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URBAN ISSUES

39

#airport fragility
#airport disruption
#climate change

Fragile airports. Fragile cities. Fragile landscapes

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Abstract

Recent events provide ample proof of the fragility of cities, territories and airport nodes when they come face-to-face with extreme and unexpected events. The Coronavirus pandemic, for example, has caused a complete disruption in the air network. Climate change, recurrent floods, rising seas, desertification, land impoverishment and, more generally, extreme meteorological events can temporarily or permanently compromise mobility networks and spaces. Airports are, in fact, highly vulnerable elements of infrastructure that require precise adaptation and mitigation strategies at various levels. What role can urban and landscape planning play in future decisions regarding new infrastructural sites and the adaptation of old infrastructure to climatic change and possible new functions?

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Fragile airports, networks, and cities

Recent events offer ample evidence of the increasing fragility of airports, cities, and territories when extreme and unexpected events occur. In 1992, the sociologist Ulrich Beck foresaw a 'risk society' (Beck 1992), a society characterized by multiple risks – environmental, technological, political, and social threats, all of which are now becoming a reality.

The Coronavirus pandemic has completely disrupted the air network. In the same way, climate change, recurrent floods, rising seas, desertification, land impoverishment and, more generally extreme meteorological events can compromise mobility networks and spaces, temporarily or permanently (ACRP 2012; Cipriani 2013, 2016a, 2016b; Eurocontrol 2013). Airports are, in fact, a highly vulnerable infrastructure and their operations have an inevitable ripple-through effect on cities and territories.

'Fragility' comes from the Latin word 'fragilis' meaning 'brittle, easily broken,' and contains the root of the verb 'frangere,' 'to break.' Therefore, it refers to materials and systems with low degrees of resilience.

In actual fact, the way in which airport systems are configured means that they exhibit a high degree of flexibility, which, in other words, also connotes extreme levels of instability and fragility. Unlike other infrastructure, such as railways or roads, for example, airports can be divided into a terrestrial space, comprising the airport, runway, terminals, and control towers and an aerial space, where airplane traffic is constantly travelling along invisible highways. Without aerial connections, airports, which only exist in relation to aircraft, would be shorn of meaning. On the other hand, without access, on a temporary or permanent basis, to ground infrastructure aeronautical bodies would be forced to suspend or change their operations.

Two basic types of fragilities can be identified in the relationship operating between cities and aviation: one

'intrinsic' to the airport infrastructure and its relationship with the surrounding territory, and one 'extrinsic' to the air operations that link territories to one another.

Firstly, 'intrinsic' fragility arises from the fact that each airport in terms its shape, size, and local context is subject to disruption. This fragility is a function of an airport's location – many airports, for example, are inappropriately sited in urban settings, i.e. in areas that are environmentally protected or at risk, or its fragility is determined by contingencies such as unexpected climatic events, system failures, physical or cyber-attacks.

Air operations are often interrupted by long-term processes whose outcomes are highly predictable. It is well known that many airports are situated in cities and areas characterized by widespread urban development. Furthermore, in many countries most main airports are built over or upon very delicate environmental systems such as watercourses, wetlands and water bodies in general. In the past, airports were previously located in the open countryside or in proximity to the undeveloped shorelines of coastal cities, but today they are so engulfed by town expansions as to become part and parcel of the urban fabric (Figure 1). Urbanization, therefore, has led to a growth in environmental constraints that can entail the progressive closure of the airports themselves. 80% of European airports, according to Eurocontrol, are now subject to territorial and environmental development constraints (Eurocontrol et al. 2010).

Sometimes an airport's fragility cannot be clearly predicted. Thus, recent episodes of what is fast becoming a major issue worldwide, climate change, have shown how fragile airport nodes are when they are forced to deal with extreme and unexpected events. Furthermore, the effects of climate change are particularly insidious for transport infrastructure as a whole, given its typically long-life cycle and the degree of uncertainty that pieces of

FIGURE 1

The evolution of the city-airport. During the first phase, the airport is built outside the city in the open country. During the second phase, as the city expands, the airport serves a number of urban centres. During the third phase, the airport is incorporated within the urban fabric. During the fourth phase, the airport is replaced by another airport located further from the residential areas. No longer in use, a practical reconversion project enables the airport to perform new functions

Source: Cipriani 2014b: 22–23; Cipriani 2016b: 142

infrastructure in general must attempt to contend with before, during and after their lifespan.

Secondly, there is an 'extrinsic' fragility peculiar to air operations that connect cities and landscapes to one another.

Thus, rather than speaking of connections between airports and cities, we should emphasize aerial 'disconnection' (Cipriani 2012a). In the past, disconnections between cities were mainly the result of low-traffic and low-profit routes, airport competition, lost subsidies, unexpected economic discontinuities and occasional conflict between companies providing public air services to the less profitable and more peripheral destinations.

Today, the cancelling of routes in response to the Covid pandemic may, if it is prolonged, become a paradigm for the territorial, social and economic impact of aerial 'disconnection.' Eurocontrol has estimated a 90% decrease in air traffic in Europe in April 2020 compared to the previous year (Eurocontrol 2020). Inevitably, such a significant economic downturn will result in changes in network connections between cities and carrier operations.

In Europe, the liberalization of air transport and subsequent emergence of low-cost airlines has increased connections between cities, especially medium-sized ones. For example, between 1996 and 2004 air connections between European cities registered a significant increase (Fan 2006).

In the meantime, the air-transport sector has become a powerful force capable of selecting, activating, or deactivating connections between cities and territories. A private infrastructure network, exclusively based on competitive dynamics and strictly adhering to capitalistic logic, is – by definition – changeable, fickle, fragile but also, on the other hand, flexible, competitive, and elastic. In short, it can disconnect just as easily as it can connect.

In the air transport sector disconnection is a permanent condition. An email sent by a company to an airport is sufficient to immediately stop a service.

Although many studies in transport geography have examined the relationship between airports and cities in depth, it is, instead, with regard to the territory that, paradoxically, air disconnection plays a decisive, and perhaps a greater role.

Actions ensuing from the 'connecting' and subsequently 'disconnecting' produce significant territorial effects. If 'connecting' two points, two cities, or two regions, initially engenders economic and social growth, and one usually accompanied by urban sprawl, subsequent 'disconnecting' cancels not only the set of flows and relationships established over time but also the territory's very 'equilibrium' (Figure 2). The removal of an air route

will have major territorial repercussions not only on the airport and surrounding areas, which then fall derelict and into disuse, but also upon related structures spread throughout the territory, such as second homes, industrial estates or other settlements.

Economic operators can expand and contract routes, connect and disconnect airports and cities, but they cannot do the same to territory, infrastructures, or buildings as these are static entities that require considerable time to adjust to change. A city whose creation and growth are directly related to air connections, is a fragile organism, always subject to future mobility flows. And its fragility will increase exponentially if its airport is highly dependent upon a limited number of carriers.

The volatility of air transport combined with changing market conditions, therefore, translates into a dangerous territorial fragility.

Both these weaknesses, the 'extrinsic' and the 'intrinsic', represent threats not only to airport operations and cities, which, as often happens, have developed around airport nodes, but also to the territories and landscapes that have been put into communication with one another.

Fragile airports in the era of climate change

Sometimes, fragility cannot be fully predicted. However, the empirical evidence and scientific data currently available suggest that climate change is happening with now irreversible dynamics. Numerous effects will have consequences for territory, for cities and for infrastructure itself, not the least important being airports and the fundamental role air transport now plays. The airport of the future will necessarily be re-shaped and transformed in a changing climate. Airports are, in fact, highly vulnerable infrastructure requiring precise adaptation and mitigation strategies at various levels.

Recurring floods, rising seas, desertification, land impoverishment and more generally extreme meteorological events can temporarily or permanently compromise mobility networks and spaces. Due to the growing impact of extreme phenomena in various areas of the planet and the prominent media coverage of the economic, social and environmental damage, the relationship between infrastructure and climate change has occupied a prominent place in international scientific debate over the last few years (Hallegatte 2007, 2009; IPCC 2007a, 2007b, 2012; Neumann 2009; Giordano 2012). Within this vast theme, three principal issues must be clarified.

The first concerns the uncertainty and variability of scientific predictions on future climate change. We know that during the next few years and decades sea level will rise, extreme events will become ever more frequent and intense, and temperature changes, increased precipita-

tion and drought cycles will affect various parts of the planet. Despite a widely shared awareness of the climate change underway, we do not however know when and with what intensity it will occur during the next few years. Moreover, the data currently available indicate that the dynamics of climate transformation are much more rapid than initially predicted (Hallegatte 2009).

The second focuses on the fact that the effects of climate change are particularly insidious for transport infrastructure, given its typically long-life cycle. Ports, bridges, roads, railways and airports are characterized by a long lifespan which in general can vary from a minimum of 30 to a maximum of 200 years (Hallegatte 2009; Giordano 2012). Much of the infrastructure existing today or currently being designed will still be in use by 2030 or 2050 when climate change could have a much greater effect than at present (IPCC 2007, 2014). For example, airport infrastructure, which takes a minimum of

20–30 years to design and has a lifecycle of 40–50 years, could theoretically still be operative in 2070–2080, unless there are radical technological changes in the meantime.

The third issue therefore concerns the degree of uncertainty which infrastructure in general must confront before, during and after its life cycle in order to limit the economic, social and environmental damage. It has been calculated that the financial losses deriving from extreme meteorological phenomena have increased appreciably from a few billion dollars in 1980 to about 200 billion in 2010 (IPCC 2012: 9). Design or re-design of the territory and the infrastructure elements must now, therefore, be redefined in order to include the measures necessary to face up to a possible change in the climate. As S. Hallegatte states: ‘There are good reasons to think that the needed climate information will not be available soon’ (Hallegatte 2009: 240). This is why the design and re-design of the territory and the infrastructure ele-

FIGURE 2
The concept of disconnection

Source: Cipriani 2012a: 300–301

ments according to resilient adaptable ecological criteria is today ever more necessary. During the next few years, the disciplines of urban and landscape planning will therefore become of central importance in the choices to be made regarding both new infrastructure sites and the adaptation of old infrastructure to the environs with soft 'green' measures alongside traditional engineering choices ('hard measures').

If climate will inevitably change the design process, what will the airport of the future be like? Can we imagine an airport infrastructure adaptable to the changing climate and landscape?

Airports at risk

Today many airports around the world are located along the coast or on plains at high risk of flooding. The rise in sea level is just one of the principal effects of climate change and its repercussions on air transportation and airport networks must be taken into consideration in the near future (ACRP 2012; Cipriani 2013, 2016a, 2016b; Eurocontrol 2013).

Recent episodes have demonstrated the fragility of airport nodes in the face of extreme and unexpected water-related events. Exceptional precipitation and floods, together with tornadoes, hurricanes and tsunamis, can all cause infrastructure to become partially or totally unusable (Figure 3). The airports of La Guardia in New York, Don Muang in Bangkok, Sendai in Japan and Brisbane in Australia are just some of the airports which have been temporarily closed during recent years due to a range of extreme events. Numerous other international airports located along coasts or on alluvial plains at high risk of flooding must be added to this list: Amsterdam

Schiphol, London Heathrow and Venice Marco Polo to name but a few.

Starting from a series of case studies, the research aimed to examine the complex relationship between airports, landscape and climate change, through an integrated multi-scale approach based on research and knowledge of the local context ('*design by research*' – '*research by design*'). Mapping played a crucial role in the research project. The final objective of the study was to identify creative but practical tools to explore whether and how one could imagine airports with a high capacity for adaptation.

An analysis of the altitudes of airports around the world identified those airports which could be affected either provisionally or definitively by the predicted rise in sea level (Figure 3). Runways located below sea level are shown in red, while runways located between 0 and 5 m above mean sea level are shown in blue.

An initial examination of the data (DAFIF 2006) shows that 22 airports are located below sea level, including two A type 'active civil airports controlled and operated by civil authorities primarily for use by civil aircraft': Rotterdam (−4.57 m/−15 ft) and Amsterdam Schiphol (−3.35 m/−11 ft) are the most important ones. Throughout the world, 539 airports are at risk from a rise in sea level as they are located between 0 and 5 m (0–16 ft) above sea level. Of these, at least 150 are type A airports for civil use (Table 1).

The most exposed to the phenomena are the infrastructure and populations of south-east Asia, the archipelagos consisting of atolls and the states lining the Gulf of Mexico, but also countries such as the Netherlands, Italy, Greece, Portugal and Egypt and the west coast of the

FIGURE 3

International airports (Type A) and elevations. Runways located below sea level are shown in red, while runways located between 0 and 5 m (16 ft) above mean sea level are shown in blue

Source: elaborated by L. Cipriani, 2020, based on data from DAFIF for 2006

TABLE 1
International airports (Type A) and elevations

ELEVATIONS (FT)	ICAO CODE	AIRPORT NAME	STATE
-114	KZ	DESERT RESORTS RGNL	California, USA
-72	UATG	ATYRAU	Kazakhstan
-65	URWA	ASTRAKHAN	Russia
-56	KZ	IMPERIAL CO	California, USA
-40	OIGG	RASHT	Iran
-15	EHRD	ROTTERDAM	Netherlands
-11	EHAM	SCHIPHOL	Netherlands
-5	HEAX	ALEXANDRIA INTL (now closed)	Egypt
2	KZ	GNOSS FIELD	California, USA
3	KEYW	KEY WEST INTL	Florida, USA
3	NTTR	UTUROA	French Polynesia
4	KMSY	LOUIS ARMSTRONG NEW ORLEANS INTL	Louisiana, USA
4	MKJS	SANGSTER INTL	Jamaica
4	NZDN	DUNEDIN	New Zealand
4	KZ	PALO ALTO ARPT OF SANTA CLARA CO	California, USA
5	NZNV	INVERCARGILL	New Zealand
5	KZ	SAN CARLOS	California, USA
5	LPPM	PORTIMAO	Portugal
5	CZBB	BOUNDARY BAY	Canada
5	NTAA	TAHITI FAAA	French Polynesia
6	KOAK	METROPOLITAN OAKLAND INTL	California, USA
6	KGLS	SCHOLES INTL AT GALVESTON	Texas, USA
6	VRMM	MALE INTL	Maldives
6	LGKR	IOANNIS KAPODISTRIAS INTL	Greece
6	NZNR	NAPIER	New Zealand
6	BIAR	AKUREYRI	Iceland
6	WBGB	BINTULU	Malaysia
6	OBBI	BAHRAIN INTL	Bahrain
7	ZBTJ	BINHAI	China
7	MHTE	TELA	Honduras
7	NTAT	TUBUAI	French Polynesia
7	KZ	MERRITT ISLAND	Florida, USA
7	LIPZ	VENEZIA TESSERA	Italy
7	GQNN	NOUAKCHOTT	Mauritania
7	MMCE	CIUDAD DEL CARMEN INTL	Mexico
7	LJPZ	PORTOROZ	Slovenia
7	EGKA	SHOREHAM	United Kingdom
7	KHST	HOMESTEAD ARB	Florida, USA
7	KZ	THE FLORIDA KEYS MARATHON	Florida, USA
7	KZ	ALBERT WHITTED	Florida, USA
7	KZ	SAINT JOHN THE BAPTIST PARISH	California, USA
7	MYGF	GRAND BAHAMA INTL	Bahamas
8	MWCR	OWEN ROBERTS INTL	Cayman Islands
8	LCLK	LARNACA	Cyprus
8	KZ	KENDALL TAMiami EXECUTIVE	Florida, USA
8	KAPF	NAPLES MUNI	Florida, USA
8	KZ	PROVINCETOWN MUNI	Massachusetts, USA
8	KZ	PETER O KNIGHT	Florida, USA
8	KZ	OPA LOCKA	Florida, USA
8	KMIA	MIAMI INTL	Florida, USA

ELEVATIONS (FT)	ICAO CODE	AIRPORT NAME	STATE
9	KFLL	FORT LAUDERDALE HOLLYWOOD INTL	Florida, USA
9	GOSS	SAINT LOUIS	Senegal
9	DTMB	HABIB BOURGUIBA INTL	Tunisia
9	ENAT	ALTA	Norway
9	KTEB	TETERBORO	New Jersey, USA
9	KZ	NORTH PERRY	Florida, USA
9	KZ	THIBODAUX MUNI	Louisiana, USA
9	KZ	HARRY P WILLIAMS MEM	Louisiana, USA
9	KZ	HOMESTEAD GENERAL AVIATION	Florida, USA
9	KZ	CRYSTAL RIVER	Florida, USA
9	KNEW	LAKEFRONT	Louisiana, USA
9	NTGU	ARUTUA	French Polynesia
10	OIAA	ABADAN	Iran
10	NWWM	NOUMEA MAGENTA	New Caledonia
10	KZ	ST AUGUSTINE	Florida, USA
10	ENML	ARO	Norway
10	FSIA	SEYCHELLES INTL	Seychelles
10	KZ	NEW SMYRNA BEACH MUNI	Florida, USA
10	KSBA	SANTA BARBARA MUNI	California, USA
10	YBCS	CAIRNS INTL	Australia
10	ZSSS	HONGQIAO INTL	China
10	NTTG	RANGIROA	French Polynesia
10	WIOO	SUPADIO	Indonesia
10	MKJP	NORMAN MANLEY INTL	Jamaica
10	GMTN	SANIAT RMEL	Morocco
10	WBKK	KOTA KINABALU INTL	Malaysia
10	KZ	HOUMA TERREBONNE	Louisiana, USA
10	KBDR	IGOR I SIKORSKY MEM	Connecticut, USA
10	KZ	BEAUFORT CO	South Carolina, USA
10	MHTJ	TRUJILLO	Honduras
10	EDWB	BREMERHAVEN	Germany
10	WPDL	KOMORO	East Timor
10	SADF	SAN FERNANDO	Argentina
10	UBBB	BAKU-HEYDAR ALIYEV	Azerbaijan
11	SBPA	SALGADO FILHO	Brazil
11	SBVT	GOIABEIRAS	Brazil
11	CYPK	PITT MEADOWS	Canada
11	WMKP	PENANG INTL	Malaysia
11	KZ	MICHAEL J SMITH FLD	North Carolina, USA
11	KPIE	ST PETERSBURG CLEARWATER INTL	Florida, USA
11	PAOT	RALPH WIEN MEM	Alaska, USA
11	ZSPD	PUDONG	China
12	WRLL	SEPINGGAN	Indonesia
12	LEBL	BARCELONA	Spain
12	TXKF	BERMUDA INTL	Bermuda
13	YMHB	HOBART	Australia
13	EBOS	OOSTENDE	Belgium
13	YBBN	BRISBANE INTL	Australia
13	MUCC	JARDINES DEL RAY	Cuba
13	ZGSZ	BAOAN	China
13	ZSNB	LISHE	China

ELEVATIONS (FT)	ICAO CODE	AIRPORT NAME	STATE
13	FOOG	PORT GENTIL	Gabon
13	LFMN	COTE D AZUR	France
13	LFRZ	MONTOIR	France
13	LFMD	MANDELIEU	France
13	LIRF	FIUMICINO	Italy
13	PMDY	MIDWAY ATOLL	Midway Islands
13	TNCM	PRINCESS JULIANA INTL	Netherlands Antilles
13	LIMJ	GENOVA SESTRI	Italy
13	NZTG	TAURANGA	New Zealand
13	KJFK	JOHN F KENNEDY INTL	NYC, USA
13	URML	UYTASH	Russia
13	KZ	ORANGE CO	Texas, USA
13	KSFO	SAN FRANCISCO INTL	California, USA
13	KBCT	BOCA RATON	Florida, USA
14	CYVR	VANCOUVER INTL	Canada
14	EDDW	BREMEN	Germany
14	LGZA	ZAKINTHOS DIONYSIOS SOLOMOS	Greece
14	KHVN	TWEED NEW HAVEN	Connecticut, USA
14	SVCU	ANTONIO JOSE DE SUCRE	Venezuela
14	KZ	PALM BEACH CO PARK	Florida, USA
14	KZ	LE MAIRE MEM	Louisiana, USA
14	KZ	FORT LAUDERDALE EXECUTIVE	Florida, USA
14	KMQI	DARE CO RGNL	North Carolina, USA
14	KSAN	SAN DIEGO INTL LINDBERGH FLD	California, USA
14	TLPL	HEWANORRA INTL	St. Lucia
15	MZBZ	PHILIP S W GOLDSON INTL	Belize
15	SBIL	ILHEUS	Brazil
15	EISG	SLIGO	Ireland
15	LGLM	LIMNOS	Greece
15	KLCH	LAKE CHARLES RGNL	Louisiana, USA
15	RJSS	SENDAI	Japan
15	RJBH	HIROSHIMANISHI	Japan
15	VOTV	THIRUVANANTHAPURAM INTL	India
15	NZGS	GISBORNE	New Zealand
15	MBPV	PROVIDENCIALES	Turks & Caicos Islands
15	EGAC	CITY	United Kingdom
15	KDCA	RONALD REAGAN WASHINGTON NATIONAL	USA
15	KZ	PALACIOS MUNI	Texas, USA
15	LESO	SAN SEBASTIAN	Spain
15	KBPT	SOUTHEAST TEXAS RGNL	Texas, USA
15	KZ	ABBEVILLE CHRIS CRUSTA MEM	Louisiana, USA
15	KZ	ASTORIA RGNL	Oregon, USA
15	KZ	FERNANDINA BEACH MUNI	Florida, USA
15	YBMC	MAROOCHYDORE SUNSHINE COAST	Australia
16	MDPP	GREGORIO LUPERON INTL	Dominican Republic
16	SADD	DON TORCUATO	Argentina
16	MYNN	NASSAU INTL	Bahamas
16	EDWI	WILHELMSHAVEN MARIENSIEL	Germany
16	GQPP	NOUADHIBOU	Mauritania
16	EVLA	LIEPAJA	Latvia
16	TFFF	LE LAMENTIN	Martinique

ELEVATIONS (FT)	ICAO CODE	AIRPORT NAME	STATE
16	MMAA	GENERAL JUAN N ALVAREZ INTL	Mexico
16	WMKC	SULTAN ISMAIL PETRA	Malaysia
16	KZ	JACK EDWARDS	Alabama, USA
16	LEXJ	SANTANDER	Spain
16	ESNN	SUNDSVALL HARNOSAND	Sweden
16	DABB	ANNABA	Algeria

Source: elaborated by L. Cipriani, 2020, based on data from DAFIF for 2006

United States, together with the northern United States, Thailand, Singapore, Malaysia, Papua New Guinea and the east coast of Australia.

The image represents an unfavourable prediction as it aims to also identify airports which could be made inaccessible due to lower-lying surrounding areas. Flooding could also be caused by possible tsunamis, hurricanes and other extreme weather events as occurred at New York's La Guardia airport or Sendai Airport in Japan.

As has been observed by a number of sources (Hallegatte 2009), the predictions made by the IPCC in

2007 indicating a minimum and maximum rise in sea level by 2100 have been updated as they did not take into consideration the fact that the ice caps are melting much more rapidly than initially thought. Regarding this, the recent IPCC document predicts a maximum rise of about 1 m AMSL in 2100 (IPCC 2013). This will not, however, be uniform across the globe.

This research study set out to map and analyse a series of airports located in major urban areas: New York (Figure 4), San Francisco, Bangkok, Melbourne, Brisbane, Sendai, Venice, Amsterdam and London.

FIGURE 4
New York State main airports

Source: elaborated by A. Benso, A. Bettiol, L. Garbo, K. Moro, C. Zanuso, under supervision of L. Cipriani, 2012, based on data from Port Authority NY NJ, 2012, edited by L. Cipriani in 2020

For each case study, the airports were analysed in relation to their environs without reference to administrative limits or the organisational structure of the owners. Moreover, during a weather event, when one or more airports serving a city can no longer be used, many other airports at regional and sometimes national level are affected by the same phenomenon.

Although the airports and cities considered are various, complex and located in different landscape and urban settings, they often have a number of common denominators. The airports, all of considerable dimensions, occupy large areas of land, often cross a number of hydrographic basins and each case study clearly shows that the extreme events are largely predictable episodes, sometimes characterized by a cyclical periodicity. Hurricane Sandy which devastated New York (October 2012), the unusual monsoon precipitations in Thailand (June-November 2011), the earthquake and subsequent tsunami which devastated Sendai in Japan (March 2011) and the floods in Brisbane Australia (January 2011) all involve events also present in those places in the past, although previously less intense.

For example, historic records of events affecting New York show a cycle of hurricanes hitting New York State which have already in the past made the airports of La Guardia and J.F.K. (two of the city's main access points) inoperative (Figure 5).

The administrative authorities of the regions considered are almost always aware of the type and scale of potential risks affecting urban areas, but often when extreme meteorological phenomena occur, there is a clear lack of coordination among the institutions and authorities involved. In many cases, the damage extends to the entire

mobility network. Not just airports, but also underground and above ground railways and roads are flooded by water with various degrees of inefficiency. In the case of road infrastructure, for example, it is possible to opt for an alternative route, giving the system a certain degree of flexibility. Given that they are 'nodes', airports, on the other hand, are revealed as weak links in the network causing a further paralysis for the city during the emergency period.

As stated in the IPCC 2012 report on extreme risk management (IPCC 2012), the seriousness of the impacts of extreme weather events depends greatly on exposure and vulnerability.

Both man-derived and natural risks are, in fact, interpreted as consequent to the stresses and pressures affecting a given area (dangerousness), the quantity and type of elements (presence of people, services, environmental resources, infrastructure, economic social or cultural elements) potentially affected (exposure) and the propensity for damage of those elements (vulnerability). Given a similar event, different landscape systems may suffer different damage, according to the quantity and characteristics of the local elements exposed.

Everything which is apparently unexpected can often, in fact, be partially planned. To plan correctly an airport landscape, we must therefore adopt 'a case by case' strategy which will involve short, medium and long-term scenarios and strategic planning. During the next few years, the disciplines of urban and landscape planning will therefore become of central importance in the choices to be made regarding both new infrastructure sites and the adaptation of old infrastructure to its environs with soft 'green' measures alongside traditional engineering choices ('hard measures').

FIGURE 5
Historic hurricanes hitting New York State

Source: elaborated by A. Benso, A. Bettiol, L. Garbo, K. Moro, C. Zanuso, under supervision of L. Cipriani, 2012, based on data from National Hurricane Center 2012, edited by L. Cipriani in 2020

Looking for resilience

While on one hand, water threatens the operation of airports in particular climatic conditions, on the other, a number of airports around the world have been defined incorrectly or correctly as ‘floating airports’ (Figure 6).

Although they actually stand on artificial islands, Kansai International Airport at Osaka in Japan and Hong Kong International airport in Hong Kong have become symbols of technological adaptation to nature.

No genuine floating airports have yet been built, but they have merely been the subject of scientific studies by engineers. They were initially designed as refuelling bases for transoceanic crossings, then were envisaged as mechanisms to put distance between air movements and the mainland, thus reducing acoustic and environmental impacts. Today they have become the symbol of a new union between architecture, landscape and water.

Clearly *floating airports* must not be interpreted literally as a banal technical-technological solution but must be perceived figuratively to adopt old and new strategies for interacting with the local area. Defensive measures cannot be the only solution to oppose the water as sooner or later nature will get the better of them.

There has been a radical paradigm change in the way the theme is approached. Water is no longer a threat to be protected against, instead it stimulates adaptation to living with water and on water by ‘floating’.

Certain cities have always had to adapt to and live with water, giving rise to a genuine *floating urbanism*. Take for example an amphibious city such as Venice, cities in the Netherlands, the floating gardens of Myanmar, or numerous examples of pile dwellings from the Alps and the Padan Plain in Italy to the city of Ozamiz in the Philippines, Galang island in Indonesia, Castro in Chile,

FIGURE 6
World's floating airports

Source: elaborated by E. Isidoro, P. Marangoni, F. Marcato, A. Marinelli, N. Mascotto under supervision of L. Cipriani, 2012, based on data from: Japanese Ministry of Land, Infrastructure, Transport and Tourism 2012; Macau International Airport 2012; Civil Aviation Department. The Government of the Hong Kong Special Administrative Region 2012, edited by L. Cipriani in 2020

Tai O in Hong Kong, Papua New Guinea, Ayutthaya in Thailand and Hanoi in Vietnam.

There are also examples of floating airports built from the late 1970s largely in South East Asia – in Japan, the airports of Nagasaki, Kansai International, Chubu Centrair International, Kobe, Kitakyushu and Tokyo Haneda International; Velana International Airport (old Ibrahim Nasir International Airport) in the Republic of the Maldives and Macau International and Hong Kong International in China.

These structures seem to ideally represent the concept of resilience. This is a notion which, in the urban context, has been borrowed from studies on the ways in which ecological systems react to stress and disturbance caused by external factors. Far from being truly resilient, the concept of a floating airport can be used as a symbol to give space to water in urban structures. From an ecological point of view C. Holling was the first to talk about the topic in 1973 (Carpenter et al. 2001), suggesting that resilience is ‘the persistence of relationships within a system’ and ‘the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist’ (Holling 1973: 17). In other words, resilience is the ability of a system to suffer disturbance and maintain its functions and its control (Gunderson & Holling 2001).

Although the overall picture of climatic weather phenomena in an urban context is complex and the elements require study at appropriate regional scales, airport systems and structures can be brought within a framework of global strategies and precise adaptation measures on various scales.

According to the IPCC definition, in natural and ‘human’ systems, adaptation is ‘the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities’ (IPCC 2012: 5).

Adaptation (in terms of scale, usually involving regional and local realities) must not exclude mitigation. Together they can significantly reduce the risks deriving from climate change.

To prepare the territory and construct infrastructure and resilient cities largely means identifying suitable prevention measures on the various scales of action to help mitigate the amplified effects deriving from the rigidity of urban and infrastructural systems.

Short, medium- and long-term scenarios and large-scale strategic planning are the first necessary steps to be achieved resilient airports – a strategy that has to be combined with effective design tactics.

In airports, for example, runways, terminal roofs, roads and large areas of hard standing prevent rainwater from percolating into the subsoil, also contributing to water pollution given the high concentration of heavy metals, oil, grease and antifreeze liquid.

As a result, rainwater runs off these impervious surfaces rapidly, flooding pipes and canals, contributing to erosion, and accumulating pollution as it flows. In response to this ‘runoff’ problem, numerous architectural and landscape solutions have been developed to slow down the rate of flow and absorb this excess water.

Water management techniques compensate for peaks caused by the excessively impervious paved ground (runways, structures, car parks, etc.), as well as improving efficiency and saving water: green roofs to improve permeability (which also reduce noise); bioswales or rain gardens to collect rainwater in vegetated ditches in place of surface waterways or underground storm sewers; settlement tanks or wetlands to be constructed upstream of the airport area and inside the airport itself where areas of water must be meticulously covered to avoid bird strike with aircraft; use of porous asphalt which allows rainwater to percolate into the subsoil under the runways.

The final aim of the research was to identify possible ways to integrate airport structures, landscape, water and technology, proposing a series of actions and visions to orient the design of a flexible airport system with low environmental impact and a high capacity for adaptation.

Resistance and resilience will be the two approaches to adopt in the design process. Some infrastructures will need to be protected and adaptively redesigned, some others will need to be relocated.

In an era dominated by uncertainty about tomorrow and by a race towards real or presumed sustainability, infrastructure must be re-planned, not just to accommodate today’s technological functions or contingent needs, but also with a view to possible future re-cycling, generating a method for re-inventing the landscape and thus becoming fertile ground for the unexpected.

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