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Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Impact of pandemic control over airport economics: Reconciling public health with airport business through a streamlined approach in pandemic control

Lap Hang Chung

Embry Riddle Aeronautical University, Asia, 75 Bukit Timah Road #02-01/02, Boon Siew Building, Singapore 229833, Singapore

ARTICLE INFO

Article history:

Received 1 September 2014

Received in revised form

7 February 2015

Accepted 13 February 2015

Available online 27 February 2015

Keywords:

Airport

Airport business

CAPSCA

Pandemic control

Public health

ABSTRACT

Rapid aviation commercialisation and upsurge in worldwide affluence created a new avenue for disease proliferation across countries at an unprecedented rate. Epidemic and pandemic occurrences over the last decade demonstrate airports' role in disease transmission; while also exhibiting their importance as containment nodes. Tremendous amount of resources and effort are necessary to achieve the latter but inevitably, disrupt normal operations. The contrasting objectives between public health authorities and airport authorities result in compromising measures for both parties. Broadly similar controlling measures were adopted by various airports during outbreaks in the last decade. Their effectiveness have been analysed in terms of disease control; economic impact to airports were, however, not quantified. This paper concludes that more efficient airport pandemic control plans cause less severe economic impact on airports during pandemic and recommends a streamlined approach that improves overall effect of pandemic control while minimising economic impacts to airport businesses.

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1. Introduction

With the rapid development in worldwide aviation over the last two decades, the risk of global pandemic had escalated with increased passenger traffic. Severe Acute Respiratory Syndrome (SARS) outbreak in 2003, Avian influenza H5N1 threat in 2006 and Swine influenza H1N1 pandemic in 2009 were all initial localised outbreak that developed into subsequent pandemic or pandemic-threat epidemics after spreading through the modern aviation network.

Throughout human history, isolation has been an effective means against communicable diseases. The Liberty Island of New York City was once famously utilised as a smallpox quarantine station to prevent the disease from entering America during the mass European migration. Nonetheless, the advancement of modern medical standard in the last century has rendered such measures rarely necessary. Opinions were, however, changed over the last decade with the various diseases to be described below.

SARS took the world by surprise in 2003. The speed of

transmission was so rampant that World Health Organization (WHO) issued travel advisories to Hong Kong SAR, Singapore, and several other countries. As such, Hong Kong International Airport (HKIA) and Singapore Changi Airport (SCA) suffered devastating repercussions as flights were cancelled and passenger flow plummeted. Air travel was pin-pointed as the main reason behind the escalation of local outbreaks to global epidemics as infections propagated at an exponential rate through aviation travel. While cross infections were not limited to within aircraft cabins or vicinity of airports, they were undoubtedly the ideal venues for screening control of infected air passengers. The psychological and economic impacts of ineffective screening at airports were substantial which directly affected airport business in 2003.

Contrary to their recommendations in 2003, travel recommendations were not issued by WHO for either the Avian Influenza threat in 2006 or the Swine Flu pandemic in 2009. The then WHO Director-General Margret Chan explained the decision against travel recommendations against Mexico in 2009: "... they do not protect the public. They do not contain the outbreak. And they do not prevent further international spread" (WHO, 2009). Interestingly, she compared the influenza pandemic to "tidal wave" that could not be realistically contained through restricting travel. Over

E-mail address: chung.laphang@gmail.com.

that period, aviation business was adversely affected albeit to a much smaller extent than 2003, the details of which would be further discussed in this study.

1.1. CAPSCA

Recognising the importance of aviation response to pandemic and other public health risks, International Civil Aviation Organisation (ICAO) initiated the Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation (CAPSCA) programme. Through bringing together relevant organisations on the international, regional, national and local fronts; a coordinated combined national aviation pandemic preparedness plans for individual states or regions (CAPSCA, 2012) can be established. Spearheaded by the Civil Aviation Authority of Singapore (CAAS) for the Asia-Pacific region in 2006, the CAPSCA has since expanded to the other four ICAO regions with regular interactions within and between.

1.2. Modelling simulations

Previous pandemics had seen indiscriminate reduction of flights worldwide through both direct and indirect government interventions (Marcelino and Kaiser, 2009, 2012). These had severe economic impact to the airlines, airports and the countries involved (Epstein et al., 2007). Advanced computers modelling had simulated sophisticated patterns of pandemic spreading via the modern airline transportation network between airports worldwide (Bobashev et al., 2008; Brownstein et al., 2006; Colizza et al., 2006; Hufnagel et al., 2004; Nicolaides et al., 2012). The simulated models allow authorities to better prepare against pandemics; nonetheless, actual preventive measures must be implemented to achieve pandemic control. However, the global epidemiological surveillance system between public health authorities, healthcare providers, and airport authorities remains a challenge for efficient monitoring and control (Briand et al., 2011).

1.3. Practical experiences

Over the course of the last decade, airport authorities around the world in Australia (Eastwood et al., 2010), Canada (Johanis, 2007), Japan (Fujita et al., 2011) and Singapore (Wilder-Smith et al., 2003) have gained valuable experiences that are crucial to the formulation of effective and organised pandemic responses. These have been used as benchmarks for the development of future pandemic controls at airports.

1.4. Better but not the best

While progress has certainly been made in the last decade, academics are still unconvinced of the readiness and preparedness of the aviation industry in times of pandemics (Lim, 2006; Iglesias and Irwansjah, 2012). Nevertheless, large-scale prevention programmes are underway; in particular, the CAPSCA programme appears most promising (Bates, 2011).

Many studies have been conducted on the role of airports in the spreading of pandemics and the lessons learnt from airport authorities worldwide. These studies focused quantitatively on the effectiveness of disease surveillance at airports while disruptions to operations were only analysed qualitatively. Moreover, existing measures mainly revolve around mass flight cancellations and exhaustive passengers screening without harnessing technological advancement. Efficiency of these control measures, while ensuring flawless execution of the overall pandemic control plan, has not been associated with the economic impact on the airports.

1.5. Quantitative analysis and streamlined approach

The focus here is to evaluate the effectiveness and efficiency of known pandemic control measures in airport; and propose an improved streamlined approach that serves the interest from the perspective of both public health and airport business.

2. Material and methods

2.1. Research model and survey population

The current research is based on existing data collated between 2002 and 2010 from 12 selected airports worldwide. Data from some of the busiest international airport hubs were analysed. From Asia-Pacific region, Hong Kong International Airport (ICAO: VHHH), Singapore Changi Airport (ICAO: WSSS), Tokyo Haneda Airport (ICAO: RJTT), Beijing Capital International Airport (ICAO: ZBAA), and Incheon International Airport (ICAO: RKSI) were selected. From European region, three were selected; London Heathrow Airport (ICAO: EGLL), Paris Charles de Gaulle Airport (ICAO: LFPG), and Frankfurt am Main Airport (ICAO: EDDF). Those from the American region include Chicago International Airport (ICAO: KORD), Los Angeles International Airport (ICAO: KLAX), Miami International Airport (ICAO: KMIA), and New York John F. Kennedy International Airport (ICAO: KJFK).

Special focus was accorded to Hong Kong International Airport (HKIA) and Singapore Changi Airport (SCA) for their uniqueness as important international aviation hubs; while being the only commercial airport in their respective administrative region/country. More detailed data were obtained from the two airports and these were analysed in conjunction with the pandemic control measures adopted by each government.

2.2. Sources of data

Annual passenger traffic from the Airport Council International (ACI) records were collated for the airports stated above. Monthly passenger traffic volume for HKIA and SCA were obtained from Airport Authority of Hong Kong and Civil Aviation Authority of Singapore respectively.

2.3. Assumptions and limitations

While conventional economic figures were not used to determine the business performances of the airports, passenger traffic volume was a good indicator to assess airport operations and reflected the impact of pandemic control on airport economic performance.

Passenger traffic volume is assumed to be directly proportional to the financial performance of the airports. In addition, the amplitude of the seasonal variations was assumed to be relatively constant across the 9 years period between 2002 and 2010.

The annual statistical collection involves airport performance over each surveyed year. Besides the impact of disease outbreak, airport business performances are also affected by other external factors that are excluded in the current study. The sensitivity of linear regression models to outliers may also affect the overall accuracy of the study.

2.4. Data treatment

To obtain useful information from the ACI data, annual records during the three incident years, 2003 (SARS), 2006 (Avian Influenza), and 2009 (Swine Flu) were used as the respective baselines. Thereafter, data from prior years were compared to quantify the

economic impact to airports; 2002, 2005, and 2008. Simple linear regression tests, using Time Series Analysis under the Forecasting module of POM-QM for Windows (Version 4), were carried out to determine if there is significant difference in the business performances in the incident years.

Additive decomposition method was applied to the monthly passenger traffic volume from HKIA and SCA. No seasonal factor rescaling was used and Centred Moving Average was adopted as the basis for smoothing. This provided a better resolution of the irregular variations resulted from pandemic impacts after adjustment for relevant seasonal variations.

3. Results

Passenger traffic volume combined the total number of passengers arriving, departing and direct transit passengers (counted once). Data from each airport across 2002–2010 were reflected through simple annual regression analyses from Figs. 1–12.

3.1. Annual data

There was a positive upward trend in passenger traffic volume from all the airports in this study except Chicago International Airport. Being some of the most important airports in their individual regions, these provided an accurate representation of the overall worldwide aviation growth in the last decade. The growth was especially prominent in the Asia Pacific region evident in the growth rate of between 368,000 and 6,000,000 movement per year among HKIA, SCA, Tokyo International Airport, Beijing Capital International Airport, and Incheon International Airport.

Despite the upward trend in passenger traffic growth, there were also two significant dips in passenger traffic volume in 2003 and 2009 for all the airports albeit in varying degree. HKIA was the worst hit, experiencing a –20.0% drop in 2003; whereas Tokyo International Airport saw a decrease of –7.2% in 2009. The only exceptions came in 2003 for Tokyo International Airport and 2009 for Beijing Capital International Airport.

3.2. Monthly data

To analyse the economic effect of particular pandemic measures, detailed breakdown of the monthly passenger traffic volume from HKIA and SCA. These were summarised in Table 1 and cross-referenced with the associated significant events pertaining to pandemic control for each month.

Consistent with the annual regression analysis shown in Figs. 1 and 2, the monthly passenger traffic volume also showed a general upward trend for both HKIA and SCA. However, significant variations for HKIA and SCA were observed for the following three 3-month periods.

March to May 2003. Variations were –77.6% and –57.0% during which control measures were implemented against SARS.

May to July 2006. Variations were +16.0% and +9.04% during the period when control measures were adopted against Avian Influenza.

March to May 2009. Variations were –7.88% and –4.12% during this period when airports were guarding against Swine Flu.

To verify that the variations were adjusted for seasonal factors, additive decomposition method was applied to the monthly data from the two airports. Corrected for seasonal adjustment, Figs. 13 and 14 demonstrated a more accurate representation of the impact of pandemic control measures across the three focus periods.

4. Discussion

Annual passenger traffic volume data showed three distinct outcomes in the years 2003, 2006, and 2009. In particular, results from the three significant periods selected from HKIA and SCA demonstrated the efficiency of the respective pandemic control measures implemented during each incident.

4.1. 2003 SARS

SARS epidemic in 2003 caught the world off-guard as states were unprepared for a pandemic threat of such scale. Almost all the airports showed significant decrease in passenger traffic in 2003 with the highest percentage plummet of –20% seen in HKIA. Being the other epidemic centre, the drastic –14.9% passenger traffic decrease in SCA was also significant as both countries were listed on the WHO and Centre for Disease Control and Prevention (CDC) travel advisory.

Uncertainties from both health authorities and airport authorities were evident through their delayed response in deploying control measures. WHO and CDC travel advisory was only issued three weeks after the index case was admitted to a Hong Kong hospital (refer to Table 1). It required another two weeks before formalised control measures were sequentially implemented at HKIA and SCA. The lapse inevitably resulted in localised epidemic outbreak in the two countries that almost escalated into a global pandemic.

It took two weeks for temperature screening to be implemented as a form of control measure to identify potential infected passengers. Initially, ear thermometers were used but the sheer volume of passengers required more efficient equipment. Forehead infra-red thermometers and subsequently the thermo-imaging cameras were deployed to efficiently scan large volume of passenger traffic. Febrile passengers were isolated for further examinations by on-site medical officers.

The three months between March to May 2003, after the implementation of the control measures, recorded a –77.6% and –57.0% drop in passenger traffic for HKIA and SCA respectively. The SARS epidemic also saw Tokyo International Airport severely affected, recording the lowest passenger number in history during the month of May 2003 (KNI, 2003). The unusually positive annual performance for Tokyo International Airport in the year 2003 was likely attributed to a more than proportional rebound in the later part of 2003 after the recovery from the SARS epidemic.

Overall, the SARS epidemic heavily impacted airport business. It also exposed the unpreparedness in airports and countries towards pandemic control in the highly-connected aviation age. Nevertheless, the epidemic established a benchmark for the aviation industry and airport authorities in terms of pandemic control measures standards.

4.2. 2006 Avian influenza

There was a common upbeat theme in 2006 with majority of airports recording positive performances in passenger traffic volume. This was an unexpected result as WHO issued strong warning messages against grim pictures of the H5N1 outbreak in mid-2006 (WHO, 2006). Anticipating peak human infections rate by end-2006, epidemiologists also concluded that the wild birds transmission to avian and other mammals had rendered all containment measures futile (IISD, 2006).

Control measures implemented during the outbreak largely mirrored those deployed during the SARS epidemic period with large-scale temperature screening using thermo-imaging cameras. There appeared to be no adverse effect on passenger traffic volume

Table 1
HKIA & SCA monthly performance 2002–2010.

Year	Month	Passenger traffic volume (1000)		Remarks
		HKIA	SCA	
2002	January	2522	2133	
	February	2712	2092	
	March	2938	2362	
	April	2923	2214	
	May	2808	2269	
	June	2681	2327	
	July	3032	2328	
	August	3194	2349	
	September	2751	2202	
	October	3011	2256	
	November	2753	2234	
	December	2988	2609	
2003	January	2835	2326	22 Feb first SARS hospitalisation in Hong Kong 15 Mar WHO and CDC travel advisory ^a ; 29 Mar arrival and departure declaration at HKIA ^b ; 31 Mar SCA arrival screening ^c 4 Apr SCA nurses visual screening ^d ; 7 Apr health declaration forms compulsory in SCA ^e ; 11 Apr SCA ear thermometers ^f ; 17 Apr departing passengers in HKIA temperature check ^g ; 18 Apr SCA thermal scanners ^h ; 24 Apr 100% temperature check in HKIA ⁱ ; 30 Apr 100% check in SCA using thermal scanners ^j . 31 May Singapore removed from WHO's list of affected area. 14 Jun health declaration form at departure in HKIA ^k ; 23 Jun Hong Kong removed from WHO's list of affected area.
	February	2705	2127	
	March	2517	2116	
	April	908	1071	
	May	564	909	
	June	1147	1414	
	July	2470	1979	
	August	3018	2117	
	September	2647	2104	
	October	2864	2158	
	November	2757	2264	
	December	3001	2557	
2004	January	3050	2365	
	February	2414	2050	
	March	2823	2230	
	April	3094	2236	
	May	2823	2245	
	June	3090	2460	
	July	3437	2510	
	August	3506	2432	
	September	3042	2281	
	October	3350	2408	
	November	3165	2581	
	December	3347	2807	
2005	January	3027	2377	
	February	3103	2183	
	March	3316	2489	
	April	3327	2427	
	May	3313	2477	
	June	3301	2674	
	July	3789	2742	
	August	3755	2625	
	September	3301	2500	
	October	3565	2605	
	November	3360	2671	
	December	3582	2950	
2006	January	3502	2676	30 May WHO published the <i>WHO pandemic influenza draft protocol for rapid response and containment</i> . 30 Jun WHO predicted upsurge in human death from H5N1 in late 2006 or early 2007.
	February	3272	2414	
	March	3533	2708	
	April	3796	2718	
	May	3545	2656	
	June	3640	2845	
	July	4112	2896	
	August	4085	2810	
	September	3525	2622	
	October	3857	2839	
	November	3667	2905	
	December	3909	3281	
2007	January	3521	2800	
	February	3629	2599	
	March	3829	2937	
	April	4036	2843	

(continued on next page)

Table 1 (continued)

Year	Month	Passenger traffic volume (1000)		Remarks
		HKIA	SCA	
2008	May	3812	2817	
	June	3895	3009	
	July	4391	3023	
	August	4422	2985	
	September	3824	2779	
	October	4123	2962	
	November	4034	3075	
	December	4268	3392	
	January	3991	2987	
	February	3890	2826	
	March	4240	3141	
	April	4055	2936	
	May	4126	3018	
	June	4088	3097	
	July	4450	3100	
	August	4186	3024	
2009	September	3643	2769	
	October	4062	3025	
	November	3813	2978	
	December	4041	3385	
	January	4003	2964	
	February	3354	2477	
	March	3907	2816	18 Mar first outbreak in Mexico City.
	April	4221	2827	24 Apr US reported cases of human infection of H1N1; 26 Apr HKIA stepped-up traveller detection; 30 Apr Health declaration started at HKIA.
	May	3599	2700	1 May first case of H1N1 in Hong Kong; 3 May thermal scanning deployed in SCA; 7 May; WHO stated containment not feasible ^l ; 27 May first case of H1N1 identified in Singapore ^m
	June	3316	2964	11 Jun WHO declared H1N1 as pandemic & raised worldwide pandemic alert level to the highest Phase 6
	July	4026	3066	8 Jul total of 1217 cases in Singapore; 20 Jul first and only H1N1-related death in Singapore.
	August	4303	3063	
	September	3522	2967	
	October	3909	3222	
	November	3833	3288	
	December	4175	3734	27 Sep total of 26,548 cases in Hong Kong.
2010	January	3934	3279	
	February	3922	3023	
	March	4147	3365	
	April	4150	3202	
	May	4113	3302	
	June	4183	3525	
	July	4729	3562	
	August	4697	3367	
	September	4115	3295	
	October	4360	3483	
	November	4134	3543	
	December	4440	3977	

Note. Passenger traffic volume obtained from Airport Authority of Hong Kong, 2013 and Civil Aviation Authority of Singapore, 2013; sequence of events obtained from press releases issued by WHO, Ministry of Health Singapore and Department of Health Hong Kong.

^a 15 Mar 02, WHO and CDC issued emergency travel advisory to Hong Kong and Singapore.

^b 29 Mar 02, HKIA required all incoming travellers to complete health declaration form before entry and departing passengers to declare history of contact and presence of fever at check-in.

^c 31 Mar 02, SCA screening of passengers inbound from affected areas.

^d 04 Apr 02, SCA employed nurses for visual screening at aerobridges.

^e 07 Apr 02, SCA implemented Health Declaration Cards for all arrival passengers.

^f 11 Apr 02, SCA used ear thermometers for temperature checks.

^g 17 Apr 02, departing passengers at HKIA to have temperature check during check-in.

^h 18 Apr 02, SCA deployed thermal scanners at aerobridges.

ⁱ 24 Apr 02, HKIA required all passengers (including transit) to have temperature checks.

^j 30 Apr 02, SCA required all passengers (including transit) and staff to have temperature checks.

^k 14 Jun 02, all departing passengers at HKIA are required to complete health declaration forms.

^l 07 May 09, WHO stated that containment was not feasible and not recommending travel restriction.

^m 27 May 09, first case of H1N1 was confirmed from a Singaporean returned from New York on 26 May but not picked-up by thermal scanner upon arrival due to the absence of febrile symptoms.

in airports worldwide; even in the face of continuous reports of massive birds culling throughout the year estimated to be around 200 million domestic birds out of a world population of 10 billion (FAO, 2013). Three-monthly passenger traffic data between May to July 2006 from HKIA and SCA even showed an increase of +16.0%

and +9.04% respectively. These increments in HKIA and SCA were likely due to seasonal fluctuation, reflecting the negligible effect of WHO's warning in mid-2006 even though most human infection cases were reported in South East Asia and East Asia (Li et al., 2008).

Despite the reportedly high mortality rate of 64% killing 47 of 73

infected people in the first half of 2006 (Gale, 2006), H5N1 retained low transmissibility between humans (CDC, 2008). This could be a contributory factor to the low impact on worldwide passenger traffic volume in 2006. Additionally, the lessons from 2003 SARS epidemic were still fresh in the minds of aviation operators. Control measures were recommended to be implemented by the ACI (2006) early in the year. The advanced warning and pre-emptive preparations very likely provided a level of assurance to citizens and travellers during the outbreak.

Retrospectively, it may be easy to conclude that control measures deployed in airports during 2006 were unnecessary with H5N1's low human-to-human transmissibility. Nevertheless, the counter argument was also valid as the population would be completely vulnerable if a slight mutation in H5N1 significantly increases its transmissibility between humans. Collectively, the Avian Influenza outbreak did little to affect passenger traffic volume in 2006 through low inter-human transmissibility and increased vigilance in airports worldwide.

4.3. 2009 Swine flu H1N1

The swine flu H1N1 pandemic in 2009 was significant because it was the first pandemic in over 40 years since the last Hong Kong flu pandemic in 1968–69. While no restriction on travel was recommended by WHO, the level 6 pandemic alert – the highest level – was issued (Chan, 2009). This brought down passenger traffic volume in 2009 in all but one of the 12 airports reviewed.

This move by WHO was received with mixed reactions as the general public was unable to comprehend the rationale behind the seemingly contradicting actions. While it was a fact that the H1N1 virus was spreading globally out-of-control and any travel restriction would be futile to stop its spread; an escalation of pandemic alert level brought uncertainties to the world.

There were no significant changes in terms of control measures compared to 2003 and 2006 as temperature screening remained the *modus operandi* in all airports. However, there were slight modifications as pre-disembarkation screenings were employed in several airports (Mackey, 2009; Reynolds, 2009).

Despite a negative impact on airport business globally, the extent of average decrease was significantly less than that in 2003 SARS epidemic; most airports reported a decrease of about –1% to –5%, with Tokyo International Airport affected most severely by –7.2%. HKIA and SCA recorded –4.8% and –1.3% deterioration in annual passenger traffic respectively. When focussing on the 3-monthly post-implementation period between March to May 2009, there was only a small drop in passenger traffic of –7.88% and –4.12% in HKIA and SCA respectively.

The better than expected performance could be attributed to the knowledge and experience shared between airports, in particular, through the CAPSCA programme initiated by the Civil Aviation Authority of Singapore (CAAS) in 2006 (CAPSCA, 2012). Valuable lessons learnt from 2003 SARS epidemic and 2006 Avian Influenza outbreak were applicable in the response to H1N1. These were evident in the positive business performance from HKIA and SCA, which kick-started organised pandemic control responses within one week of reported human infection in the U.S. (refer to Table 1).

SCA appeared to have fared better during the 2009 pandemic in terms of airport economics. Multi-agency exercise such as SPARROWHAWK II (MOH, 2006) conducted by the SCA and other relevant authorities seemed to pay dividends as SCA only suffered a –1.3% 3-monthly, and –4.12% yearly deterioration; compared to HKIA's –4.8% 3-monthly, and –7.88% yearly record.

It would be premature to be complacent with the positive performance from 2006. H1N1 pandemic revealed the incompetency of the existing control measures which remained largely

unchanged since 2003. Temperature measurement, which served well in identifying potential SARS virus carriers, was found to be ineffective in H1N1 screening control.

Research found that more than half of the H1N1 infected patients did not exhibit febrile symptoms at the beginning of infection (Jeong et al., 2010). Recent studies also discovered that most infected patients took medications during the onset of mild infection which masked febrile symptoms for the first couple of days (Nishiura and Kamiya, 2011).

The varying effectiveness in thermal screening between SARS and H1N1 lies in the difference in the pathogen lifecycle. SARS has a much shorter incubation period as patients quickly developed high fever and became contagious; while H1N1 has a longer incubation period with milder symptoms that were often mistaken as common flu at the on-set. This was mainly attributed to the fact that SARS was caused by a novel virus as compared to the evolved H1N1 influenza virus that was molecularly recognised by the humoral immune system, activating various pyrogenic pathways that manifests as a fever.

Beijing Capital International Airport was the only airport where passenger traffic volume appeared to be unaffected by H1N1. In fact, it recorded a +16.9% yearly increment in passenger traffic in 2009. The unique performance could be attributed to three factors.

The surge of passengers in late-2008 to early-2009 after the addition of a third runway and the opening of Terminal 3 at Beijing Capital International Airport could have significantly affected passenger traffic volume. The extra runway and the operationalisation of the second largest terminal in the world relieved some airport saturations in late-2008 which saw passenger volume in pre-2008 almost plateauing out. Hosting the Olympic had greatly enhanced the Beijing's image in the world stage. The post-Olympic phenomenon of tourist surge witnessed in every host cities in the last century (Xin, 2008) could also have influenced the passenger traffic volume in 2009. With the Beijing Olympic in August 2008, approximately five months before the beginning of the swine flu pandemic; the spike in tourism in early 2009 could have overshadowed the impact of H1N1 in late-2009.

Interestingly, the Chinese implemented the pre-disembarkation temperature screening in 2009 (Mackey, 2009; Reynolds, 2009). This stringent control measure deployed by the Chinese authority could have contributed to the positive passenger traffic volume. Nevertheless, with only annual passenger traffic data available, no substantial conclusion could be made of the efficiency on the control measures employed by Beijing Capital International Airport.

Overall, Swine Flu H1N1 caused a significant impact to business in airports worldwide. While concerted pandemic control measures appeared to have delivered screening protection while minimising disruptions to airport business; it was apparent that the measures require further refinement both in terms of effectiveness and efficiency.

5. Recommendations

Similar pandemic control measures used in 2003, 2006, and 2009 demonstrated different levels of efficiency. Consequently, business performance of the airports varied drastically as a result of the control measures employed. As such, the hypothesis that the efficiency of the airport pandemic control plan has no significant effect on the negative economic impact on the airport during a pandemic is rejected. The more efficient the airport pandemic control plan, the less severe the economic impact on the airport during a pandemic.

Figs. 13 and 14 provide apt summary of the impact of the three pandemic to airport business – catastrophic in 2003; insignificant in 2006; while things were under control in 2009. These results

also reflected the performance of pandemic control measures implemented; 2003 was unprepared; 2006 was fortunate; while 2009 revealed potential shortcomings.

It was undeniable that the aviation industry was not prepared in 2003. Ever since then, lessons learnt have been shared among airports and thermal-scanning cameras gradually became the industrial standard for containment screening. While 2006 saw a pretty low transmissible avian influenza H5N1 that did not sufficiently test the overall system, it was not as fortunate in 2009 where the swine flu H1N1 exposed the short-comings. Although thermal screening was useful (Cowling et al., 2010a), there were weaknesses in the overall process which allowed asymptomatic carriers to slip through detections in Singapore (Mukherjee et al., 2010), Japan (Nishiura and Kamiya, 2011) and New Zealand (Priest et al., 2010) during the 2009 pandemic.

5.1. Proposed changes

Since 2006, CAPSCA has overseen much progress in the readiness of pandemic responses within the aviation industry. Organisations were united and efforts combined to develop a coordinated approach in preparation against pandemics (CAPSCA, 2012). International airport organisations also tried to institute recommended practices (ACRP, 2013), guidelines (ACI, 2009) and share good practices (ACI, 2012) within the industry to enhance global preparation. Nevertheless, more improvements are still necessary. Even the most comprehensive streamlined approach till date proposed by Gaber (2011), which has been adopted by many airports, is still short of being both effective and efficient. It is paramount to airport authorities to reconcile public health concerns with airport business considerations.

5.1.1. Fundamental changes to screening

Airborne pathogens infecting the respiratory system should remain the centre of focus as these are the most communicable contagion. Characteristically, respiratory diseases resulted from these pathogens almost always produce three easily identifiable symptoms, fever, sneezing and coughing. In particular, sneezing and coughing are the pathogens' main mode of human transmissions through aerosolised particles. Therefore, screening of passengers for signs of fever, sneezing and coughing remains the most effective form of detection.

Screening of every passenger, even healthy individuals, would inevitably affect operating efficiency and thus negatively impact airport business. On the other hand, effective detection would require thorough screening of all passengers for more than just a quick thermal screening lasting for several seconds. These seemingly contradicting objectives appear to eliminate any chance of a most effective, yet most efficient, measure to be implemented by airport authorities. To overcome the apparent contradiction, fundamental changes must be made to the existing screening system for detecting of potential pathogen carriers.

Current practice to screen passengers after disembarkation is inherently inefficient as passengers are delayed in the airport after leaving the aircraft. Simulations have proven the effectiveness of pre-departure screening in pandemic control (Brigantic et al., 2009); as febrile passengers are turned-away before boarding. The method, which was proposed by Gaber (2011), would obviously be more effective; nonetheless, this is also more restrictive and complicated for airlines, airports and passengers alike. Airlines are inclined to make the unpopular decision to disallow all febrile passengers from boarding if pre-departure screenings are to be conducted. This could be the reason why the approach of pre-departure screening did not gain widespread acceptance at airports worldwide; as such, the proposed changes do not

recommend denial of febrile passengers before departure. Screening just prior to boarding also appears to be efficient as passengers would have to spend that time awaiting boarding in any case.

Instead of a single screening at the arrival airport, multiple screenings across a period of time would significantly reduce the rate of missed detections – increasing overall screening sensitivity. Current screening sensitivity rate fluctuates greatly between 50.8% and 70.4% (Nishiura and Kamiya, 2011; Priest et al., 2010), demonstrating the unreliability of a single screening process. Multiple screenings would, therefore, be able to compensate for the low sensitivity of thermal scanning through repeated sampling. In addition, multiple screenings at regular interval would be more effective at detecting asymptomatic carriers that could have fever symptoms suppressed by medication (Nishiura and Kamiya, 2011). Infected passengers would also be more likely to develop symptoms during the entire duration of the flight as compared to just after disembarkation (Brigantic et al., 2009).

The recommendation for pre-departure and multiple screenings would definitely increase the existing workload on airport screening. Changes have to be supplemented with technology to achieve maximum effectiveness and efficiency. Tablet-based system has advanced rapidly in the last decade. Increasingly, CrewTablet is evolving to be the default equipment for cabin crew in terms of manifest handling as well as other transactions processing (SITA, 2012). CrewTablet is the backbone of this proposal which would be further elaborated.

Prototype portable on-board screening systems have been successfully invented to capture both normal and infra-red images (Sun et al., 2011). Combining both still images and thermal images from each individual, individual passenger profiles can be created and processed in the CrewTablet for easy tracking. Importantly, these devices would be simple to handle and capture images instantaneously like ordinary cameras. Alternatively, new RFID (Radio Frequency Identification) sensing tags that were successfully implemented in several hospitals can be adapted for usage on selected passengers. These tags continuously monitor the bearers' temperature non-invasively and wirelessly upload the data to a central system (IHIS, 2013).

5.1.2. Real-time consultation

Distant online medical consultation has become a reality in many places worldwide, real-time consultations between passengers and medical doctors can alleviate the responsibility from non-medically qualified cabin crew to identify suspected case of communicable disease on board. Based on observable symptoms and verbal interactions, doctors can determine the likelihood of potential infection carriers. Furthermore, medical officers can be better prepared for the necessary procedures upon the passengers' arrivals.

Commercially available rapid diagnostic kits can also be used to conduct preliminary checks on the suspected carriers within 15 min (CDC, 2013a). If requested by the medical doctor, these tests can be conducted in-flight by the cabin crew through several simple steps. The results can provide a quick point of care diagnosis that influences the medical doctors' decision-making. The concept of this process is not to identify the exact strain of pathogen responsible; but rather, to determine if the passenger is carrying the common prevalent strain, which would pose significantly less danger. Any negative or ambiguous cases should warrant attention from the ground medical team.

5.2. A proposed streamlined approach

Combining the proposed changes discussed earlier, a

streamlined approach considering the various aspects from check-in to post-flight is elaborated here. This approach attempts to reconcile public health concerns with airport business considerations through maximising screening effectiveness while ensuring efficiency for airport business.

5.2.1. ITT

Central to the entire approach is the In-flight Temperature Tracking (ITT) system that would be installed on the CrewTablet. Individual profiles of each passenger would be created only during check-in as these would be linked to the electronic manifest of each flight.

5.2.2. Check-in

At automatic check-in kiosks or manual check-in counters, each passenger would have his/her temporary profile created in the ITT. The first still image and thermal image would be captured with portable scanner to create the first record. Although no passengers should be refused boarding, passengers would be informed of their febrile status and provided the option to reschedule their flights. They would also be recommended to don face masks for public hygiene considerations and required to bear the small RFID sensing tags that wirelessly upload their temperature data onto the ITT system. Although commonly-used surgical face mask has not been proven to prevent infections, research has demonstrated its effectiveness in abating the spread of aerosol pathogens by infected personnel (Cowling et al., 2010b).

5.2.3. Pre-boarding

A second screening would be conducted at the boarding gate prior to embarkation. CrewTablet would have been uploaded with the latest manifest and the associated ITT profiles of each passenger. Data from the second scan would be automatically updated onto the CrewTablet's ITT system through facial recognition processing. Similarly, any passengers that exhibit fever, sneezing or coughing symptoms would be persuaded to wear face masks and carry the RFID sensing tags.

5.2.4. In-flight

Periodic screening would be conducted by the cabin crew with passengers seated in their assigned seats. The non-intrusive nature of the portable scanner allows resting passengers to remain undisturbed even when cabin crew conduct the screenings. Frequency of the periodic screenings is recommended to be at least two-hourly to achieve maximum effectiveness. This would ensure high screening specificity to identify asymptomatic or medically-suppressed passengers throughout the duration of the flight. Attached with the RFID sensing tags, passengers exhibiting fever symptoms pre-departure would have their temperature automatically updated in the ITT system throughout the flight. This in-depth monitoring of specific passengers – while effortless for cabin crew – provides important data on individuals with high clinical suspicion. The ITT system would be synchronised automatically with all the data and alert cabin crew towards passengers requiring special attentions based on pre-determined criteria designed by medical professionals.

5.2.5. Real-time consultations on-board

Passengers meeting certain criteria would be automatically flagged by the ITT system. They would be required to undergo real-time consultations with duty medical officers from the arriving airport through video conferencing. This can be conducted through the CrewTablet or via the personal Inflight Entertainment System. Passengers' ITT profiles would be electronically delivered to the medical officers for reference upon

request. Direct communications between medical doctors and passengers allow the former to determine if further medical investigations would be required upon arrival. Medical officer would prepare the ground medical team while notifying the airport operation team to arrange for special disembarkation procedures upon landing. To prevent miscommunication of information between the passenger and cabin crew, the medical officers would relay their decisions to the cabin crew via the ITT system upon the completion of the consultation.

5.2.6. Rapid diagnosis on-board

Occasionally, duty medical officers would request for rapid diagnostic tests through oral swabs sampling. Cabin crew are to assist in conducting these rapid tests and relay the result through the ITT system. These tests allow medical officers to determine if the infected passengers are infected by the prevalent strains of viruses versus an uncommon strain which could possibly be the novel (pandemic) strain. Different diagnostic kits should be utilised during various phases of epidemic outbreak, the rationale of which is beyond the scope of this study.

5.2.7. Pre-landing

Duty medical officers would decide on the labelling of passengers in accordance to their risk in transmitting certain diseases. Similar to the proposal by Gaber (2011) which adapted the practice from HKIA, passengers are to be triaged into Red, Orange, Yellow, or Green. Medical officers would assign code Red on passengers if it was deemed necessary after consultations and rapid diagnostic tests; this would be updated via the ITT system. The ITT system would automatically colour-code passengers seated in the vicinity of a Red patient in accordance to physical distance as recorded in the electronic manifest.

5.2.8. Disembarkation

Upon landing, Red-coded passengers would be instructed to disembark first to allow for efficient isolation. Ground medical team activated in advance by the duty medical officer would be on stand-by at the aircraft gate to escort Red-coded passengers. They would be separated from other airport users for additional medical screening at designated areas of the airport. Other on-board passengers would then be allowed to disembark normally regardless of their colour code. The colour coding information, embedded in the ITT profiles, would be electronically transferred to the arrival airport central system together with the manifest data.

5.2.9. Post-flight

These data, together with immigration records, would be crucial for the airport and health authorities to conduct contact tracking if required in the future. Data on the CrewTablet would be securely erased after the transfer and stored data at airports would also be deleted after two months.

5.3. Benefits and potential problems

The scenario described depicts a situation where infected patients are deemed as highly contagious. This proposed approach provides a robust system in which pathogen carriers can be effectively detected, identified and isolated before entering the arrival airports. Healthy passengers are not delayed, allowing airport operations to be conducted efficiently. In addition, capacities are created for ground medical teams to focus on cases with high clinical suspicion; thus, further enhancing effectiveness and efficiency of the overall pandemic control plan.

Nonetheless, the approach is not without its potential problems;

and the main argument revolves about shifting responsibilities from airports to airlines. In addition, free rider effects may benefit non-participating arrival airports if without 100% global cooperation from airports worldwide; dissuading airports from implementing the approach. As such, both top-down and bottom-up approaches are required to ensure success. Through cooperation between key stakeholders and standardisation by administrative authorities, this can be resolved as the overall benefits associated with the successful implementation far out-weigh the potential problems.

Equipped with the highly-automated ITT system, demands on cabin crew is reasonably low as no specific training is required. Cabin crew simply have to capture images of passengers at fixed intervals and follow on-screen prompts. Occasionally, cabin crew may be requested to conduct rapid diagnostic tests but these are quick and simple kits designed for the general public. The most important responsibility for the cabin crew is to hand-over Red-coded passengers to the ground medical team.

Besides convincing airlines of the benefits behind this approach, rulings have to be enforced by ICAO and FAA for airlines compliance. Non-cooperative airlines would be subjected to higher landing fees as these flights would require special parking gates where extended checks on all passengers are necessary. The cost savings from airports should also be transferred to cooperative airlines through landing fee subsidisation.

Implementation of the proposed approach would see significant reduction in administrative demands on arrival airports. Combined with the effectiveness of the approach, these are attractive incentives for airports to reciprocate the effort in ensuring pre-departure screening. ICAO and FAA should also exert pressures on the diplomatic front, demanding airport authorities to fulfil their corporate social responsibilities. Airport authorities must realise that pathogens know no boundaries and they are in the best position to prevent local outbreaks from developing into global pandemics.

6. Conclusions

It is important for airport authorities to recognise the importance of a pandemic control approach that is both effective and efficient. Without effective control measures, economic growth would be fragile as airports' reputation and confidence could be eroded overnight in times of pandemic crisis. Conversely, inefficient control measures would incur unnecessary costs to the airports, hampering economic growth.

This study has demonstrated the impact of pandemic control measures' efficiency on airport business. It has also provided a viable proposal to reconcile public health with airport business through the implementation of an effective yet efficient approach in pandemic control. This approach, however, cannot achieve the intended results without collaborations of airline operators. With co-operations from airlines, airports and the travelling public, the resultant business benefits would accrue to both airlines and airports as well as the general population in the long run.

The aviation industry cannot hesitate in adopting the proposed approach for the following reasons. Scientists estimated at least 320,000 more unknown zoonotic viruses circulating in mammals (Anthony et al., 2013). Harboured in animal reservoir hosts, these viruses can potentially infect human beings and cause the next major pandemic. While public health experts are working on the pathological aspect of identifying these viruses, it is a race against time before viruses manage to cross transmits between animal and human vectors.

Recurring every 10–50 years throughout recorded human history (WHO, 2005) – before the prevalence of air travel – the next

pandemics can strike anytime. Without effective restrictions at airports, the gantries to every countries, increased popularity in air travel is going to exponentially increase the frequency of global pandemics (Epstein et al., 2007). Influenza expert has even concluded that there is no longer any predictability in periodicity or pattern of influenza epidemics (Kilbourne, 2006). Historical records of influenza support a prevailing view that influenza pandemics occur as frequently as once every 10–11 years (Dowdle, 2006; Taubenberger and Morens, 2009). The recent H7N9 outbreak in 2013 was a timely reminder of the unpredictability and danger of the influenza virus.

Despite the advancement in medical knowledge, the next pandemic is inevitably around the corner. The constant arm-race between virus and human means that the next influenza pandemic is a certainty with the only queries being a matter of when and how virulent the pandemic would turn out to be. Effective airport pandemic controls, though, can drastically limit the number of infections.

Simulations predict that air travel will radically change disease propagation pattern. Diseases would no longer spread from a single source in a regional epidemic-like manner; but create multiple nodes in several locations and spread world-wide in a pandemic manner (Hufnagel et al., 2004; Nicolaides et al., 2012). This means that without effective containment systems, previously localised outbreak of diseases would rapidly spread worldwide via the aviation network resulting in global pandemic.

Scientists have predicted geographical hotspots in Asia and Middle-East where novel influenza viruses are likely to evolve; these regions include the northern plains of India, coastal and central province of China, and the Nile Delta in Egypt (Fuller et al., 2013). These are places which have seen tremendous aviation growth over the last decade. There would be dire consequences if new viruses are allowed to spread through the new-found connectivity to the rest of the world.

NextGen development has been at the centre of aviation focus in the last couple of years. FAA and many leading industrial figures have great vision of the advancement in the next generation of aviation. Despite revolutionary progress in Air Traffic Control (ATC) systems and satellite-based navigation systems, greatly enhancing flight safety and efficiency; insufficient progress is seen from systems or managing approach towards pandemic control. It would be disappointing if future passengers would enjoy safer and faster flight in the air but are endangered and delayed by ineffective and inefficient disease screening checks at the arrival airports.

Airport authorities, therefore, remain as the last line of defence between controllable local outbreak and catastrophic global pandemic. Effective and efficient airport control measure would be the difference between 1000 local fatalities against 10,000,000 worldwide mortalities. It is, therefore, a heavy corporate social responsibility that the aviation industry could take on.

Although this study has primarily focused on influenza viruses, there is a need to move beyond that. Coronavirus, a sub-type of which was culpable for SARS, is also a dangerous airborne contagion. Another sub-type of coronavirus, the Middle East Respiratory Syndrome (MERS) coronavirus, was the source of the latest pandemic threat in early-2013. First identified in Saudi Arabia, it has since spread to seven countries; to as far as the United Kingdom, infected 130 and killed 58 (CDC, 2013b). The ongoing Ebola Virus Disease (EVD) epidemic in West Africa has also received significant attentions by the aviation community as the WHO formally designated it as a public health emergency of international concern in Aug 2014 (WHO, 2014).

While the pathogens for airborne diseases are vastly different, the symptom of fever, a sign of infection, is common. Nevertheless,

earlier discussions had revealed problems associated with thermal screening as containment measure. Viruses have also long been found to be capable in inhibiting fever in infected hosts (Alcami and Smith, 1996). Therefore, detection mechanism should extend beyond merely temperature screening. Cough detectors (Marks, 2009), cough analysers (Abeyratne et al., 2013) and breath test analysis (Phillips et al., 2010; Xu et al., 2012) are potential areas for further technical research. Future studies should also focus on

technological improvement on more accurate, expeditious and portable analysing equipment to execute effective pandemic control measures with efficiency.

Appendix

Fig. 1–12. Regression analysis of passenger traffic volume 2002–2010; Hong Kong International Airport, Singapore Changi Airport, Tokyo International Airport, Beijing Capital International Airport, Incheon International Airport, London Heathrow Airport, Paris Charles de Gaulle Airport, Frankfurt am Main Airport, Chicago International Airport, Los Angeles International Airport, Miami International Airport and John F. Kennedy International Airport.

Fig. 13. Additive decomposition model of monthly passenger traffic volume Jan 2002–Dec 2010, Hong Kong International Airport.

Fig. 14. Additive decomposition model of monthly passenger traffic volume Jan 2002–Dec 2010, Singapore Changi Airport.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jairtraman.2015.02.003>.

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