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Research Article

Study of air quality and noise levels in King Fahad International airport in Dammam, Saudi Arabia

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ABSTRACT

Background: Air transportation growth has increased continuously over the years. Air quality and health impacts from aviation have been considered focusing mainly on the air pollutants emissions and noise exposure from aircraft landing/take-off, aircraft taxi/ servicing, local car traffic, fuel transportation and storage. This study aimed to assess noise pollution and air quality levels in King Fahad International Airport in Dammam.
Methods: Measurements of noise levels and air quality parameters (Carbon monoxide (CO), Carbon Dioxide CO2, Ozone O3, Nitrogen Dioxide NO2, Sulphur Dioxide SO2, Volatile Organic Compounds VOCs and particulate matter PM10 were measured in taxiway, runway, cars parking area and waiting area using calibrated equipment.
Results: the results of the present study revealed that airport workers are exposed to significant high levels of noise and different air pollutants parameters in different studied areas and airports activities.
Conclusions: The situation in some of this area as taxiway, runway and cars parking calls for a rapid planning strategy for the control of airport. It may also be noted that the result of this study point to the need of further studies at the studied airport and others airports in Kingdom of Saudi Arabia as well.

Keywords: Air quality, Airport, Dammam, Particulate, Noise, Air pollution, Health hazards

INTRODUCTION

Air transportation growth has increased continuously over the years. However, the growth has not been uniform and varies from country to country. The general increase in air transport activity has been accompanied by a rise in the amount of energy used to provide air transportation services. Along with the increase in air transport activity and energy consumption increased environmental impacts are assumed. On the one hand, air quality impacts from aviation have been considered by regulators, airports and aircraft manufacturers, focusing mainly on the emissions from aircraft occurring during the landing and take-off phases.[1]

Air traffic is dramatically increasing and expected to double nationally by the year 2017 and internationally by 2010. Associated airplane emissions are expected to increase accordingly. Aircraft emission depends on engine and fuel type used; however, emissions invariably include compounds, such as CO, CO2, SO_2, and NOx; particles; and a great number of organic compounds.[1]

The growth in commercial aviation has fueled concerns over air quality around airports and the surrounding communities. Aircraft engines and auxiliary power units are the primary sources of emissions at airports.[2]

The pollution sources in airport areas are mainly external, since significant local airport emissions occur such as aircraft landing/take-off, aircraft taxi/ servicing, local car traffic, fuel transportation and storage. During take-off and landing of aircrafts, as well as auxiliary unit operation of aircrafts, significant concentrations of VOCs are emitted, mainly because of the incomplete kerosene burning.[1,2]

Noise is an environmental problem that has adverse effects on the daily life of many people. People become annoyed; sleep is disturbed and adverse health effects are to be feared. Scientists and health experts consider noise levels to be unacceptable. long term exposure to noise levels of about 90 dB (A) may lead to permanent hearing loss while prolonged exposure to noise of 100 dB (A) may cause irreparable damage to the auditory organs. A noise level of about 120 dB (A) is considered painful and may cause instantaneous loss of hearing; while more than 140 dB (A) may produce insanity.[3]

The environmental impact of air pollution is often mainly associated with noise nuisance, smoke and gaseous emissions of carbon monoxide, unburned hydrocarbons, including methane, nitrogen oxides and sulphur oxides.[1]

Airport operations have been shown to contribute to increased PM levels in surrounding communities. PM emissions from aircraft engines have been found to have mean particle diameters less than 100nm; these ultrafine particles can pose a significant risk to human health.[4-6]

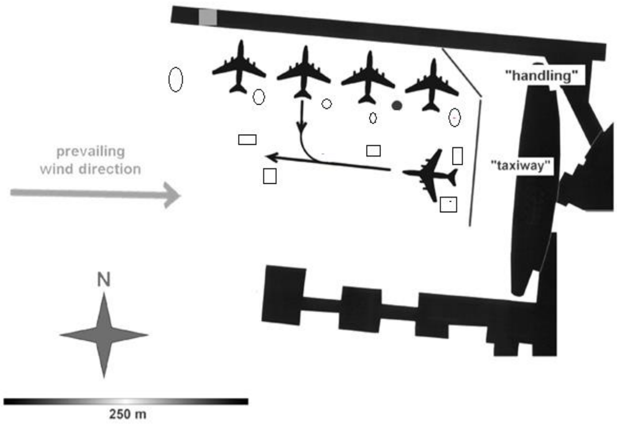
The combustion products of jet fuel include gas phase species such as carbon dioxide (CO_2), water (H2O), carbon monoxide (CO), unburned hydrocarbons (UHC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and soot or black carbon referred to as primary PM. VOC (Volatile Organic Compound) emissions related to aircraft are not only emitted during combustions, but also result from resting losses from aircraft fuel tanks, during the refuelling of an aircraft. Usually, aircraft are refuelled shortly after arrival.[7-9]

This study aimed to assess noise pollution and air quality levels in king Fahad international airport in Dammam and to suggest remedial measures for reducing noises and air pollution or their impacts.

METHODS

Site description

King Fahd International Airport (KFIA) is located 20 kilometers (12 mi) northwest of Dammam, Saudi Arabia, (Figure 1) and is the largest airport in Saudi Arabia, as well as being the largest airport in the world. The General Authority of Civil Aviation of Saudi Arabia finally opened the new Dammam King Fahd International Airport on November 28, 1999 to commercial traffic, and all airlines transferred their operations to it .However, the passenger terminal's total area is 327,000 m² (3,519,798 ft²). Approximately 247,500 m² (2,664,067 ft²) were built. Moreover, The airport has two parallel runways with a length of 4,000 m (13,123 ft) each, in addition to taxiways parallel to the runways and a cross taxiway to connect the two runways. A distance of 2,146 m (7,041 ft) separates the two runways to facilitate simultaneous take-off and landing operations (Figure 2).



O Sampling point (Taxiway)
□ Sampling point (Runway)

Figure 1: Sampling Point in Selected Areas in airport.

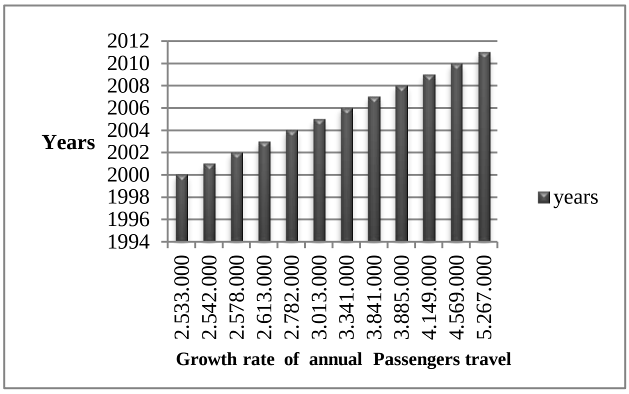


Figure 2: Growth rate of annual passengers travel.

This study was conducted between December 2012 and January 2013.Measurements was conducted on weekday and weekend day respectively. Measurements of noise levels and air quality parameters were measured using calibrated equipment. A study boundary was chosen to be an area forming a radius of 1 km from the center line of the runway. Fifteen positions were selected at the airport representing the working environment where different areas were selected as Taxi way, run way, waiting gate area and car parking areas at king Fahad international airport in Dammam. These settlements are located about 150 and 200 m away from the runway, respectively.

Instrumentation suite

Portable instrumentation IAQRAE were used for monitoring VOCs, CO and CO_2 concentrations .The IAQRAE system provides also measurements of temperature and relative humidity, as one hour mean values. Automated Horiba analysers measuring NO_2, O_3, and SO_2.[10,11]

Noise levels were measured using an integrating sound level meter, type 2225, with microphone type 4129, manufactured by BruÈ el & Kjaer.[12]

Statistical analysis

Data were analysed using SPSS program version 19. Descriptive statistics, independent t test and ANOVA techniques were used for measuring statistical significance of the studied parameters.

RESULTS

Table 1 shows the descriptive statistics of noise and air pollutions parameters in different studied areas where the mean levels of carbon monoxide (CO) were 0.27±0.45 in taxiway, 0.27±0.45 in runway, 0.1±0.13 in waiting areas and 0.73±0.45 in cars parking respectively. All levels of CO are within Saudi air quality guideline of 35 ppm.

Table 1: Descriptive statistics for studied air quality and noise parameters.

Locations	Air quality and noise parameters							
	CO ppm	CO_2 ppm	VOC ppm	NO_2 ppm	SO_2 ppm	O_3 ppm	Noise dB(A)	PM_{10}ug/m^3
Taxiway	0.27±0.45	635±15	0.2±0.13	0.12±0.05	0.29±0.19	0.14±0.12	96.1±3.70	1256±178
Runway	0.27±0.45	505±11	0.26±0.14	0.15±0.1	0.14±.14	0.04±0.03	97.1±11.4	1247±363
Waiting area	0.1±0.13	824±46	0.38±0.39	0.2±0.10	0.1±0.12	0.01±0.00	65.7±3.50	341±9.8
cars parking	0.73±0.45	630±10	1.2±0.72	1.7±0.42	0.13±0.02	0.84±0.25	74.6±4.22	650±111

Table 2: ANOVA comparison between mean levels of air pollutants and noise in studied four locations.

	P-Value							
	CO	CO_2	VOC	NO_2	SO_2	O_3	Noise	PM_{10}
Taxiway Runway	1.00	0.002**	0.70	0.70	0.001**	0.51	0.03*	0.90
Waiting area	0.07*	0.003**	0.25	0.13	0.001**	0.01*	0.002**	0.003**
Cars parking	0.002**	0.90	0.004**	0.00**	0.001**	0.002*	0.002**	0.001**
Runway Taxiway	1.00	0.002**	0.70	0.70	0.001**	0.05	0.67	0.92
Waiting area	0.07*	0.004**	0.43	0.06	0.003**	0.49	0.002**	0.003**
Cars parking	0.002**	0.004**	0.002**	0.001**	0.89	0.03**	0.001**	0.001**
Waiting area Taxiway	0.07*	0.001**	0.25	0.13	0.003**	0.01*	0.002**	0.001**
Runway	0.07*	0.001*	0.43	0.06	0.003**	0.49	0.001**	0.002**
Cars parking	0.001**	0.001**	0.004**	0.002**	0.004**	0.002**	0.001**	0.003**
Cars parking Taxiway	0.002**	0.90	0.001**	0.001**	0.001**	0.001**	0.001**	0.001**
Runway	0.002**	0.004**	0.003**	0.001**	0.89	0.001**	0.001**	0.003**
Waiting area	0.001**	0.001**	0.001**	0.002**	0.004**	0.002**	0.001**	0.001**

*P<0.05; **P<0.01

However, carbon dioxide (CO_2) was 635±154 in taxiway, 505±118 in runway, 824±46 in waiting area, 630±102 in care parking respectively. All levels of CO_2 are within Saudi air quality guideline and of 1500ppm. However, volatile organic compounds (VOC) were 0.2±0.13 in taxiway, 0.26±0.14 in runway, 0.38±0.39 in waiting area and 1.2±0.72 in care parking respectively. All level of VOCs is within Saudi air quality guideline of 0.5 ppm except in cars parking (1.2±0.72) which exceeds the Saudi air quality guideline.

Moreover, nitrogen dioxides (NO_2) were 0.12±0.05 in taxiway, 0.15±0.1 in runway, 0.2±0.10 in waiting area and 0.13±0.02 in car parking respectively. All level of NO_2 is within Saudi air quality guideline and of 0.5 ppm. Except in car parking (1.7±0.42) is exceed the Saudi air quality guideline.

Concerning sulfur dioxide (SO_2) were 0.29±0.19 in taxiway, 0.14±0.14 in runway, 0.1±0.12 in waiting area and 0.13±0.02 in car parking respectively. All level of SO_2 is within Saudi air quality guideline and of 0.169 ppm. Except in taxiway (0.29±0.19) is exceed the Saudi air quality guideline of 0.169 ppm.

Regarding ozone (O_3) levels were 0.14±0.12 in taxiway, 0.04±0.03 in runway, 0.01±0.00 in waiting area and 0.84±0.25 in car parking respectively. All level of O_3 is within Saudi air quality guideline and of 0.075 ppm. Except for taxiway and cars parking due to high traffic air pollution and the total levels is exceed the Saudi air quality guideline.

However, Noise (dB) were 96.1±3.7 in taxiway, 97.1±11.4 in runway, 65.7±3.5 in waiting area and 74.6±4.25 in car parking respectively. All level of Noise (dB) is within Saudi air quality guideline and of 85 (dB). Except in taxiway (96.1±3.7) and in runway (97.1±11.4) is exceed the Saudi air quality guideline of 85 dB. Finally particulate matters (PM10) were 1256±178 in taxiway, 1247±363 in runway, 341±9.8 in waiting area and 650±111 in car parking respectively. All level of $PM_{10}ug/m^3$ exceeds Saudi air quality guideline and of $315ug/m^3$ and these might due to working in open areas in airport and different in meteorological factors in airports studied areas.

DISCUSSION

Urban environment is characterized by two environmental pressures, air and noise pollution. Air pollution is considered as one of the most significant urban environmental health stressors. In most cities road traffic airport operations are the most important source of local air pollution which can cause adverse effects on health and the environment. In parallel to air pollution, excessive exposure to environmental noise during daytime is associated with annoyance and reduced quality of life (headache, dizziness and fatigue) or direct hearing loss and/or hearing impairment.[12]

All aircraft, including ground service equipment (GSE) and auxiliary power units (APU) at airports, release one or more of the following pollutants into the atmosphere: carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate matter (PM), and other hazardous pollutants.[13]

Our results have shown that the levels of noise in the electro production industry plants under study exceeds both TLW-TWA (8-h shift), and action level as they are defined by the Saudi and international legislation.

Occupational exposure to noise is one of the most significant health risks for workers being able to determine irreversible hearing damages. Exposure for a long time to high noise levels, greater than 80 dB (A), may lead to a permanent increase in the Noise Induced Permanent Threshold Shift. The risk of noise-induced hearing loss involves the ramp's operators who perform various tasks in the airport. Following the placement of the aircraft in the apron, "turn around" phase begins and consists of operations to support the aircraft.[14]

In this peculiar environment operators perform their tasks in the presence of noise from many sound sources, equipment normally using to carry out specific activities but also aeronautic noise, and follow precise security procedures. It is therefore necessary to identify the characteristics of places and the types of work activities, operators, equipment and other sound sources present, typical working days.[14]

The measured concentrations of CO, NO_2, and VOCs characterize specific air quality levels at ground support locations of airports. In the present study the low level of CO concentration with aircraft movements in taxiway and runway reflect low emission of co from aircraft engines. However, similar study has been found The high correlation of CO concentration with aircraft movements is related to the typical emission characteristics of a jet engine. For idle power, jet engines emit high amounts of CO, due to incomplete combustion, for amounts of NOx, due to low temperature. Only little correlation with aircraft movements. High NO concentrations observed during cars parking activities and traffic pollutions.[15]

Recent studies indicate that as the wind speed increases from any direction, the concentration of NO_x decreases. This pattern of decrease is what would be expected from a ground level source where the concentration takes the form of a function that is inversely proportional to the wind speed (Table 4).[16]

High levels of tested parameters might due to aircraft: engine emissions during taxiing and in the air, during testing on the ground; an aircraft's auxiliary power unit (on-board generator) whilst being prepared for flight. However high levels of NO_2, CO_2 and VOC may result from local road traffic: non-airport related vehicles (70-90%) and airport related vehicles (10-30%).

In the present study ,TVOCs and CO2 concentrations were kept at "low" levels during almost the whole measurements period; based on the limit value suggested by the scientific community for the outdoor TVOCs (300 $\mu g/m^3$) and the limit set by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) for the indoor CO_2 (1,000 mg/m3).[17,18]

Both VOCs and NOx are precursors of ground-level ozone, which can interfere with lung function and aggravate diseases such as asthma, chronic bronchitis, and emphysema. High levels of SOx or PM can also irritate the respiratory system, contribute to respiratory illness, and aggravate asthma and existing heart and lung disease.[15]

Aircraft NO_X emissions are broken down further into a number of 'activities'. Take-off roll is the biggest emissions source (46%); though taxiing and use of auxiliary power units (APUs) are almost as large when considered together. In the present study the PM10 concentrations were measured in all airport locations in runway and taxiway, these might due to high air pollution in the heaviest polluted areas in airport.[18]

Table 2 and Figures 3, 4 shows that there is highly significant differences between taxiway and run way concerning CO_2, SO_2 and noise where, there is no significant differences in the levels of CO, VOCs, NO_2, O_3 and PM_{10}. However there are high significant differences between taxiway and waiting area CO, CO_2,

SO_2, O_3, Noise and PM_{10}, where there are no significant differences in the level of VOC and NO_2. There are highly significant between taxiway and care parking.

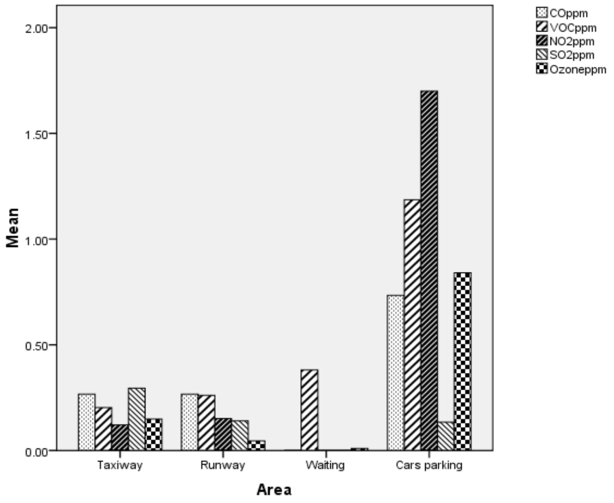


Figure 3: Mean levels of different air pollutants in different areas of airport.

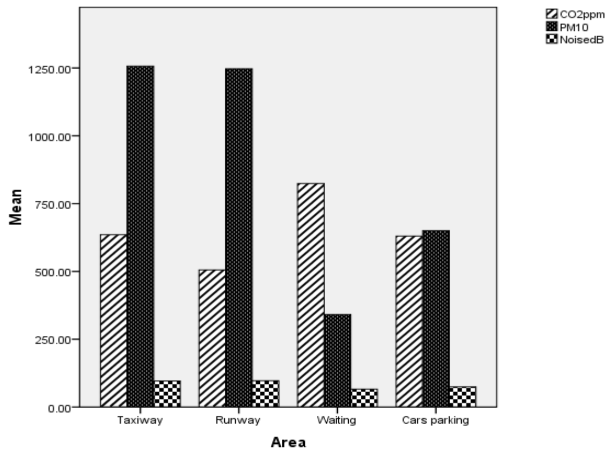


Figure 4: Mean levels of different air pollutants in different areas of airport.

Regarding, CO, NO_2, SO_2, VOC, O_3, Noise and PM_{10}. Where there are no significant in the level of CO_2. However there are highly significant differences between runway and waiting area CO, CO_2, SO_2, Noise and PM_{10}, where there are no significant in level of VOC, NO_2 and O_3. There are significant between runway and care parking regarding for CO, CO_2, NO_2, O_3, Noise and PM_{10}, where there are no significant in the level of SO_2.

VOCs at airports are released by aircraft exhaust, traffic exhaust, or fuel handling. VOC signatures could be clearly identified. Aircraft exhaust is largely dominated by high volatile and reactive C2–C3 alkenes. Also ethane can be found, a compound closely related to any VOC exhaust emission, including ground-based traffic. Numerous pollutants are emitted from fuel combustion and other airport activities.[16]

The most important of these are oxides of nitrogen, hydrocarbons (also referred to by the broader term volatile organic compounds (VOCs) which include carbon in combination with elements other than hydrogen) and carbon monoxide.[8,9]

The risk of Noise-induced hearing loss (NIHL) is felt to be low at exposures below 85 dB (8-hour time-weighted average) but increases significantly as exposures rise above this level. Continuous noise exposure throughout the workday and over years is more damaging than interrupted exposure to noise.[19-21]

Concerning week days, data of the present study revealed that all measured air pollutants and noise levels are highly significant in weekend days than week days and theses might due to increasing total passengers and number of travels national and internationals and increasing in traffic activities in taxiway and cars parking areas. Table 3 and Figures 5, 6. The data of the present study are similar to recent study that found there is increase rate of air pollution parallel to increase flow and rate of traffic activities.[22,23]

Table 3: Comparison between mean levels of air pollutants and noise in weekend and normal days.

Parameter	Week days	Weekend days	P-value
CO	0.33±0.48	0.36±0.46	0.0287
CO_2	682±143	637±163	0.034
VOC	0.27±0.24	0.58±0.63	0.07
NO_2	0.34±0.48	0.74±0.80	0.038
SO_2	0.20±0.20	0.520.13	0.011
O_3	0.27±0.32	0.250.38	0.048
Noise (dB)	86.42±14.91	92.36±15.24	0.013
PM_{10}	982±429	837±450	0.012

*P<0.05; **P<0.01.

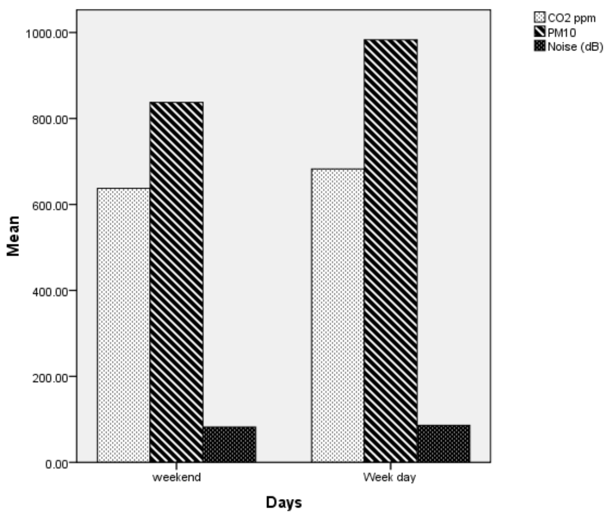


Figure 5: Mean levels of different air pollutants in week days of airport activities.

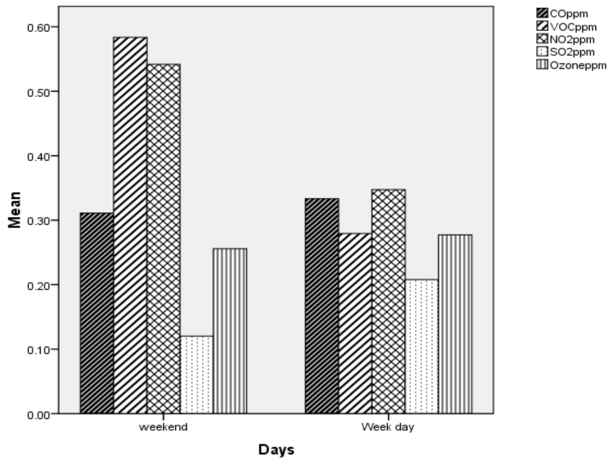


Figure 6: Mean Levels of different air pollutants in week days of airport activities.

Table 4 shows the average of different metrological parameters that affect many of measured air pollutants as PM_{10}. NO_2, SO_2 and Ozone levels respectively.

Table 4: Meteorological parameters in airport.

	Mean	SD	Min	Maxi	Range
Wind speed km/h	02.94	2.24	00.00	08.10	08.10
Temperature ºC	22.11	2.00	17.30	25.80	08.50
Relative humidity %	63.91	4.81	54.90	75.10	20.20

CONCLUSION

The measured concentrations of CO2, NO_2, SO2 ,O3 and VOCs characterize specific air quality levels at ground support locations of airports. In this study, high significant association between levels of measured air pollutants and measuring sites and airport activities (higher number of daily flights) especially taxiway and cars parking where the air quality levels exceeds Saudi air quality levels. Continuous monitoring of air quality parameters in the studied airport and others airports in Kingdom of Saudi Arabia (KSA) are required periodically.

It may be concluded that airport noise pollution can present health and social problems to the workers in the airport activities. Levels of noise in most of the studied areas are higher than the acceptable industrial standards. The situation in some of these areas as taxiway, runway and cars parking calls for a rapid planning strategy for the control of airport.

In this study the occupational exposure to airborne particles and other pollutants in a jet engine airport was carried out. In particular, particle size PM_{10}. In conclusion this work emphasizes the high dust exposure impact of the airport under study mainly due to the higher number of daily flights especially weekend days in respect to others airports.

It may also be noted that the result of this study point to the need of further studies at the studied airport and others airports in Kingdom of Saudi Arabia as well.

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