjallajökull eruption and airspace dependencies

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Abstract: The Icelandic volcano Eyjafjallajökull erupted in April 2010 disturbing European airspaces for over a week, leaving millions of passengers stranded and costing the airlines 1.8 billion Euros. The eruption generated large quantities of volcanic ash with the potential of damaging an aircraft within minutes, a situation which left the Volcanic Ash Advisory Centre in London with no choice but to recommend to national airspace controllers the closure of their airspaces. The eruption revealed how much our modern societies, tourists included, are dependent on aeromobility. The airspace closure demonstrated the adaptability of Europe first and foremost in the face of a dramatically altered situation. However, the airspace closures also generated a wide range of criticism of the methods and thresholds used in assessing the risk level of the ash cloud. This article reviews the problems associated with volcanic ash, offers a brief assessment of Finnish media responses to the chaos, and evaluates the risks of nine different airports in terms of conceivable eruptions.

Introduction

On Thursday 15 April 2010 I was getting ready for a morning session concerning international air traffic networks at the annual meeting of the Association of American Geographers in Washington. I switched on the TV to check the weather for the day and the first thing I heard was "If you're going to Europe today, don't bother". Closer observation revealed that the Eyjafjallajökull volcano in Iceland had erupted spreading a plume of volcanic ash towards northern parts of Europe, with forecasts implying the sulphuric tephra-soaked clouds would spread throughout Europe and the Northern Atlantic along the currents within days. Predictions estimated that parts of the European airspace would be closed until further notice and the worst-case scenario was a total halt to Northern hemisphere flights for half a year or more. The conference continued its course with increasing twitches and poor jokes towards the end of the week. For the European geographers, the AAG in Washington was turning into 'Hotel California'.

However, as the conference drew to a close on Sunday 18 April, hopes of getting over the renamed 'Ashlantic' increased as parts of Norwegian airspace reopened. Being on board an airliner on a safely northern course, sitting next to a white-knuckled fellow passenger, and eventually landing in Gardermoen, Oslo instead of Copenhagen during a clear skied gap in the ash cloud estimates, included more jameslowell-kind of excitement than anyone could possibly hope for when crossing the Atlantic. Nevertheless, the continuing eruption showed just how vulnerable modern aeromobile lives and economies are, revealing our dependence on the incessant streams of globalization or spaces of flows. The unexpectedly huge amounts of volcanic ash illustrated how quickly individuals and societies are capable of transforming being stranded into other means of transport, coping with altered situations and finding alternatives to air travel.

In this article I will first illustrate the magnitude of air traffic, different views on air travelling and how air travel can be regarded as indispensable. I will also illustrate past problems with volcanic ash and how they are only likely to continue in the future. Second, I demonstrate how the Eyjafjallajökull eruption disturbed the European airspaces and take some examples from the media of their effects on Finland. Third, I run a short analysis of the risks nine different airports have when their direct flight connections are affected.

Air traffic with respect to tourism and volcanoes

Air traffic and volcanoes do not go well hand in hand (Johnson & Casadevall 1991; Casadevall 1994; Casadevall & al. 1996; Miller & Casadevall 2000; Guffanti & al. 2009; Mastin & al. 2009; Prata & Tupper 2009). The steady increase in global passenger air traffic, despite recession driven decreases approximately every ten years, and the inevitable volcanic activity in all continents, suggest that aircraft-ash related problems continue to threat the modern global society (see Figure 1). Prata and Tupper (2009: 243) maintain that "the problem stems from the inherently unpredictable nature of volcanic activity, the ability of the earth's wind circulation systems to spread ash and gas over large distances quickly and the difficulty associated with managing the highly complex and vital aviation business". In 2009 there were 2.2 billion air passengers in the world (ICAO 2010), a figure that dropped by 3.1 per cent compared to 2008. According to the World Tourism Organization, international tourist arrivals declined in 2009 even more critically as the recession caused a decline in leisure travel and the H1N1-flu affected negatively travel recommendations. The number of tourist arrivals declined worldwide by four per cent in 2009 to 880 million. However, both figures are expected to rise in 2010 and 2011 (ICAO 2010).

European airspace, excluding the Baltic states, Russia, Belarus and Iceland, is the second most congested in the world with an average of 26 000 flights per day and some 31 000 on peak days. The geographical distribution of the most active airports follows the largest conurbations with the strongest economic activity, combined with some remote tourist sites where air traffic helps tourism and plays a catalytic role (Wegner & Marsh 2007; Vainikka 2008). The European air traffic network is a mix of relatively short-haul scheduled flights, long-haul intercontinental flights from hub airports and midrange flights serving the tourism industry (Wegner & Marsh 2007). In-built reciprocality means that short-haul traffic is more prompt in returning passenger flows to the origin than in the case of longer distances.

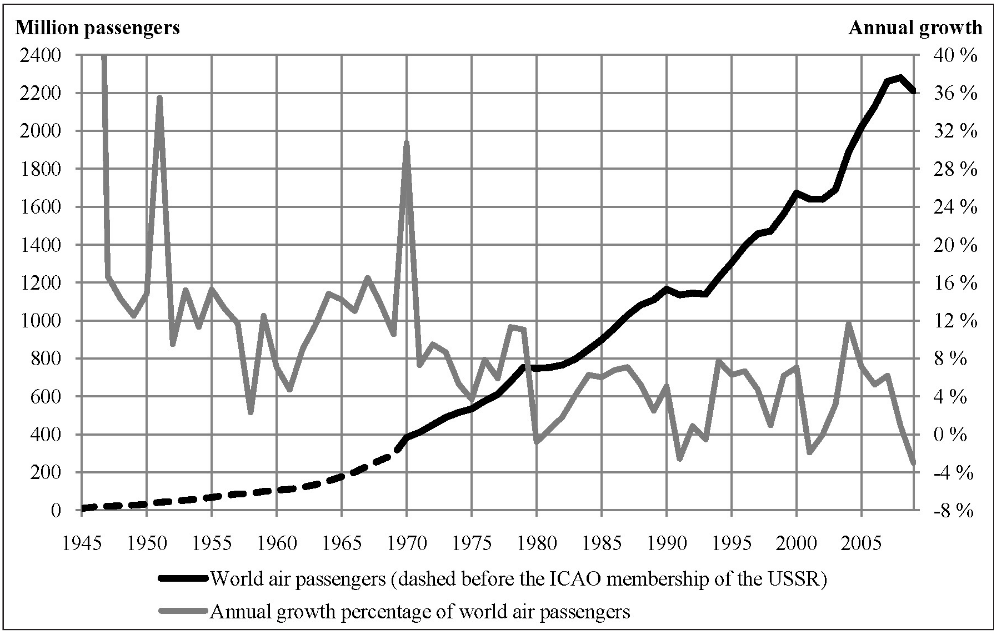


Figure 1. Annual air passenger numbers in the ICAO member states 1945–2009. Data sources: ICAO 2008, 2010.

Overall, air travel "has broadened our sense of geography and human experience" (Edwards 1998: ix). With the assistance of aviation goods, people, and people's perceptions travel from one place to another. Dodge and Kitchin (2004: 195) argue that "air travel provides one of the key physical supports to the global economic system by connecting together people and activities into a shared time and space." Some authors suggest that air transport can be equated to globalization (Graham & Goetz 2008: 141). The thread-like connections air traffic makes between different places across distances have become so self-evident and unquestionable that we could not imagine a world without aviation. Hamish McRae (2006) envisions that the end of air travel would be the end of international tourism, that high value exports would diminish from their current levels and that countries and perhaps even continents which currently greatly rely on seemingly immediate transportation would suffer. Even though the world of aviation has become evermore banal and everyday there are obvious differences as to how different people see the experience. Some use a year's savings for a holiday trip, whereas others fly quite frivolously across the oceans for hair cuts or dinners. The security and relative ease of air travel advance a multitude of perceptions. Rosler (1998: 37) sees air travel simply as a trajectory that is "dreamlike but without compelling narrative" following Andreu's (1998) vision of a travel in 'a segmented tunnel'. However, air travel is one of the few first-hand experiences that help an individual to come into contact with the planetary scale. Gottdiener narrates:

> *"After a time, on an ocean flight, when there are still no signs of land, the sea below takes monumental proportions. The space of the airplane interior begins to shrink in comparison. Suddenly it seems that we are of no significance, a little plain with its frail cargo of little lives. […] From seven miles high, I lost myself in the immense scale of things, like contemplating the night sky full of stars or the ocean." (Gottdiener 2001: 201).*

However, alongside the global extent and expansion of scale, not forgetting the masses that can now afford it, air travel cannot escape the extensive natural hazards and unexpected catastrophes.

Encounters with volcanic ash

While no plane has ever crashed during the history of aviation (since the Wright brothers) because of volcanic ash, various volcanic eruptions have shaped the safety procedures of aircraft-ash encounters. The first such encounter occurred on 22 March 1944 when tephra and hot ash falling from Mount Vesuvius on Pompeii airfield resulted in the USA's largest single loss of aircraft in WWII (Brooker 2010). Mount St. Helens damaged at least three aircraft in 1980; however, the international aviation community paid little attention to these incidents (Miller & Casadevall 2000). The volcanic ash from the Mount Galunggung in Java Indonesia resulted in five incidents between April and July 1982. On two occasions, ash on the flight path resulted in multiple engine failures in Boeing 747 aircraft, the 'sand-blasting' of the exteriors and subsequent emergency landings (Johnson & Casadevall 1991). A similar incident took place on 15 December 1989 when a Boeing 747 encountered volcanic ash from Mount Redoubt in Alaska. Within a minute of noticing the loss of visibility and the volcanic smell in the cabin all engines lost thrust. However, the crew was able to re-start the engines at 13 000 ft and land the aircraft enroute from Tokyo to Amsterdam at Anchorage (Przedpelski & Casadevall 1991). Between December 1989 and February 1990 four other jetliners were damaged in ash encounters (Casadevall 1994). Because of serious damage to each of the aforementioned Boeing 747s, their engines were replaced and additional maintenance work was carried out on their airframes.

The eruption of Mount Pinatubo in the Philippines in 1991 gave a handful of incidents ranging from the usual electric discharges and St. Elmo's fires to engine replacements and exterior abrasion. Some aeroplanes were damaged within minutes (Casadevall & al. 1996). The difference with regard to earlier incidents was only that the existence of volcanic ash at flight altitudes was known. Some airlines, however, were either unaware or ignorant of the possible outcomes of flying into a concentration of ash. Casadevall & al. (1996) maintain that the large number of encounters in 1991 "prompted volcanologists, meteorologists, and aviation authorities to reevaluate the hazard that [ash] clouds present to aviation safety and how available technology and operational procedures can be applied or modified to mitigate the ash hazard."

After the Mount Galunggung eruption in 1982 and other aircraft threatening eruptions volcanic ash has become a serious issue for air traffic safety regulations. There have been 126 recorded ash-aircraft encounters in the period 1953–2008 and at least 101 airports in 28 countries were affected by eruptions at 46 volcanoes in the period 1944–2006. (Guffanti & al. 2009; Guffanti 2010). The International Airways Volcano Watch (IAVW), that exists under the International Civil Aviation Organisation (ICAO) and World Meteorological Organisation (WMO), has given a guideline to avoid volcanic ash clouds completely (ICAO 2001; Tupper & al. 2004). This can ultimately be difficult as small and often undetectable quantities of ash can spread throughout the whole atmosphere.

The Eyjafjallajökull eruption between 14 and 21 April 2010 and its consequences

The chaos unfolds

The ice-capped Eyjafjallajökull volcano in southern Iceland erupted for the first time since 1821–1823 on 20 March 2010. The small basaltic fissure eruption on the volcano's eastern flank lasted until 12 April (Gudmundsson & al. 2010). By this time some 25 000 tourists had visited the volcano (Gertisser 2010). The more volatile summit eruption started on the 14 April, first as a subglacial activity and later on as a phreatomagmatic eruption creating a dense, black plume of ash. The electrified cloud of ash it generated was pushed to the south-east and south by the prevailing winds. On 18 April, the eruption changed largely to magmatic with decreased intensity. However, the first three days provided extremely widely dispersed erupted material, around 250 million cubic metres of ejected tephra, in commercial flight altitudes with and slow atmospheric removal rates (Gudmundsson & al. 2010). Davies & al. (2010) report that the eruption was a small-to-intermediate size whose dispersal pattern was normal in respect of longer-term Icelandic eruptions. Quite ironically, Leadbetter and Hort (2010) presented calculations from a possible eruption in Iceland and its dispersal probabilities only weeks before the actual plume.

Volcanic ash consists of particles that are smaller than two millimetres. They become problematic for commercial jet engines because the melting point of volcanic ash is lower than the operating temperature of the engines, resulting in the ash melting onto engine parts – fuel nozzles, combustors and turbines (Brooker 2010). Flying an aircraft through an ash cloud not only damages its engines but the corrosive sulphur dioxide accompanying the cloud damages the airframe. In addition to abrasive problems the particles of the plume are electrified and potentially dangerous to the aircraft cabins and a cause of radio interference (Lorenz 2008). Harrison & al. (2010) note that the Eyjafjallajökull volcanic ash plume had the characteristics of radioactive charging. With the current cost of the Airbus A380 in the region of 240 million Euros and the Boeing 747 around 180 million Euros, airlines have their fleet to protect as well as ensuring the safety of their passengers.

The prevailing winds pushed the ash plume towards the Nordic countries, the

British Isles and continental Europe, leaving Reykjavik relatively untouched for the main stage of the eruption. The tortuous cloud induced airspace closures from 14 April 2010 onwards and led to the cancellation of some 104 000 flights and the disruption of 10 million passenger journeys. Between 15 and 22 April 48 per cent of flights were cancelled, peaking at 80 per cent on 18 April (Eurocontrol 2010), marking the largest airspace closures since the Second World War. Later in May the continuing eruption led to a further 7 000 ash–cloud cancellations. The worst hit airports during the eight-day crisis were Helsinki, Dublin, Edinburgh and Manchester, where over 75 per cent of flights were cancelled. After 20 April, 5 000 additional flights were initiated in order to reposition aircraft and crew and to accelerate the repatriation of stranded passengers (Eurocontrol 2010).

The Volcanic Ash Advisory Centre stationed in London and the Meteorological Office in Britain were responsible for the call to recommend airspace closures. The rest of Europe followed the ash dispersal maps of the Met Office. The London VAAC is one of nine IAVW commissioned centres worldwide. Using mathematical models it forecasts the dispersion of atmospheric pollutants while proceeding with caution, but it has a tried and tested record for accuracy. After four days of airspace closures the pressure to recalibrate the safety thresholds regarding volcanic ash started to pile up, especially after Air France-KLM and Lufthansa had made 'test flights' by repositioning aircraft.

By the time of the Eyjafjallajökull eruption the airframe or engine manufacturers had not given thresholds as such for the concentration value where flights could be regarded as safe. MetOffice used a threshold value of 0.2 mg/m3 (Brooker 2010). In the middle of the airspace closure, the ministers of transport of the EU held an Internet meeting on Monday 19 April to discuss moderations in the flight safety recommendations. Promptly, the UK Civil Aviation Authority after consulting aeroplane manufacturers set out its own criteria for tolerance levels (2 mg/m3) that freed much of the British airspace and consequently European airspace (CAA 2010). Fortunately, the amount of ash pluming into the air had by then decreased. The ash crisis had cost for Finnair, for example, over 30 million Euros (Finnair 2010) and over 1.8 billion Euros for the airline sector as a whole (IATA 2010b), sums that contrasted to the economic recession worldwide were small when no lives or planes were lost.

Viewpoints of the Finnish media

The magnitude of the situation was not readily realized by the Finnish media. The third largest newspaper Turun Sanomat (2010), for example, greeted the eruption with a 140-word piece on 15 April. On the next day, it stated that "Helsinki Airport avoided chaos" (Kahilainen 2010). The reality was, however, that on 15 April when the European airspace gradually started to close, it instantly created a vacuum of flights not only affecting the countries that closed their airspace, but air travel worldwide leaving millions of people stranded, as well as disrupting postal services and exports from 15 April onwards. The main newspaper of Finland, Helsingin Sanomat (2010), reported on 16 April "European skies silenced" and of "total chaos at European airports" (Mannila & Miettinen 2010). While trying to cover the topic widely, newspapers took an individualistic view, reporting on different individual destinies at Finnish airports, revealing how much everyday life is dependent on air travel. However, the situation was worse for those passengers that were stranded inbound. The passengers for domestic flights quickly filled trains or rented cars or in some cases bought cheap cars for longer routes. Social media quickly came to help while trying to repatriate travellers from greater distances. At the same time the new-found nomads travelling through Europe had to encounter the progressive change of landscape that the networking aeromobile world has tried to fade.

The European airspace closure also made for some entertaining headlines, for example that of the British actor John Cleese who took a £3 300 taxi ride from Oslo to Brussels (Alhroth), and of some Finnish politicians, including President and Nobel prize winner Martti Ahtisaari, who took a rerouted trip from Reykjavik to Lisbon via New York and Caracas and continued by minibus back to Finland. Journalist Riku Jokinen (2010) commended the European coach travellers as epic heroes and self-critically argued that media galvanized the stranded public figures into self-aggrandized Odysseys (or Snufkins). In a Helsingin Sanomat interview Professor Soile Veijola even gushes from the 'volcanic turn' and how it has revealed our dependency on air traffic and mobility like a grand social experiment (Alhroth 2010). However, it would be a fallacy to state that the airspace closure would have made mobility more democratic. It left passengers in the lurch and uncertainty of the duration forced many to find other means of travel. Those with tickets for the recommenced flights outstripped those stranded in previous days, and buying a first-class ticket could in some cases get the passenger into a higher slot on the waiting lists.

Volcanic ash probabilities

The fear of volcanic ash is an issue that the modern aeromobile society has to face. As the demand for air travel is ever increasing and volcanism remains steady, the probability of airspace shut-downs and damage to aeroplanes continues to increase. Some pathways are less prone to sudden eruptions and some airports are further away from active volcanoes. Knowledge of these risks is essential, as a plume of volcanic ash can reach flight altitudes in minutes. Tupper & al. (2004) note that warnings can in practice take hours. Nevertheless, as air traffic is a global system, the effects of even small amounts of ash in a localized eruption can affect other flights on other continents. The risk of flying into an ash cloud or plume is relational to the flight paths originating from an airport.

The following analysis regards nine different airports in Europe and Southeast Asia and their great circle flight paths in July 2008. Figure 2 exemplifies the active volcanoes that have erupted since 1800 and the flights paths from Helsinki Airport and Singapore Changi Airport.

There are obvious differences in the positionalities of the selected airports. For instance, the flights departing from Helsinki Airport to Northern America each fly over the Icelandic volcanic zone. Other active volcanoes in the paths of Helsinki originating flights are Etna in Italy and numerous Japanese volcanoes. The flights originating from Singapore are even more at risk of volcanic eruptions as the volcanic lines of Indonesia, North Island of New Zealand, Japan, Kamchatka Peninsula, and Piton de la Fournaise in Réunion cross their paths.

The risk factors are different for different locations. Figure 3 illustrates the percentage of flight paths within the vicinity of recently active volcanoes. The analysis includes all direct connections from selected airports and those active volcanoes which lie at a minimum altitude of -25 meters and which have erupted since 1800. Here volcanoes are divided into four different timeframe categories: those that erupted in 2008 or later, between 1964 and 2007, between 1900 and 1963 and in the 19th century. The vicinity here has been attributed as an intersection of a flight path within a 100 km radius of a volcano.

The results show that Southeast Asian airports and especially Jakarta Soekarno-Hatta Airport have significantly higher risk level of volcanic ash. For the selected five airports in Europe, Helsinki Airport has flights that fly over volcanic areas more frequently. One reason for this is that flights crossing the Atlantic from the selected European world cities to North America take a more southern path around Iceland than those flown from Helsinki. Helsinki Airport also has relatively more flights to Asian cities near volcanoes than the other selected airports.

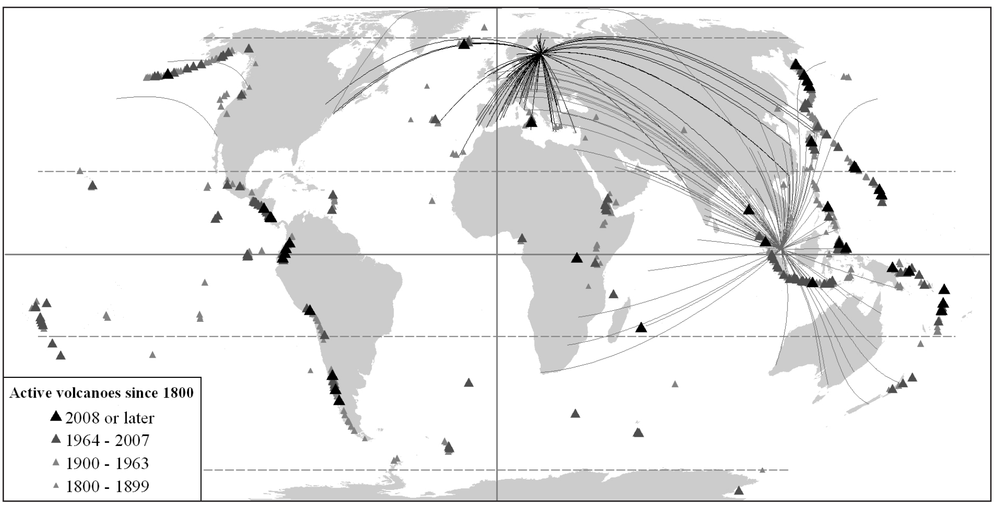
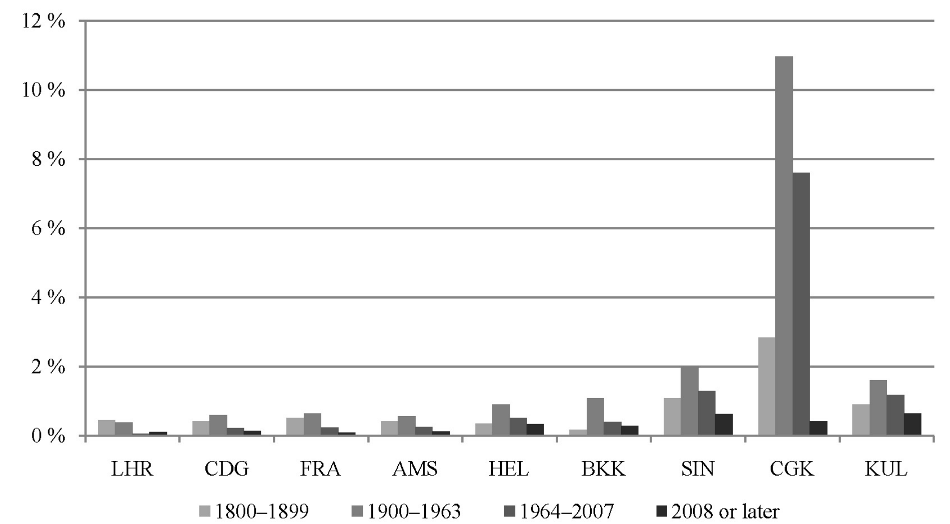


Figure 2. The world's active volcanoes since 1800 and the great circle flight paths of Helsinki Airport and Singapore Changi Airport in July 2008. Data sources: Global volcanism project (2010) and OAG (2008).



	LHR	CDG	FRA	AMS	HEL	BKK	SIN	CGK	KUL
Passengers in millions 2008	67.1	60.9	53.5	47.4	13.4	38.6	37.7	32.2	27.5
NoDD 07/2008	167	246	270	221	94	120	106	56	89

Figure 3. The portion of cumulative flight paths within 100 km radius of an active volcano (an altitude minimum of -25 m) according to great circle flight paths in July 2008 of London Heathrow (LHR), Paris Charles de Gaulle (CDG), Frankfurt (FRA), Amsterdam Schiphol (AMS), Helsinki (HEL), Bangkok Suvarnabhumi (BKK), Singapore Changi (SIN), Jakarta Soekarno-Hatta (CGK) and Kuala Lumpur (KUL). The figure also indicates the passenger numbers in 2008 and the Number of Direct Destinations (NoDD) in July 2008.

Discussion

The Eyjafjallajökull eruptions in 2010 were a grand scale social experiment that showed how societies can cope momentarily without air traffic. The costs for the eight-day disturbance in April, however, were extensive. The lack of coordination in Europe heaped harsh criticism from the International Air Transport Association and from airlines on European governments and airspace controllers. The most vehement criticism was directed at the assumptions on which the airspace closures were based. Airlines in the front line, wanted direct measurements of the ash, not theoretical modelling (IATA 2010a). Nevertheless, setting up an extensive and reliable observation network for the whole Europe in a time of near chaos seems unreasonable. Avoiding five billion Euros of losses for the European Economy in the future, however, poses a serious question of finding the proper operationality of the European air traffic system without hammering flight security.

On a more sociological note, the eight-day ash crisis revealed our mobile and modern societies' airspace dependencies on a scale never witnessed before. As we live in a world characterized by the acceleration of time, in a world where the elevator sound always lingers, fast microwave dinners have come to define single households and ten minute workouts are argued to be enough for a healthy life (see Gleick 1999), the idea of not being able to travel from A to B regardless of terrestrial location, strikes a deep chord. Davies & al. (2010: 605) note that the "event highlights our increased vulnerability to natural hazards". The eruption of Eyjafjallajökull volcano in April and May 2010 was not the last volcanic eruption that will ever disrupt air traffic. It might increase web-based meetings and encourage holidaymakers to choose destinations closer to home. However, the world continues to globalize in spite of a handful of dust in our way.

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