Assessing the economic impact of the closure of Ninoy Aquino International Airport caused by XiamenAir Flight 8667: A Dynamic Inoperability Input-Output Approach

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Abstract: Aviation incidents, especially when occurred within the vicinity of an airport, can cause, at least, its partial closure. This puts a strain not only on the aviation sector but to other sectors as well. Several incidents outside of the Philippines estimate the impact of airport closures through airlines' lost revenue, compensation or welfare costs. However, these does not include forward linkages and to the country's economy overall. Using a dynamic inoperability input-output model, we estimate the economic impact of the runway closure of Ninoy Aquino International Airport caused by the crash landing of XiamenAir Flight 8867 in 2018 to the Philippine economy. Using this approach, the government can develop improvements in policies that will make fines and penalties commensurate to the opportunity cost that these incidences bring about to the economy.

Keywords: Dynamic inoperability input-output model, runway closure, economic impact

1. INTRODUCTION

Many airport-related incidents that lead to at least its partial shutdown are caused by adverse weather conditions or aircraft accidents within the airport, obstructing other aircraft to perform their normal functions. In these kinds of situations, passengers are stranded either in the airplane or the airport terminal waiting for the status of their own flights, costing their time and money in the process. While some member states of the International Civil Aviation Organization have implemented the Warsaw Convention in 1933, which regulates airlines' liability on persons, luggage, or goods performed by aircraft for compensation, and succeeded by the Montreal Convention in 2003, these do not cover those who are indirectly affected by the damages caused by airport-related incidents. In response, some countries have placed additional regulations on airlines regarding compensation and assistance to passengers in the event of delays and cancellations.

The European Union enacted EU Regulation 261/2004, establishing common rules on compensation and assistance to passengers if they are denied boarding or had their flights delayed or cancelled. These regulations apply to passengers, who have confirmed reservations on the flight concerned, departing from an EU member state, and travelling to an EU member state on airline based in an EU member state. Some of its provisions on compensation are based on distance and circumstances, whether it is a delay of a few hours or a cancellation (European Parliament, 2004).

The Philippine government through the Civil Aeronautics Board and the Department of Trade and Industry enacted Joint Administrative Order 1 (titled as the Air Passenger Bill of Rights) in 2012, providing a framework for airlines and passengers in terms of services provided by the former and protection that the latter should get in case of being bumped off, experiencing delays or getting a cancellation of flight. Provisions in the Bill include the right to be informed, to non-misleading advertisements, to board the aircraft, and compensation and amenities in case of cancellation or delay of flight (Department of Transportation and Communications, and Department of Trade and Industry, 2012).

In the United States, however, there is no federal law that mandates compensation or assistance by airlines for delays or cancellations; however, they have their own policies inserted during flight bookings for passengers who may have delayed or cancelled flights (U.S. Department of Transportation, 2018). In case of accidents on US soil by foreign carriers, the Foreign Air Carrier Family Support Act of 1997 mandates these carriers to provide information, services, and support to family members of the passengers; provisions include: a reliable toll-free number, updates on the latest happenings of the victims' remains, and assistance that the family are able to travel and stay near the site of the accident (Elser, 2014).

Even with the distinct policies some of the countries have in terms of compensation and assistance, there are some cases in which individual airlines have paid the price for the flight delays and cancellations, no matter if they are directly or indirectly affected.

This study utilizes a loss estimation technique to assess the economic impact of disruptions to transportation systems. Section 2 gives an overview of air transport incidents with estimated costs and compensation given to the passengers. Section 3 provides a discussion of the model for estimating economic losses due to disruption in critical infrastructure. Section 4 illustrates how such modelling technique is useful for assessing runway closures as in the case of the Philippines. Section 5 provides conclusions and recommendations.

2. PAST EXAMPLES

Historically, aviation disruptions may be caused by natural and man-made disasters among others. Natural causes such as volcanic eruptions and snowstorms that prevent travel through air can indeed cause losses in revenue to the air transportation industry due to cancellations. Man-made disasters in the form of crash landings and runway incursion and excursion can cause runway shutdowns that can also yield similar results. However, man-made causes can be prevented through implementation of strict rules and regulations. This section provides an overview of past events around the world and how the aviation industry has handled the consequences.

United States of America

During Valentines' Day in 2007, the eastern half of North America experienced a severe snowstorm which affected many travel plans, including those who booked American airline JetBlue Airways from New York's John F. Kennedy Airport (JFK). The airline's slow response to the severe storm left at least 1,000 passengers on nine JetBlue planes stuck on JFK's taxiways and tarmac for nearly nine hours, and many more inside its terminal without any notification about the status of their flights. It took hours for JetBlue top management to decide to cancel the flights as a result to the logistical nightmare that they experienced. It took the airline one week to return to normal operations, costing them US$41 million in lost revenue, extra costs, and free travel vouchers to their affected passengers and cancelling 1,200 flights ("JetBlue tries to bounce back from storm of trouble", 2007).

Asiana Airlines Flight 214 on July 6, 2013 caused a five-hour full closure of San Francisco International Airport as the Boeing 777-200ER that took off from Incheon International Airport clipped a seawall on approach and landed short of the runway. The airport gradually opened two out of the four runways, while having to divert flights to airports near the state, such as Los Angeles and Oakland during the closure ("Plane crash at San Francisco airport, 2 dead", 2013). The airline offered US$10,000 per surviving passenger and a greater amount of compensation to each of the three deceased passengers. However, they were fined US$500,000 for violating the provisions of the Foreign Air Carrier Family Support Act of 1997 as the Department of Transportation revealed that it took more than five days for the airline to notify all of the families of the victims, that they also lacked translators and adequately trained crash staff to assist victims. (Nakaso, 2013; "Asiana Airlines fined $500,000 over San Francisco crash", 2014).

United Kingdom (European Union)

London Heathrow Airport experienced heavy snowfall in the days running up to Christmas in 2010; coupled with the lack of adequate facilities and supplies to move and melt the snow to continue operations, this led to the closure of the airport for four days and more than 4,000 cancelled flights over five days. BAA plc, the operator of Heathrow, reported that the closure cost the company £24 million in lost income from take-offs, landings, and other income not only just in Heathrow but also in the other airports that are owned by BAA, such as Edinburgh and Southampton. British Airways, one of the biggest operators in the airport, had an initial assessment of a negative financial impact worth £50 million due to airport closures and reduced capacities in the network that they serve, particularly regional and trans-Atlantic flights (Wilson, 2011; Osborne, 2011; "Heathrow airport triples snow clearance fleet", 2011).

At least two different drone sightings near Gatwick Airport days before Christmas forced the closure of the airport for around 33 hours, affecting an estimated 1,000 flights, either cancelled or diverted, and 140,000 passengers. While the English military installed anti-drone measures at Gatwick to prevent drone incursions during the closure, travelers are trying to know the status of their flights and trips, in which EU Regulation 261/2004 comes into consideration for compensation; however, since the closure of the airport is deemed to be of "extraordinary circumstance" as Gatwick air traffic control declared to suspend flights, passengers are not eligible to get monetary compensation but are eligible to receive food, beverages, means of communication, and hotel accommodation and transport, the latter if they delay is overnight. Some airlines went beyond the minimum regulation and promised that passengers can claim and reimburse for some expenses occurred due to delays and cancellations. In the aftermath of the incident, British low-cost carrier EasyJet announced that the airline lost £15 million in lost revenue and customer welfare costs; a total loss of £50 million was estimated as a total for all airlines and the airport itself. (Morris, 2018; Detrick, 2019; Milligan, 2018).

United Arab Emirates

An Emirates Boeing 777 flying as flight 521 from Thiruvananthapuram, India, on August 3, 2019, attempted to go-around for the second time due to prevailing winds but it all went wrong; crash-landing on the runway of Dubai International Airport, Emirates' main network hub. A 5.5-hour closure and 4-hour network wide delay for Emirates occurred and a loss of US$330 million is estimated not just for the airport, but for the city itself in lost income from tourism, business activities, and the like. Flights were diverted to Sharjah and Maktoum with affected passengers transported to Dubai by bus. Victims of the flight each received US$7,000 compensation plus a full refund of the ticket, in which US$2,000 is for the loss of luggage and personal items, and US$5,000 for any other damages ("Flight EK521: Landing gear issues not confirmed", 2016; Saseendran, 2016; Clarke & Butalia, 2016; Browning, 2016).

Philippines

A Cebu Pacific Airbus A320 flying as flight 971 bound to Davao veered to the right side of Runway 23 as it attempted to land at Davao International Airport on June 2, 2013. The airport was closed for around 48 hours as the airline and the Civil Aviation Authority of the Philippines attempted to move the plane out of the runway. An estimated 3,000 passengers were stranded in Davao and many more in the airports that serve Davao, such as Manila, Cebu, and Zamboanga. Some airlines provided shuttle buses to catch their rerouted flights at General Santos City, food and drinks, and waived rebooking fees. The economic loss resulting from the incident were disputed, one group mentioned the city's economy is losing P5 million a day; while the Davao City Investment Promotion Office placed the losses at P247 million, which includes losses from cancelled bookings, lost revenues, and cargo transactions. Around a month later, Cebu Pacific started to compensate the affected passengers of the flight, the compensation amount is ranged from P100,000 to P1 million ("Jet towed; Davao airport reopens", 2013; Rivera, 2013; "Cebu Pacific compensates flight 5J 971 passengers", 2013).

Various countries manage these disruptions differently. More developed countries have stricter rules and regulations that implement more rigid penalties and fines to airlines to compensate passengers for their troubles. However, passengers are not the only ones suffering from welfare losses. Other businesses also suffer spillover effects through lost transactions resulting from passengers not being able to travel. It is necessary for governments to include these spillover effects when implementing sanctions.

3. METHODOLOGY

Input-output analysis is a framework that illustrates the economy as a system of linear equations to capture the interdependencies among various industries in an economy (Leontief, 1936). Its capability to account for inter-industry linkages has made it a useful tool for estimating the ripple effects that cascade through the economy as a result of an external shock. Extensions of the model have been developed to account for dynamic impacts (Leontief, 1970), environmental impacts (Henrickson et al., 1998), and disaster impacts (Okuyama and Santos, 2014) among others. The basic input-output model is defined as:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{1}$$

where $\mathbf{A}$ is the technical coefficients matrix such that each element a_{ij} represents the proportion of total input requirement of sector j that is from sector i, $\mathbf{x}$ is the total output vector such that each element x_i is the total output produced by sector i, and $\mathbf{y}$ is the final demand vector such that each element y_i is the final demand for sector i's output.

The equation above can be re-written as:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{2}$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse matrix, wherein the column sums yield the direct and indirect impact of initial impact.

The inoperability input-output model is a notable extension used for capturing the inability of a system to perform its intended function (Haimes and Jiang, 2001). The initial model was meant for critical infrastructure systems; hence, it was re-developed for use in economic systems such that:

$$\mathbf{q} = \mathbf{A}^{*}\,\mathbf{q} + \mathbf{c}^{*} \tag{3}$$

which can be re-expressed as:

$$\mathbf{q} = (\mathbf{I} - \mathbf{A}^{*})^{-1}\mathbf{c}^{*} \tag{4}$$

where $\mathbf{q}$ is the inoperability vector such that each element $\mathbf{q}_i$ represents sector i's level of inoperability, $\mathbf{A}^{*}$ is the interdependency matrix which represents the pairwise inoperability between each sector, and $\mathbf{c}^{*}$ is the perturbation vector that represents the initial demand reduction due to the external disruption (Santos and Haimes, 2004). It should be noted that the elements in Equation 3 are derived from Equation 1 through normalization with the output vector **x**. Inoperability is a dimensionless measure of a sector's failure to operate such that its values are between 0 and 1, 1 denoting complete failure. To calculate for economic loss, the level of inoperability (*q*) and initial output level of each sector (*x*) can be multiplied, estimating the monetary value of the loss in output level for sector *i*.

$$EL_i = q_i * x_i \tag{5}$$

The dynamic nature of effects and policy strategies led to the development of the dynamic inoperability input-output model [DIIM] (Lian and Haimes, 2006). The model is specified as:

$$\mathbf{q(t{+}1)} = \mathbf{q(t)} + \mathbf{K}[\mathbf{A}^{*}\mathbf{q(t)} + \mathbf{c}^{*}\mathbf{(t)} - \mathbf{q(t)}] \tag{6}$$

where **K** is the industry resilience matrix that denotes the recovery process of each sector, and *t* is the time indicator. The monetary value of the economic loss for each time period can be calculated such that,

$$EL_i(t) = q_i * x_i \tag{7}$$

taking the sum across all time periods, *T*, will yield the total economic loss to sector *i* due to the initial perturbation.

The assumptions of the DIIM are similar to the static version and the original input-output model of Leontief. These include constant technical coefficients (meaning prices and production is constant), total supply must equal total demand, and the Leontief technical coefficient entries are substitutes for industry interdependency data. For the IIM and the dynamic version, the estimates that are derived from certain scenarios and perturbations and the original interdependencies of a country's economy are based on the input-output tables from their respective statistics office for normal economic conditions (Crowther & Haimes, 2005; Kujawski, 2006).

4. CASE STUDY

Last August 16, 2018, a XiamenAir Boeing 737-800 flying as flight 8667 attempted to land the aircraft for the second time at Ninoy Aquino International Airport amidst heavy rains and low visibility after missing the runway during its first attempt to land at the airport. The aircraft failed to land properly as the aircraft veered off runway 24 and settled in the grassy patches beside the runway. Immediately after the incident, rescue and emergency services were alerted to the scene helping affected passengers and crew to escape from the aircraft. This resulted to a 36-hour closure of the airport, affecting hundreds of flights along with tens of thousands of passengers not only in NAIA but from all airports that NAIA serves (Marasigan, 2018).

The Manila International Airport Authority will determine the financial liability of XiamenAir, passenger complaints will be processed through the Civil Aeronautics Board, while sanctions for XiamenAir based on the International Civil Aviation Organization standard will be imposed by the Civil Aviation Administration of China (Arayata, 2018). Furthermore, the PhP 72 million fine imposed on XiamenAir only includes the expenses the Manila International Airport Authority incurred in removing the plane and other expenses that covered the full cost of the whole MIAA operations during the runway closure (Terrazola, 2018); however, this does not include economic losses as MIAA general manager Mr. Ed Monreal claims that they have no capacity in estimating the economic losses due to such incidence and that it is not within the mandate of MIAA (Economic losses not part of P33 million fine vs Xiamen Airlines: MIAA, 2018). Hence, there is a need to quantify the economic losses for regulators to develop stricter policy to prevent the occurrence from happening again.

Numerous studies have been conducted on the crisis management aspect of airport closures. Voltes-Dorta et al. (2017) looks into the reducing passenger delays in the European airline market. However, there are very few that focus on the economic impact of airport closures and disruptions. Prager et al. (2015) assessed the economic impact of reducing wait times in U.S. International Airports. Serrano and Kazda (2018) provided a roadmap for assessing the financial risks of an airport shutdown due to multiple scenarios. Mazzochi et al. (2010) estimated the financial impact of the 2010 Volcanic Ash Cloud to the European Airline Industry. While these studies provide financial estimates, they do not account for the spillover effects to other sectors of the economy. Furthermore, airport closures considered were mostly due to natural hazards.

Using a dynamic inoperability input-output modelling approach, this study is able to quantify the economic losses brought about by the 36-hour runway closure at the Ninoy Aquino International Airport (NAIA). Given that NAIA is the main gateway to the Philippines and serves as host to 92% of all passengers in the country (CAAP, 2018), such closure can have a significant impact on the national economy. This case considers an initial 80% shutdown to the air transportation industry with a 20% recovery after 36 hours and an estimated 7-day full recovery period as a result of the XiamenAir incident. This assumption was made as the main runway 06/24 was closed because it did not meet ICAO safety guidelines for the continued use of the runway even after the incident of XiamenAir 8667; that flights were able to operate again after 36 hours for some parts of the airport, and recovery flights were scheduled for the next days to ferry affected passengers (Marasigan, 2018). The 2012 Philippine Input-Output Table published by the Philippine Statistics Authority (2018) calibrated using 2017 gross domestic product to update the values serves as the basis of our analysis. It is disaggregated into 16-sectors (transportation sector is disaggregated to land, water, air and other transportation) to highlight the sectors that are related to the air transportation industry. Figure 1 presents the inoperability suffered by each sector with the assumption of the initial 80% shutdown of the air transport industry and the eventual ripple effects within the next seven days.

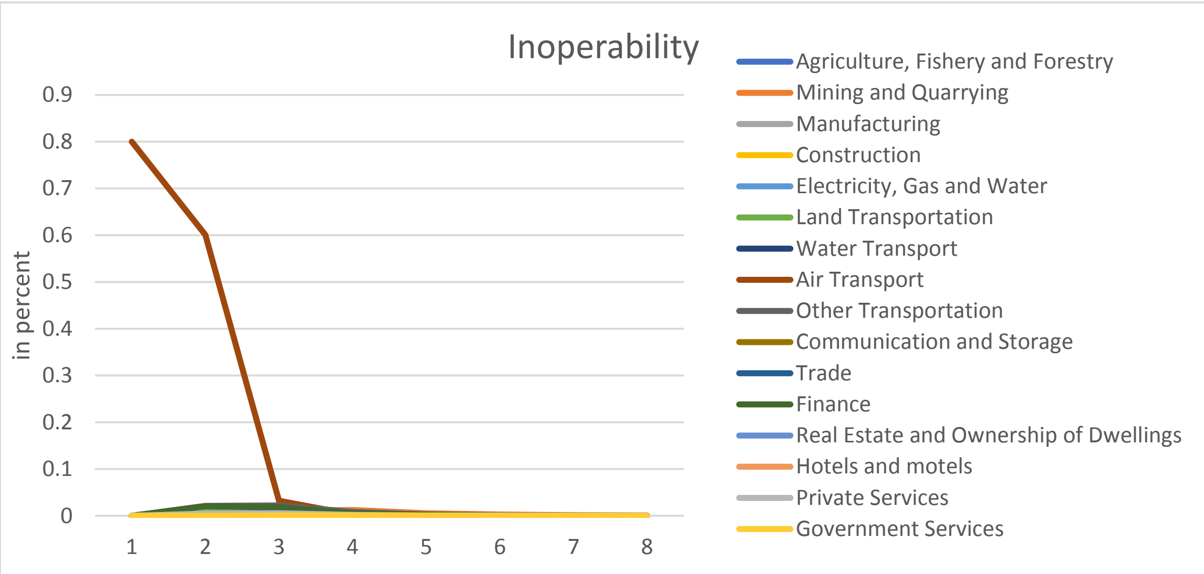

Figure 1. Inoperability for each sector over the 7-day period

The largest inoperability is borne by the air transportation industry as with only around 40% of demand served on the second day, and returns to recover from the 3rd day onwards, since NAIA was only operating flights with smaller aircrafts and including all other airports in the Philippines. Such incidence yields negative impacts to initially unaffected sectors. During the first two days, most affected sectors are the finance, land transportation, and private services sectors. However, as days pass, these sectors experience a gradual recovery to normality while the mining and quarrying sector suffered increased levels of inoperability by the 4th day.

Figure 2 presents the estimated economic loss incurred per sector during the runway closure in Manila. The air transport sector incurred the largest loss at around an estimate of P450 million during the first day, around P300 million during the second day; by recovery time, the sector accumulatively lost P810 million pesos. Other heavily affected sectors include the finance and manufacturing sectors which experienced losses peaking by the second day. Some sectors take longer time to manifest the economic losses such as the trade sector which had their losses peak only by the third day and the private services and mining and quarrying industry only on the fourth day. For the overall economy, losses peaked by the second day with air transport, finance, and private services contributing to most of the economic loss for that day.

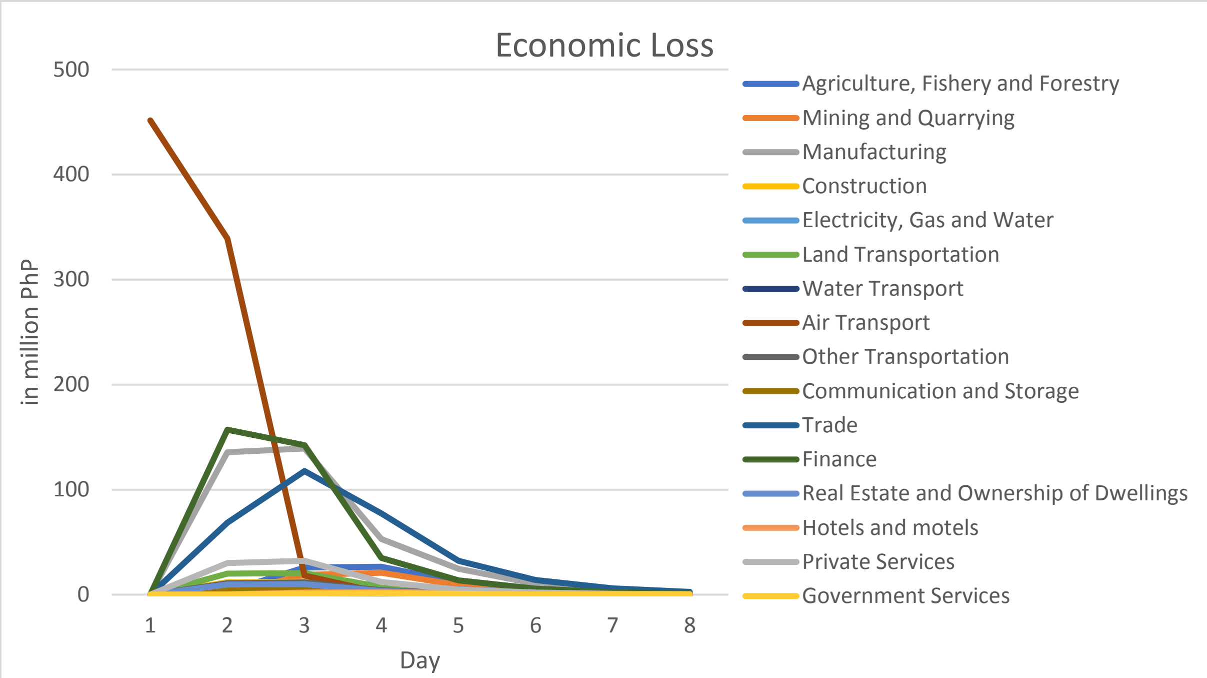

Figure 2. Economic Loss incurred per sector over the 7-day period

Table 1 presents the accumulated economic losses for each of the 16 sectors for the entire seven-day period. While some sectors suffered relatively low levels of inoperability, economic losses can still reach millions. Overall, the country lost an estimated PhP 2.27 billion worth of output resulting from the XiamenAir incident. In addition, other non-monetary costs such as potential loss in employment opportunities for stranded overseas Filipino workers, and discouraged tourists who will no longer visit the Philippines after the poor handling of ground services remain unaccounted for.

Table 1. Economic Losses for each sector

Sector		in million PhP
S01	Agriculture, Fishery and Forestry	76.03
S02	Mining and Quarrying	55.83
S03	Manufacturing	369.95
S04	Construction	32.10
S05	Electricity, Gas and Water	28.75
S06	Land Transportation	52.57
S07	Water Transport	0.83
S08	Air Transport	810.91
S09	Other Transportation	29.37
S10	Communication and Storage	14.77
S11	Trade	319.57
S12	Finance	357.15
S13	Real Estate and Ownership of Dwellings	25.62
S14	Hotels and motels	6.57
S15	Private Services	82.41
S16	Government Services	3.67
Total		2,266.08

5. CONCLUSIONS AND FUTURE RECOMMENDATIONS

This study provides a sound estimation of the economic losses due to the runway closure at the NAIA in August 2018. Using the dynamic inoperability input-output model, the total effect is broken down into each sector, giving policymakers information on which sectors were heavily affected as a result of the incident. Based on reports, XiamenAir was only fined PhP 72 million, while the economic losses amounted to PhP 2.27 billion. Ergo, the amount fined does not even account to 1% of the total losses estimated. This could provide insights on how to formulate sanctions and penalties such incidences. Penalties and fines can be redistributed to actors such as other airlines who needed to provide food to their stranded passengers, stranded passengers who needed to make arrangements to the place they are travelling to among others, hotels and businesses that lost opportunities resulting from cancelled flights. More stringent policies such as stricter reinforcement of the Bill of Passenger Rights will result to more efficient measures in responding both on the side of the airline management and airport authorities. In addition, government should realize that too much dependence on NAIA as the main gateway to the Philippines pose serious risks to the economy. Other airports should be developed in order to serve more night flights and bigger aircrafts to reduce dependence and over congestion at NAIA.

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