香港城市大學
City University of Hong Kong

396EM Airline Operations and Scheduling/ 6075MAA Airline Scheduling and Operations

Lecture 4a
Airline Irregular Operations

Developed & Revised :
Dr Yang Dai (Coventry)
Kimman Lui & Rossella Lau (Scope)
Presented: Kinki Leung

專業 創新 胸懷全球
Professional · Creative
For The World

SCOPE
School of Continuing and Professional Education
專業進修學院

Coventry University

Learning Outcome

Identify	the impact of airline irregular operations
Understand	the principles how airlines handle their irregular operations and their response strategies
Apply	the airline irregular operations strategy and theories to propose the solutions for various airline irregular operations

What is airline irregular operation?

- Describes and measures flight delays, missed connections, and cancellations.

- Be viewed as the journey disruptions if they result in any change to a booked element of passengers' original journeys.

Reasons

- Nature forces e.g. weather or environmental events
- Air traffic delays
- Aircraft mechanical problems
- Employee actions e.g. strikes by airlines, airports and ATCs.
- Passengers
- Lack of capacity
- Crew sickness
- Airport curfews
- Security

Delay

mechanic

The impact of the Volcanic Ash Cloud

- The eruption of Eyjafjallajökull in Iceland (2010) and the resulting ash cloud, caused the cancellation of 90% of all flights in Northern Europe over a six-day period.
- The loss in airline revenues from this event is estimated at $1.7 billion.

Airline	Flights cancelled	Lost revenue	Revenue/ flight
All	100,000	$1.7B	$17,000

BBC | Sign in | News | Sport | Weather | Capital | TV | Radio | More... | Search BBC News

NEWS — Watch ONE-MINUTE WORLD NEWS

News Front Page
Africa
Americas
Asia-Pacific
Europe
Middle East
South Asia
UK
Business
Market Data
Economy
Companies
Health
Science & Environment
Technology
Entertainment
Also in the news
Video and Audio

Page last updated at 11:46 GMT, Wednesday, 21 April 2010 12:46 UK

E-mail this to a friend | Printable version

Flight disruptions cost airlines $1.7bn, says IATA

Global airlines have lost about $1.7bn (£1.1bn) of revenue as a result of the disruptions caused by the Icelandic volcanic eruption, a body has said.

This content doesn't seem to be working.

Please try again later.

Sir Richard Branson: "I don't think we will ever, ever see a blanket ban again"

The International Air Transport Association (IATA) said that at its height, the "crisis" hit almost a third of global flights.

It also estimated that 1.2 million passengers a day were affected.

On Tuesday night, flights started landing in the UK after a six-day shutdown of UK airspace.

The decision to lift the ban followed safety tests that showed plane engines could cope in areas of low density ash.

VOLCANIC ASH CLOUD

LATEST NEWS
- More airports shut over ash risks
- Flights resume after new ash risk
- Ash ban 'might have ended sooner'
- EU ministers agree volcano action
- Warning over ash passenger rights
- London 'lost £100m' in flight ban
- Europe flights 'back to normal'

FEATURES AND BACKGROUND

Ash threat returns
Why new cloud has disrupted flights

Airlines and passengers face a slow return to normality as flights resume after a six-day shutdown because of volcanic ash from Iceland.

Tens of thousands of Britons are still stranded abroad and it could take weeks to get back to business as usual.

Further delays and cancellations are occurring because of the backlog and planes not being in the right place.

Aviation officials lifted the airspace ban on Tuesday night, saying it was now safe for planes to fly.

For the first time in almost a week, there have been scenes of joy at UK airports with passengers finally arriving home.

But the departures and arrivals boards at many airports remain full of cancellations.

Transport Secretary Lord Adonis admitted to the BBC that the government had been "too cautious" but said the regulators needed to have time to test the impact of the ash.

Officials from Airline Co-ordination Limited said 90% of Heathrow flights were set to resume as normal after 1500 BST. Service should be at 100% by Thursday.

KEY POINTS
- UK and European airports reopen for business
- Many flights still cancelled or delayed
- Airlines begin to repatriate stranded passengers
- 80% of European flights due to operate
- Flight disruptions cost airlines $1.7bn (£1.1bn)
- Icelandic volcano has lost 80% of its intensity

Updated: 17:36 BST, 21 April

- Was the flight ban necessary?
- How do the stranded get home?
- Ash aftermath: Making a complaint

The impact of Hurricane Sandy

- Hurricane Sandy (2012) resulted in a total of 20,245 flight cancellations in North America between October 27 and November 1, 2012, as well as a significant loss of revenue and profits for the major US carriers.

Airline	Flights cancelled	Lost revenue	Lost profit	Revenue/ flight	Profit/ flight
American	759	$65M	N/A	$85,000	N/A
US Airways	1,454	N/A	$20M	N/A	$14,000
Delta	1,293	$75M	$45M	$58,000	$35,000
United	2,149	$140M	$35M	$65,000	$16,000

Impact of Typhoon Mangkhut in 2018 (HK)

- Two runways at HKIA need to remain open overnight to handled 2,000 rescheduled flights within 48 hours after Typhoon Mangkhut

A total of 889 flights were cancelled on Sunday. Photo: K.Y. Cheng

2018 News

2017 News

Impact of heavy fog in 2018 (HK)

- At least 7 flights diverted to Macau and Shenzhen between 6am and 8 am due to thick fog and poor visibility around HKIA.

Thick fog at Hong Kong International Airport caused reduced visibility early Friday morning, but has since cleared. Photo: Facebook

2018 News

Impacts of irregular operations

- Passenger's Journey disruptions due to the delay and cancellation
- Hidden revenue impact
- Impact load factors
- Government actions – introduce consumer protection measures, e.g. EU air Passenger rights legislation

EU 261

- Cross-carrier re-accommodation
- Regional differences
  - 74% Chinese travellers experienced at least one moderate delay over the last 12 months (Surveyed in Feb. 2013)
  - UK Travellers has the lowest incidence of journey disruptions (44%)
- Passenger dissatisfaction
- Impact on GDP e.g. air transportation delays reduced US GDP by $4 billion in 2007

Passenger experiences & attitudes in regard to irregular operations

Key findings

HX

- The greatest challenge and opportunity to improve the impact on passengers from irregular operations lies with managing moderately delayed passengers.
- Lack of communication is the top issue for most markets. Airlines have an excellent opportunity to alter customer sentiment by providing proactive, authoritative communication around delays and journey disruptions.
- Passengers believe they should be compensated for airline delays and journey disruptions, and many are happy with soft compensation. Airlines should view soft compensation as an investment in passenger loyalty, regardless of whether the carrier is at fault.
- Chinese travellers have different experiences and expectations with regard to journey disruption management. China is the largest growth market for air travel over the next two decades, so global carriers should understand and be sensitive to the different expectations and behaviour of Chinese travellers.
- Passengers will continue to talk about their journey disruption experience and influence others through social media.
- Airlines must embrace a more analytical approach, including the use of social network analysis, to more fully understand the influence of individuals and identify ways to change passenger sentiment.

A standard service approach to irregular operations management

- Robust Scheduling
- Empowering the passenger with intelligent re-accommodation
- Implement a pax centric solution
- Transparent communication and compensation
- Offer soft compensation e.g. club room access, mileage credit or meal vouchers
- Managing the social media impact of journey disruptions

Direct operational costs of delays and cancellations

- US airlines direct costs of delays and cancellations in 2012

Direct cost category	Cost per minute	Total delay cost for US
Fuel	$39.26	$3.6B
Crew	$16.26	$1.5B
Maintenance	$12.02	$1.1B
Aircraft Ownership	$7.92	$0.7B
Other	$2.71	$0.3B
Total Direct	$78.17	$7.2B

- Direct operational costs per minute for the US ($78.17) and Europe (€81)

Indirect Costs

- Monetary cost of passenger re-accommodation borne by both the airline and the passenger.

- Impact on the brand image and loyalty

Objectives of irregular operations

- Minimise total passenger delay
- Minimise cancellation

  (Midnight arrival/departure curfew)
- Minimise total cost
- Communication and compensation to customers

Strategies

- Airlines can adopt a combination of the following tactics to deal with the irregular operations:
  - Flight delays
  - Flight cancellations
  - Aircraft substitutions
  - Ferry flights
  - Aircraft diversions to return to their published scheduled flights ASAP
  - Diversion costs from $15,000 (narrow-body domestic flight) to $200,000 (wide-body international flight)

United Airline: Flight delays and cancellations

- Notification of delays and cancellations
- Getting rebooked
- Lengthy tarmac delays
- Amenities for meals and overnight stays
- Children travelling alone and customers with special needs
- Checked bags
- Refunds
- Other helpful tips

CX

Case study

- This case involves 3 aircraft, 12 flights, and 4 cities.
- Assume one of the aircraft becomes unavailable owing to some mechanical problem at an airport.

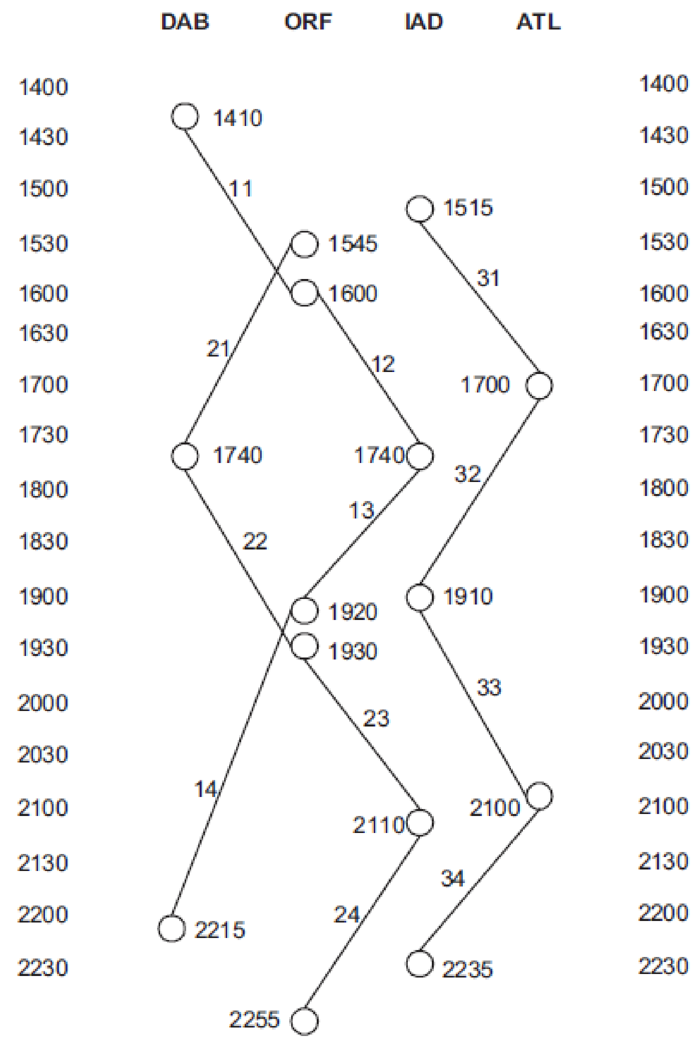
Aircraft ID	Flight ID	Origin	Destination	Departure	Arrival
Aircraft 1	11	DAB	ORF	1410	1520
	12	ORF	IAD	1605	1700
	13	IAD	ORF	1740	1840
	14	ORF	DAB	1920	2035
Aircraft 2	21	ORF	DAB	1545	1700
	22	DAB	ORF	1740	1850
	23	ORF	IAD	1930	2030
	24	IAD	ORF	2115	2215
Aircraft 3	31	IAD	ATL	1515	1620
	32	ATL	IAD	1730	1830
	33	IAD	ATL	1910	2020
	34	ATL	IAD	2100	2205

Time-band Approximation Model

- **Objective**: handle all the remaining flights in the network through a series of delays and/or cancellations so that the total cost to the airline is minimized.

- The flight numbers are shown on the **flight arcs and nodes** represent an arrival and departure at a specific time.

- The cities and times are represented horizontally and vertically respectively.



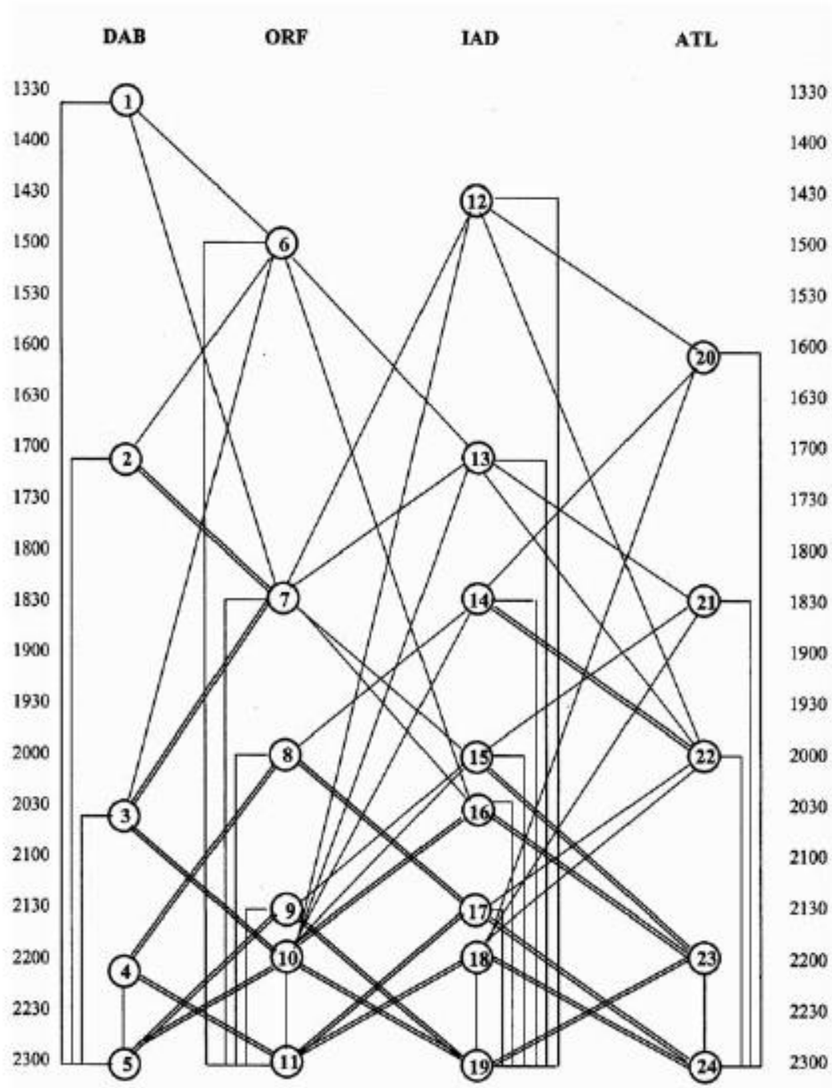
Assumptions on this case study

- Each station requires a minimum of 40 minutes turnaround time;
- Midnight arrival/departure curfew (no arrival or departure after midnight);
- Each minute of delay on any flight costs the airline $20;
- The cancellation cost for each flight leg is shown below

Aircraft ID	Flight ID	Origin	Destination	Cancellation cost
Aircraft 1	11	DAB	ORF	$7,350
	12	ORF	IAD	$10,231
	13	IAD	ORF	$7,434
	14	ORF	DAB	$14,191
Aircraft 2	21	ORF	DAB	$11,189
	22	DAB	ORF	$12,985
	23	ORF	IAD	$11,491
	24	IAD	ORF	$9,581
Aircraft 3	31	IAD	ATL	$9,996
	32	ATL	IAD	$15,180
	33	IAD	ATL	$17,375
	34	ATL	IAD	$15,624

Time band approximation network

- Any flight arc from any airport (node) can be available to other feasible airports (nodes) during the recovery period



Time band approximation network (Con’t)

- Transshipment nodes (station-time nodes): the nodes that the aircraft arrives into and leaves.

- Sink nodes (station sink nodes): represent the nodes that aircraft arrives into but does not leave until the end of recovery time.

- They are similar to the starting nodes for wrap-around arcs taught before.

Scenario A

- Aircraft 2 in airport ORF becomes grounded due to some mechanical failure at 14:00 and is unavailable for the rest of the day.
- The obvious solution without permitting any rerouting of other aircraft is to cancel flights 21, 22, 23 and 24 which are conducted by this grounded aircraft for the day.
- The total cost of these cancellations is $45,246
- Another option – solve this problem through a series of aircraft rerouting and cancellations to minimise the total cost to the airline

Non-zero delay costs

Flight number	Origin node	Destination node	Delay cost
11	2	7	4,200
11	3	10	8,500
11	4	11	10,300
12	7	15	3,900
12	8	17	5,700
12	9	19	7,800
12	10	19	8,100
13	14	8	1,800
13	15	9	3,900
13	16	10	4,200
13	17	11	5,700
13	18	11	6,100
14	8	4	1,800
14	9	5	3,900
14	10	5	4,200

Non-zero delay costs

Flight number	Origin node	Destination node	Delay cost
21	7	3	4,300
21	8	4	6,100
21	9	5	8,200
21	10	5	8,500
22	3	10	4,300
22	4	11	6,100
23	8	17	1,600
23	9	19	3,700
23	10	19	4,000
24	17	11	1,400
24	18	11	1,800
31	13	21	2,900
31	14	22	4,700
31	15	23	6,800
31	16	23	7,100
31	17	24	8,600
31	18	24	9,000
32	21	15	2,300
32	22	17	4,100
32	23	19	6,200
33	15	23	2,100
33	16	23	2,400
33	17	24	3,900
33	18	24	4,300
34	23	19	2,000

Decision variables

- z_i = Number of aircraft (integer) terminated at station node i (node i being a station sink node)
- Objective function:

  need include delayed costs & the cancellation costs

$$x_{i,j}^{k} = \begin{cases} 1 \text{ if flight } k \text{ is conducted from station time node } i \text{ to } j \\ 0 \text{ otherwise} \end{cases}$$

$$y_k = \begin{cases} 1 \text{ if flight k is cancelled} \\ 0 \text{ otherwise} \end{cases}$$

$$\text{Minimize } 4200x_{2,7}^{11} + 8500x_{3,10}^{11} + \ldots.. + 7350y_{11} + 10231y_{12} + \ldots + 15624y_{34}$$

Constraints Set 1- Flight Coverage

- Each flight must either be flown or be cancelled.
- For example: flight 11 with 4 possible flights plus 1 cancellation

$$x_{1,6}^{11} + x_{2,7}^{11} + x_{3,10}^{11} + x_{4,11}^{11} + y_{11} = 1$$

- Similar equations for every available flight could be written, and total 12 constraints for this set.

Constraints Set 2 - Station Time-Node Flow

- Need to list out the flow of aircraft at each node
- Supply nodes are those have aircraft available to start the flow within the network (such as node 1,6 & 12)
- Transshipment nodes signifying the net flow is zero
- The number of aircraft in a node
- = number of outgoing aircraft from the node – incoming aircraft into the node + the number of aircraft carried over from this node to sink node (same city) for the next day.
- Node 1: $x_{1,6}^{11} + x_{1,7}^{22} + z_1 = 1$ Node 2: $x_{2,7}^{11} + x_{2,7}^{22} - x_{6,2}^{21} + z_2 = 0$
- Z: represents the number of aircraft at any specific cities for the next day's operation
- Total 20 Station-Time Nodes resulting in 20 Constraints.

Set 3 – Station Sink-Node Flow

- Without this set of constraints, the aircraft may end up at the wrong airports at the end of day.
- Required number of aircraft at any sink node = Total incoming flight terminating at this sink node + number of carried over aircraft from previous transshipment notes at this airport.
- In this case, we must have one aircraft available in DAB, ORF and IAD each for the next day.
- For DAB station sink node 5:

$$x_{9,5}^{14} + x_{9,5}^{21} + x_{10,5}^{14} + x_{10,5}^{21} + z_1 + z_2 + z_3 + z_4 = 1$$

- Four sink nodes result in four constraints.

Solution 1

Aircraft ID	Flight	Origin	Destination	Origin node	Destination node	Delay cost	Cancellation cost
Aircraft 1	11	DAB	ORF	1	6	-	-
	21	ORF	DAB	6	2	-	-
	22	DAB	ORF	2	7	-	-
	23	ORF	IAD	7	16	-	-
	24	IAD	ORF	16	10	-	-
	14	ORF	DAB	10	5	4,200	-
Cancel	12	ORF	IAD	-	-	-	10,231
	13	IAD	ORF	-	-	-	7,434
Aircraft 3	31	IAD	ATL	12	20	-	-
	32	ATL	IAD	20	14	-	-
	33	IAD	ATL	14	22	-	-
	34	ATL	IAD	22	18	-	-
Total cost						4,200	17,665

Solution 1 (Con't)

- Total 64 arcs (x variables), 12 flight cancellation (y variables) and 20 termination nodes (z variables) => Total of 96 binary/integer variables.

- The minimum cost solution for this scenario is 2 cancellations and 1 delayed flight at a total cost of $21,865 (= $4,200+$17,665)

- Compare with the cost with the trivial solution of $45,246 resulting from cancelling all flights operated by aircraft 2.

The detailed and final solution 2

Aircraft ID	Flight	Origin	Destination	Departure time	Arrival time	Delay cost	Cancellation cost
Aircraft 1	11	DAB	ORF	1410	1520	-	-
	21	ORF	DAB	1600	1715	300	-
	22	DAB	ORF	1755	1905	300	-
	23	ORF	IAD	1945	2045	300	-
	24	IAD	ORF	2125	2225	200	-
	14	ORF	DAB	2305	0020	4,500	-
Cancel	12	ORF	IAD	-	-	-	10,231
	13	IAD	ORF	-	-	-	7,434
Aircraft 3	31	IAD	ATL	1515	1620	-	-
	32	ATL	IAD	1730	1830	-	-
	33	IAD	ATL	1910	2020	-	-
	34	ATL	IAD	2100	2205	-	-
Total cost						5,600	17,665

Note:

- The departure and arrival times in the final solution accommodate for 40-minute aircraft turnaround times.

- The actual cost is $23,265.

- The cost for the final solution schedule is higher than the previous one with 30-minute aggregation in a single node.

Maths Formulation

- This approach is based on the time-band approximation model by Arguello et al 1998

i,j	= node indices
k	= flight index

Sets

F	= set of flights
$G(i)$	= set of flights originating at station-time node i
$\mathrm{H}(\mathrm{k},i)$	= set of destination nodes for flight k originating at station-node i
I	= set of station-time nodes
J	= set of station-sink nodes
$L(i)$	= set of flights terminating at node i
$M(k,i)$	= set of origination station-time nodes for flight k terminating at node i
$P(k)$	= set of station-time nodes from which flight k originates
$Q(i)$	= set of station-time nodes at airport containing station-sink i

Maths Formulation (Con't)

Parameters

a_i = Number of aircraft available at station-time node i
c_k = Cost of canceling flight k
$d^k_{i,j}$ = Delay cost of flight k from station-node i to node j
h_i = Number of aircraft required to terminate at station-sink node j

Decision Variables

$$x^k_{i,j} = \begin{cases} 1 \text{ if flight } k \text{ occurs through station time node } i \text{ to } j \\ 0 \text{ otherwise} \end{cases}$$

$$y_k = \begin{cases} 1 \text{ if flight k is cancelled} \\ 0 \text{ otherwise} \end{cases}$$

z_i = integer number of aircraft terminated at station time node i to station sink node at that airport

Maths Formulation (Con't)

Objective function

$$\text{Minimize} \quad \sum_{k \in F} \sum_{i \in P(k)} \sum_{j \in H(k,i)} d_{i,j}^{k} x_{i,j}^{k} + \sum_{k \in F} c_k y_k$$

Subject to

(flight cover) $\quad \sum_{i \in P(k)} \sum_{j \in H(k,i)} x_{i,j}^{k} + y_k = 1 \quad$ for all $k \in F$

(station-time node flow) $\quad \sum_{k \in G(i)} \sum_{j \in H(k,i)} x_{i,j}^{k} - \sum_{k \in L(i)} + z_i = a_i \quad$ for all $i \in I$

(station-sink node flow) $\quad \sum_{k \in L(i)} \sum_{j \in M(k,i)} x_{i,j}^{k} + \sum_{j \in Q(i)} z_j = h_i \quad$ for all $i \in J$

(binary aircraft flow) $\quad x_{i,j}^{k} \in \{0,1\} \quad$ for all $k \in F$, $i \in P(i)$ and $j \in H(k,i)$

(binary cancellation flow) $\quad y_k \in \{0,1\} \quad$ for all $k \in F$

(integer termination arc flow) $\quad z_i \in Z^{+} = \{0,1,2,\ldots\} \quad$ for all $i \in I$

Key Reference

- Bazargan, M. (2010) Airline Operations and Scheduling. 2nd edition, Ashgate
  - Chapter 10 Airline Irregular Operations

- HKIA Business Continuity

  https://www.youtube.com/watch?v=xwolrzE4dJs
    - Typhoon Contingency Plans(0:36-3:48)
    - Lightning Warnings (3:50-4:50)
    - Airport System Contingency Plans (4:51- 7:18)
    - Quarantine Measures for Inbound Pandemic Infection (7:19-8:34)
    - Land Transport Disruption Contingency Plans (8:35- 10:20)
    - Aircraft Accident Response Plans (10:21-12:53)