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Study on air pollution trends (2010-2015) due to fireworks during Diwali festival in Delhi, India

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Abstract: The burning of massive amount of fire crackers on the evening(s) of a nation-wide celebrated festival called 'Diwali' in India, gives rise to a remarkably high concentration of criteria air pollutants and it is of utmost importance to investigate the impact of such high loads originated during a relatively shorter time span in a mega-city like Delhi where the situation of ambient air quality has already been alarming almost through-out the year. In view of the same, the present study analyzes available concentration data during this festival's night for five criteria pollutants namely PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO (Particulate Matter, Sulfur Dioxide, Nitrogen Dioxide and Carbon Monoxide respectively) along with NH_3 at six key locations of Delhi. Following the analysis, PM_{10} concentration in Anand Vihar during nighttime of Diwali was reported to be ~8 times higher than the 24 hours values prescribed by National Ambient Air Quality Standards (NAAQS). On the other hand, the same at IGI airport was recorded lowest even though about 3.5 times that of the guiding standard. $PM_{2.5}$ concentrations were reported as highest and lowest at RK Puram and Civil lines respectively, in both the cases quite exceeding the comparable standard values. Interestingly, remaining criteria pollutants, namely, SO_2, NO_2 and CO along with NH_3 measured in 2015 showed no values in excess of corresponding 24-hrs guidelines, thereby reporting a better scenario compared to previous years. Further, the extensive use of firecrackers during Diwali festival leads to substantial increase in air pollutants necessitating special measures to control.

Keywords: Fireworks, Diwali, Aerosols, Criteria pollutants, NAAQS.

1. Introduction

The Indian sub-continent witnesses Diwali as the festival of lights and crackers in October/November every year which is celebrated with inordinate zest. Most widely reflected by firing crackers and enlightened lanterns almost all over the country during festival night(s), the celebration often characterizes itself filled with trace gases and particulates including metals into the atmosphere, giving rise to thick smoke clouds, characteristics and concentration of which are determined by composition of sparklers and crackers (Barman et al., 2009). Having constituents such as potassium nitrate, charcoal, sulphur, potassium and trace elements, the crackers are reported to have significant adverse effect on environment as well as human health (Barman et al., 2009). The effect of firework activities on the air pollutants like particulate matter, its components and trace gases during various festivities has been studied by many researchers and reported worldwide. Kong et al. (2015) studied the impact of firework-burning particles on air quality and human health during the winter season in Nanjing in 2014 and reported that fireworks contributed to about 50% of the $PM_{2.5}$ during the spring festival period. Vecchi et al. (2008) observed that particles number concentrations driven by firecracker's burning increased significantly during the celebration of FIFA world Cup win in 2006 over Italy (up to 6.7 times in 1h for the $0.5<d<1\mu m$ size bin).

Drewnick et al. (2006) studied the chemical composition and chemically resolved size distributions of fine aerosol particles at high time resolution (5 min) during the New Year's 2005 fireworks in Mainz, central Germany and found that main non-refractory components of the firework aerosol were potassium, sulfate, total organics and chloride. Wang et al. (2007) studied the effects of the burning of fireworks on air quality in Beijing from the ambient concentrations of various air pollutants (SO_2, NO_2, $PM_{2.5}$, PM_{10} and chemical components in the particles) during the lantern festival in 2006 reporting measured values

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as five times higher in the lantern days than in the normal days and also that over 90% of the total mineral aerosol and 98% of Pb, 43% of total carbon, 28% of Zn, 8% of NO_3^-, and 3% of SO_4^{2-} in $PM_{2.5}$ were from the emissions of fireworks on the lantern night.

Moreno et al. (2007) investigated aerosol samples collected during Las Fallas in Spain and during the Guy Fawkes celebrations in London, reported that the celebrations added to the pollution spikes in suspended particles, NO, SO_2, and the creation and dispersal of an aerosol cloud enriched in a range of metallic elements.

In India's perspective also, various researches and studies have been conducted in a bid to assess the deterioration in air quality caused by firework activities during Diwali festival and few of them are presented as below.

Khaparde et al. (2012) studied the influence of burning of fireworks on particle size distribution of PM_{10} and associated Barium in Nagpur city, India reporting an increase of 4 to 9 times in PM_{10} levels while an increase in Ba levels by 8 to 20 times higher in alveolar region, when compared with the levels observed before Diwali festival. Chatterjee et al. (2013) studied the diurnal variations in PM_{10} and SO_2 in metropolitan region of Kolkata, and reported that their maximum concentrations were on Diwali night between 8 P.M.–3 A.M., indicating maximum firework activities during this period. PM_{10} and SO_2 concentrations increased by ~5 times compared to those on normal days during this period at this site. Ravindra et al. (2003) investigated the effect of fireworks on air quality from the ambient concentrations of various air pollutants (SO_2, NO_2, PM_{10} and TSP) during Diwali festival in Hisar city, India, in November 1999 and reported that due to extensive use of fireworks during the festival, the concentration of SO_2 was observed to be increased ∼10-fold at few sites, whereas the concentrations of NO_2, PM_{10} and TSP increased 2–3 times, compared to the data collected on a typical winter day in December 1999.

Thakur et al. (2010) reported the pollutant concentrations as recorded during Diwali in Salkia, Kolkata, India, to be several times higher (6.44 times for SPM, 7.16 times for PM_{10}, 5.35 times for $PM_{2.5}$, 1.73 times for SO_2 and 1.27 times for NO_2) compared to a typical winter day value. The particulate concentrations on festival night exceeded its respective 24 hour residential standards by several times (11.6 times for SPM, 22.3 times for PM_{10}, and 34.3 times for $PM_{2.5}$).

Kulshrestha et al. (2004) studied high magnitude of concentration of metals on the day of Diwali festival (compared to background values on previous days) and reported that the concentrations of Ba, K, Al and Sr went up to 1091, 25, 18 and 15 times higher. Barman et al. (2008, 2009) while studying the effect of fireworks on ambient air quality during Diwali Festival in Lucknow City, covering PM_{10}, SO_2, NOx and 10 trace metals, reported 24 hrs. average concentration of these pollutants to be as high as 2.49 and 5.67 times for PM_{10}, 1.95 and 6.59 times for SO_2 and 1.79 and 2.69 for NOx, when compared with the respective concentration of Pre-Diwali and normal day, respectively. Also, on Diwali day, 24 hour values for PM_{10}, SO_2, and NOx were found to be higher than prescribed limits of National Ambient Air Quality Standard (NAAQS), and exceptionally high (7.53 times) for PM_{10}. Ganguly et al. (2009) and Attri et al. (2001) have reported effect of firework activities during Diwali on surface Ozone in Delhi. While former's study found normally observed surface ozone levels higher during Diwali and in excess of NAAQS values by 5.4 - 13.3 ppbv, the later presented the detailed process and source identification of formation of ozone due to cracker burning.

Similar to those on ambient air quality, there has been worldwide studies attempting human health effects of aerosols, trace gases, metals and other constituents of air pollution and are well documented to an extent that adversative health impact of PM_{10} are recognized by all leading health institutions and researchers (WHO, 2003).

Clark (1997) reported that owing to excessive firecracker burning during the Diwali festival in India, cases of respiratory diseases, wheezing, exacerbation of the bronchial asthma and bronchitis patients of all age and gender groups, amid a family's history of asthma or not, have seen rise of 30–40%. Hirai et al. (2000) reported a case wherein inhalation of smoke from fireworks for 3 consecutive nights, led to complaint of cough, fever and dyspnea in patients and ultimately an acute eosinophilic pneumonia (AEP).

Dockery et al. (2005) found statistically significant associations between air pollution and

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ventricular arrhythmias for episodes within 3 days of a previous arrhythmia.

Barnett et al. (2005) studied the strength of the association between outdoor air pollution and hospital admissions in children and reported that the largest association found was a 6.0% increase in asthma admissions (5-14 years) in relation to a 5.1 ppb increase in 24 hour NO_2, inter alia for $PM_{2.5}$ and PM_{10}, nephelometry and SO_2. Barman et al. (2008) reported that fireworks which induce short-lived but relatively substantial emission of trace elements were able to aggravate human health in terms of hematological and neurological effects on the recipients and while Pb, Cd & Ni were reported to give rise to carcinogenic effects, Cr was shown to be associated to neurotoxic problems.

Delhi, being national capital of India, gradually expanding towards neighboring states under the arena of NCR (National Capital Region) has witnessed an ever-seen rapid pace of industrialization and urbanization, high vehicular density plying on insufficient road space, with air quality over this region severely affected resulting in to heavy PM loadings in almost all its districts. The country's capital celebrates Diwali festival with great zeal along with rest of India. Massive quantities of crackers and sparklers both manufactured indigenously and imported from neighboring countries are burnt on almost 3 days, that is, day before (pre-Diwali day), on the festival (Diwali day) and even after (post-Diwali day) improvised by the mythological belief in this festival of lights and sound.

The available secondary data with respect to the measurement of effect of fire-cracker burning on aerosol and its components during Diwali festival in Delhi have been used to analyze the trends of air pollution from 2010 to 2015. Five of the criteria air pollutants namely aerosols (PM_{10} and $PM_{2.5}$), oxides of sulphur and nitrogen, ammonia and carbon monoxide were analyzed for the available data during Diwali night at six locations of the capital state (Figure 1 and 2) and the study attempted to assess the extra load on urban air quality due to Diwali festival over these locations, where air pollution is prevailing as a grave problem through-out the year.

2. Materials and methods:

2.1. Study area and general climatic feature

Delhi, situated between 28°21′17″ to 28°53′,00″ latitude and 76°20′37″ to 77°20′37″ longitude, is at around 160 km away in south from the southern part of Himalayas. The average altitude of Delhi is ~218 meter above mean sea level while is bounded by the Thar-Desert of Rajasthan in the West, plains of central India in the South and Indo-Gangetic Plains (IGP) in the East. The megacity extends over 1,483 km^2 with the present inhabitants of ~18 million. The study areas lie between 28.36° N–28.92° N and 76.82° E–77.41° E (Figure 2). The climate of Delhi is semi-arid and is mainly influenced by its inland position and prevalence of continental air during most of the year. India Meteorological Department (IMD), Delhi configures four distinct seasons, such as, winter (December–March), pre-monsoon or summer (April–June), monsoon (July–September) and post-monsoon (October–November). Summer is extremely hot, with maximum temperatures of 45–48 °C. Dust storms from nearby Thar Desert are influencing the weather of Delhi during summer (April–June). Humidity is high during monsoon, characterized by heavy rainfall (between 600 and 800 mm); while the air is dry during the rest of the year. Winter is moderately cold, with minimum temperatures around 1–4 °C. During winter, conditions of atmospheric stability (low wind speed and temperature inversion) lead to the accumulation of atmospheric pollutants in the lower atmospheric layer, causing morning hour foggy conditions. Winds are predominantly westerly and north-west

Figure 1. Geographical representation of district and sub-district's boundaries of Delhi.

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and north-west during most of the year, except for the monsoon season, when they are easterly and north-easterly. During such conditions, pollutants could not be dispersed or mix with free troposphere.

The six locations/stations for the current study in the mega city of Delhi were selected based on the different land-use patterns features which are presented in Table 1.

Figure 2. Geographical locations of study areas in map of Delhi.

According to the available data from the general and economic census of Delhi, the rapid pace of urbanization and growth of urban population, have led to the continuous decline in rural population and rural areas (from 0.95 million in 1991 to 0.42 million in 2011) with number of villages reduced from 209 in 1991 to 112 in 2011. Further, for the first time since 1951, the decadal growth rate of population of Delhi declined and was recorded at 21.2% in 2011 compared to 47.02% in 2001. However, the swift increase in population has raised density of population from 6352 persons per km^2 in 1991 to 11320 in 2011. District-wise population and enterprise employment status are presented in Table 2.

Delhi is the most prosperous state with highest per capita income in India with average per capita income remaining more than INR (Indian National Rupees) Rupees 0.2 million in two consecutive years i.e., 2013-14 and 2014-15. The gross state domestic product (GSDP) of Delhi at current prices during 2014-15 is INR 451.154 billion, which recorded growth of 15.35% over previous year. Delhi's economy has a predominant service sector with its share of contribution to GSDP at 87.48% during 2014-15 followed by contribution of Industries and Agriculture sectors (DSH, 2015; ESD, 2014-15).

Table 1. Land use pattern of selected locations.

No	Location /Study Area	District	Land-use Pattern
1	Civil Lines	North Delhi	Residential
2	Anand Vihar (ISBT)	East Delhi	Mixed (Passenger circulation - Major Railway and Bus stations / District parks / Residential)
3	Mandir Marg	New Delhi	Proximity of southern and central ridge forest covers
4	RK Puram	South-west Delhi	Residential
5	IGI Airport	South-west Delhi	Mixed (Passenger circulation - Largest International Airport / Commercial districts)
6	Punjabi Bagh	West Delhi	Residential

Table 2. Population and enterprise employment status in different districts of Delhi.

No	District	Geo. Area (km^2)	Popl. (mill.)*	No. of Enterprises and Persons employed**
1	North Delhi	59	0.89	74875/ 31641
2	East Delhi	64	1.71	82329/ 218314
3	New Delhi	35	0.14	38498/ 273212
4	South-west Delhi	421	2.29	41953/ 100001
5	West Delhi	129	2.54	106524/ 305626

* *As per Census 2011;* ** *As per Economic census 2011(Geo.–Geographical;Popl.–Population;Mill Million)*

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2.1 Data collection

Secondary data available for six years (from 2010 to 2015) on Diwali night for five air pollutants for the referred six locations of Delhi were collected from print and electronic media and used for further analysis. These published data can be accessed at http://epaperbeta.timesofindia.com/index.aspx?eid=31808&dt=20151113 which further showed it to have been sourced from the dedicated air quality monitoring stations belonging to various Indian government agencies like 1) DPCC (Delhi Pollution Control Committee; 2) MOES (Ministry of Earth Sciences) and 3) CPCB (Central Pollution Control Board). These stations do record 24 hours. X 365 days concentration data of different air pollutants covering almost the entire megacity of Delhi. This is to be mentioned here that the secondary data available for the years 2010 to 2015 refer to various dates of the Diwali festival i. e., 5th Nov. in 2010; 26th Oct. in 2011; 13th Nov. in 2012; 3rd Nov. in 2013; 23rd Oct. in 2014 and 11th Nov. in 2015 thus generally spanning between 15th Oct. and 15th Nov.

3. Result and discussion

The collected data were analyzed using MS-EXCEL programme and pollutant-specific graphs were plotted. The inferences were drawn in terms of the magnitude of the recorded concentration and compared with the corresponding 24 hrs. and 1 hr. values as prescribed in National Ambient Air Quality Standards (NAAQS). The analysis and results along with pollutant-wise graphs are presented as below:

3.1 PM_{10}

Figure 3 depicts PM_{10} concentration measured during festival night in six locations of Delhi which was recorded maximum at Anand Vihar at 777.8 µg/m^3 followed by other locations in descending order as RK Puram, Punjabi Bagh, Mandir Marg, Civil Lines and IGI Airport. A close look in to the data in view of corresponding 24 hrs. NAAQS value of PM_{10}, reveals that at all locations under investigation, pollutant exceeds the limit of 100 µg/m^3 as per NAAQS. A possible reason of minimum observed concentrations at IGI airport is due to attributable to the fact that this is an area with relatively less population density and restricted public movement whereas all other areas fall in category of highly dense residential areas. The presence of one of the largest inter-state bus terminal (ISBT) and railway terminus in the close proximity, together catering to about 400,000 passengers per day at Anand Vihar location signifies it as a major transport hub thereby contributing to a very high vehicular emission (from terminal buses, railway diesel locomotives and road traffic) leading to the highest value of PM_{10} recorded.

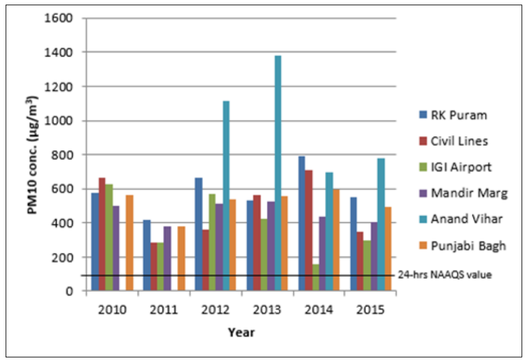

Figure 3. PM_{10} concentration data during Diwali in Delhi (2010:2015) sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB).

It is also noted that a comparison of PM_{10} concentration at all six locations during previous years (2012:2014) reveals that there has been a decrease in it over the years although never below NAAQS values. The graph also presents that Anand Vihar recorded maximum ever concentration of PM_{10} in 2013 as 1378 µg/m^3 during the period 2010 :2015 whereas IGI Airport recorded a minimum ever concentration of 156.1 µg/m^3 in 2014.

3.2 $PM_{2.5}$

Figure 4 presents $PM_{2.5}$ concentration measured during festival night in six locations of Delhi which was reported maximum at RK Puram at 369.1 µg/m^3 followed by other locations in descending order as Punjabi Bagh, Anand Vihar, IGI Airport Mandir Marg and Civil Lines. It is evident that observed values of $PM_{2.5}$ at all six locations exceed the corresponding 24 hours. NAAQS value of this criteria pollutant which is prescribed as 80 µg/m^3 It is also noted that a comparison of $PM_{2.5}$

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concentration at all six locations during previous years (2010–2014) reveals mixed values as different locations exhibit different pattern, for e. g., RK Puram, Mandir Marg and Punjabi Bagh showed some improvement in levels of $PM_{2.5}$ in 2011, Civil Lines in 2013 whereas IGI Airport in 2014 reported lowest ever recorded values. The trend of $PM_{2.5}$ generally follows the trend of population density areas and existence of higher vehicle ownership and/or movement.

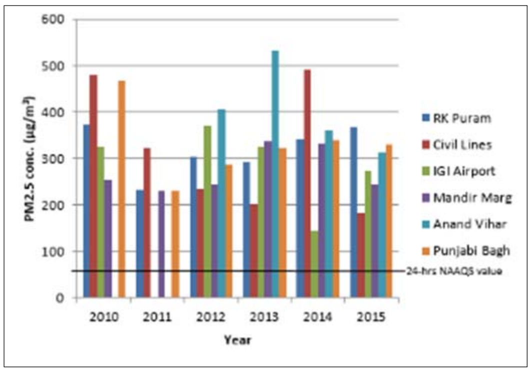

Figure 4. $PM_{2.5}$ concentration data during Diwali in Delhi (2010:2015) sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB).

The $PM_{2.5}$ to PM_{10} ratios for all six locations have been presented in Figure 5 which reveals the significant proportion of the former in the ambient air quality recorded during festival nights from 2010 to 2015 and is found to vary from 0.35 to 0.92 barring only one erroneous data available as 1.11 for Civil Lines location in the year 2011 which might be a typo error. Also, the figures of 0.000 indicate non-availability of data for the particular location / year.

3.3 SO_2

Figure 6 depicts SO_2 concentration measured during festival night in six locations of Delhi which was recorded maximum at Anand Vihar at 64.2 $\mu g/m^3$ followed by other locations in descending order as R K Puram, Punjabi Bagh, Mandir Marg, Civil Lines and IGI Airport.

A close look in to the data in view of corresponding 24 hours. NAAQS value of SO_2 reveals that at none of the six locations under investigation, pollutant exceeds the limit of 80 $\mu g/m^3$. It is also noted that a comparison of SO_2 con-centration at all six locations during previous years (2010–2014) reveals that while for three locations, namely RK Puram, IGI Airport and Mandir Marg there has been a decrease in it over the years although never above NAAQS values, for other three locations, the data brings about that at least once or twice, the observed values do exceed the guideline values. While Anand Vihar recorded maximum ever concentration of SO_2 in 2012 as 117.3 $\mu g/m^3$, Mandir Marg recorded a minimum ever concentration of 8.3 $\mu g/m^3$ in 2014.

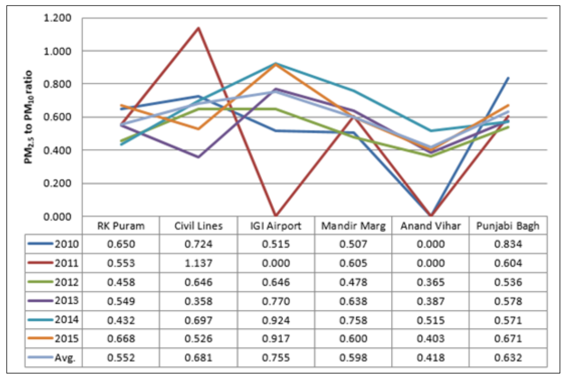

Figure 5. $PM_{2.5}$ to PM_{10} ratios for all six locations during Diwali festival in Delhi (2010:2015).

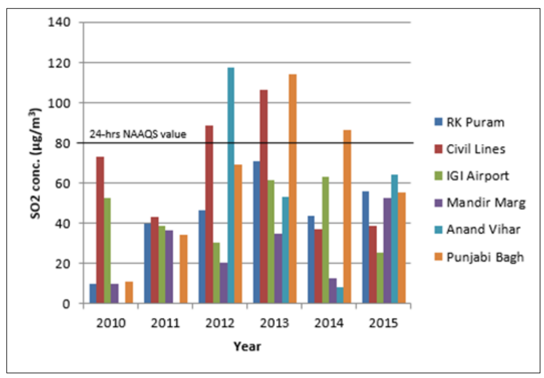

Figure 6. SO_2 concentration data during Diwali in Delhi (2010:2015) – sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB).

The reason of higher SO_2 at Anand Vihar location can be understood from the presence of vehicular emission from ISBT, railway terminus and inter-state traffic whereas for IGI Airport, the low population density and restricted public movement helps. For remaining areas of study, relatively lesser but closer concentrations can be linked to lesser dense residential areas having distributed traffic.

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3.4 NO_2

The NO_2 concentration measured during festival night in six locations of Delhi which was reported maximum at RK Puram at 79 µg/m^3 followed by other locations in descending order as Punjabi Bagh, Anand Vihar, Civil Lines, IGI Airport and Mandir Marg (Figure 7).

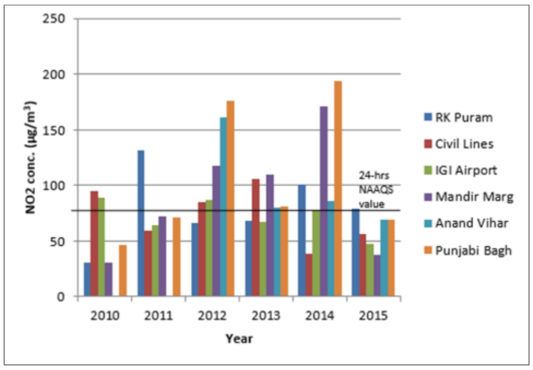

Figure 7. NO_2 concentration data during Diwali in Delhi (2010:2015) sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB).

It is evident that observed values of NO_2 at all six locations in 2015 do not exceed the corresponding 24 hours. NAAQS value of this criteria pollutant which is prescribed as 80 µg/m^3. It is also noted that a comparison of NO_2 concentration at all six locations during previous years (2010–2014) in terms of values in excess of NAAQS reveals that in year 2011, RK Puram recorded maximum NO_2 concentration as 131.7 µg/m^3 whereas Civil Lines saw maximum observed value in year 2013 at 105.6 µg/m^3. Further, IGI Airport recorded maximum value of 89.3 µg/m^3 in the year 2010 and Mandir Marg observed 171.4 µg/m^3 in year 2014. While Punjabi Bagh recorded maximum observed value as 193.8 µg/m^3 in 2014, from the available data between 2012 to 2014, Anand Vihar observed 161.6 µg/m^{3}value in 2012.

3.4 CO

Figure 8 denotes CO concentration measured during festival night in six locations of Delhi which was recorded maximum at Civil Lines at 4 mg/m^3 followed by other locations in descending order as RK Puram, Anand Vihar, Punjabi Bagh, Mandir Marg, and IGI Airport. A close look in to the data in view of corresponding 1 hours. NAAQS value of CO reveals that at none of the six locations under investigation, pollutant exceeds the limit of 4 mg/m^3.

It is also noted that a comparison of CO concentration at all six locations during previous years (2013, 2014) reveals that, in fact, the maximum recorded values never exceed the NAAQS limits for any locations and there has been a gradual decrease in CO values as far as festival night is concerned, while for preceding years (2011 –2012) except two locations, i. e., RK Puram and Mandir Marg where the recorded values show violation of the limits at least once, the other locations have been fairly within the limits. While Civil Lines recorded maximum ever concentration of CO in 2010 as 9.5 mg/m^3, Mandir Marg recorded a minimum ever concentration of 0.6 mg/m^3 in the very same year.

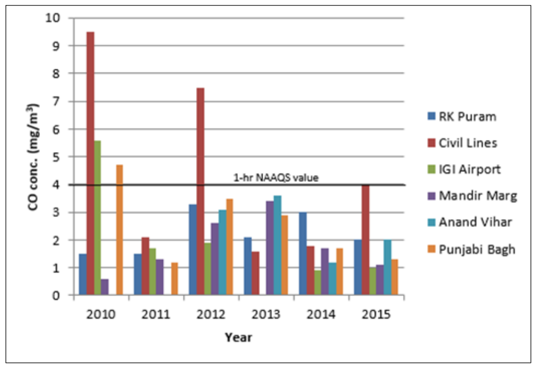

Figure 8. CO concentration data during Diwali in Delhi (2010:2015) – sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB)

The improvement over the years can generally be seen in context of increased public awareness focusing on the harmful human and environmental effects of firecracker activities. This is further induced by campaigning by Government agencies, Non-governmental Organizations (NGOs) and to some extent by the Courts directing local administration to ensure compliance to its previous orders on control over public and off-late firecracker burning during the festival night.

3.5 NH_3

Figure 9 presents NH_3 concentration measured during festival night in six locations of Delhi which was reported maximum at Mandir Marg at 77.4 µg/m^3 followed by other locations in descending order as RK Puram, Anand Vihar, Punjabi Bagh, Civil Lines and IGI Airport.

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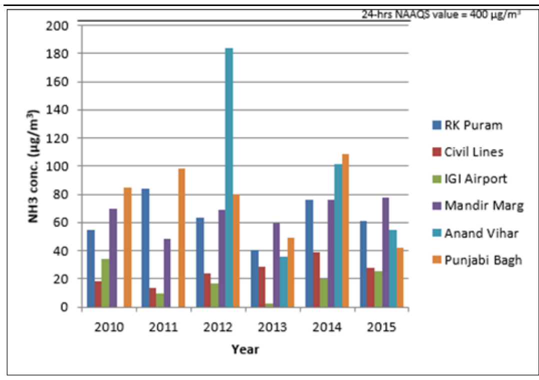

Figure 9. NH_3 concentration data during Diwali in Delhi (2010:2015) – sourced from print media (cross-referred from the monitoring stations of DPCC, MOES and CPCB).

A summary of observed minimum, maximum, average concentrations during the festival night over six years along with % increase vis-à-vis. NAAQS values for minimum observed value is presented in Table 3.

Table 3. Severity of air pollution during Diwali night in Delhi.

No	**Pollu.**	**Observed Conc. (2010-15)**			**% Incr. above AQS (for Min. conc.)**
		Avg.	**Max.**	**Min.**	
1	PM_{10}	549.6	1378.0 (Anand Vihar/ 2013)	156.1 (IGI Airport /2014)	56.1
2	$PM_{2.5}$	318.1	533.1 (Anand Vihar /2013)	144.3 (IGI Airport /2014)	80.4
3	SO_2	50.2	117.3 (Anand Vihar /2012)	8.3 Anand Vihar /2012)	-89.6
4	NO_2	85.9	193.8 (Punjabi Bagh /2014)	30.7 (Mandir Marg, RK Puram /2010)	-61.6
5	CO	2.6	9.5 (Civil Lines /2010)	0.6 (Mandir Marg /2010)	-85.0
6	NH_3	55.3	183.4 (Anand Vihar /2012)	2.7 (IGI Airport /2013)	-99.3

(Pollu.–Pollutant; Conc.–Concentration; Avg.–Average; Max.–Maximum; Min.–Minimum; Incr.–Increase; AQS – Air Quality Standards/NAAQS)

It is evident that observed values of NH_3 at all six locations under investigation in 2015 do not exceed the corresponding 24-hrs. NAAQS value of this air pollutant which is prescribed as 400 µg/m^3. It is also noted that a comparison of NH_3 concentration at all six locations during previous years (2010–2014) in terms of values in excess of NAAQS reveals that in years 2012 and 2014, Anand Vihar recorded maximum NH_3 concentrations as 183.4 and 101.5 µg/m^3 respectively while Punjabi Bagh saw maximum observed value in year 2014 at 108.2 µg/m^3 highlighting that no location under the study ever reported a value above NAAQS' 24-hrs. guideline. This trend is similar to that observed for CO and is understandable for similar reasons of improvement over the years.

4. Conclusion

The present investigation shows that the burning of firecrackers, sparkles etc. in huge amounts has a substantial impact on increase in the concentration of criteria air pollutants especially PM_{10} and $PM_{2.5}$ and that of trace gases (CO, SO_2, NO_2 and NH_3) components over all six study areas. Vehicular emission remains the most prominent source of air pollution at all the six locations undergone the study and second major one during the Diwali festival night. The most prominent source of criteria air pollutants are burning of various types of firecracker during the Diwali festival night throughout the city aggravating the concentration of pollutants in the ambient air already coming from exhaust emissions. Late evening mass entry of the inter-state diesel-driven heavy-duty vehicles in the city also contribute to elevated level of air pollution. In addition to the above-mentioned mobile sources, the dust sourced from the on-going construction activities such as road/flyover, metro

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rail track, station and various other buildings such as commercial, institutional, retail etc. prevailing in the study areas also contribute greatly to the air pollution levels. Importantly, burning of crackers and sparkles during Diwali festival also emit a huge amount of metals in the atmosphere (for e. g., Al is added to make the crackers more bright and colorful and to produce white flames and sparks; Zn is used in the crackers to create smoke effects; Fe, Cu, Co are used as coloring agents and to produce sparks; The oxides, nitrates and nitrites of some elements like Pb, Mn, Cd and V are used as the ready source of oxygen for the process of combustion of the firecrackers Chatterjee et al. (2013). However long-term data collection and analysis is required to exactly pinpoint sources of these elements in Delhi's atmosphere. A location-wise interpretation leads to a conclusion that PM_{10} and $PM_{2.5}$ are most affected by firework activities and the observed concentration during 2015 or the preceding years have been dangerously above the NAAQS values of 24-hrs. Though other trace gases reveal a rather mixed pattern over the years (2010-2015), sometimes reporting a decreased value and vice-versa as far as records of values exhibit during festival night. The prevailing short-term exposure of referred criteria pollutants and the associated remarkable surge in their concentrations during Diwali festival can not only present a threat to overall ambient urban air quality, but also can trigger severe human health effects.

This situation is further worsened by the un-favorable meteorological conditions (which are further intensified by presence of vehicular air pollutants throughout the day-night cycle in this megacity) during night-time when Diwali, the festival of light and sound attains peak celebration activities attributing to the accumulation of air pollutants near the earth surface till next day day-time. While, such persisting concentration of aerosols and trace gases has been reported in megacity of Delhi (with present study on trends during 2010-2015), the situation is most likely to be existing in other urban areas of the country. Therefore, in view of the above, it is need of the hour to adopt and ensure compliance of adequate and appropriate measures so as to not only reduce the excessive firework activities on festival nights, but also to control, as far as possible, the emission and subsequent dispersion of the pollutants.

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Minimum K-S estimator using PH-transform technique

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Abstract: In this paper, we propose an improvement of the Minimum Kolmogorov-Smirnov (K-S) estimator using proportional hazards transform (PH-transform) technique. The data of experiment is 47 fire accidents data of an insurance company in Thailand. This experiment has two operations, the first operation, we minimize K-S statistic value using grid search technique for nine distributions; Rayleigh distribution, gamma distribution, Pareto distribution, log-logistic distribution, logistic distribution, normal distribution, Weibull distribution, log-normal distribution, and exponential distribution and the second operation, we improve K-S statistic using PH-transform. The result appears that PH-transform technique can improve the Minimum K-S estimator. The algorithms give better the Minimum K-S estimator for seven distributions; Rayleigh distribution, logistic distribution, gamma distribution, Pareto distribution, log-logistic distribution, normal distribution, Weibull distribution, log-normal distribution, and exponential distribution while the Minimum K-S estimators of normal distribution and logistic distribution are unchanged.

Keywords: Minimum K-S estimator, PH-transform technique, Grid search technique.

1. Introduction

Majority data analysis methods depend upon the assumption that data were sampled from a normal distribution or at least from a distribution which is sufficiently close to a normal distribution that so called parametric test. If the conditions for the parametric are not met, non-parametric tests are useful in this situations. The Kolmogorov-Smirnov (K-S) statistic is a well-known nonparametric statistic test used to solve the goodness of fit (GOF) between a hypothesized distribution function and an empirical distribution function. The K-S statistic test is the same as Chi-Square test but K-S statistic consider the evaluating of Maximum distant between the empirical cumulative distribution function and the theoretical cumulative distribution function. The proportional hazards transform (PH-transform) has been proposed to calculate the risk adjusted premium by (Wang, 1995). Furthermore, PH-transform can be used to quantify risk process, risk parameter, and risk dependency.

In this paper, we are interested in Minimum K-S estimator using PH-transform technique to improve the parameter estimation. Related research such as an algorithm for computing the parameter estimates in a univariate probability model for a continuous random variable that minimizes the K–S statistic presented and implemented by (Weber,et al., 2006). The algorithm uses an evolutionary optimization technique to solve for the estimates. Several simulation experiments demonstrate the effectiveness of this approach. The tool is modified by extending it in order to use the Kaplan-Meier estimate of the cumulative distribution function for distribution function (CDF) for right-censored data. The algorithm computes Minimum K-S estimators for several different continuous univariate distributions, uses an evolutionary optimization algorithm, and recommends the distribution and parameter estimates that best minimize the K-S statistic (Wieczorek, 2009).

In the next section, we introduce materials and methods, and interpret definition of K-S statistic and PH-transform including distributions that using in this experiment and Maximum likelihood estimator (MLE). In section 3, we describe the process of experiment and the results. In section 4, we conclude and discuss the future applications of the outlined method here.

2. Materials and Methods

2.1 Kolmogorov-Smirnov statistic

The Kolmogorov-Smirnov test is based on the following mathematical definition.

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Definition 1. Let $x_1, x_2, \ldots, x_N$ such that $x_1 < x_2 < \cdots < x_N$ be a sample of N independent and identically distributed observations of a real-valued one-dimensional random variable X that has parameter vector θ. The cumulative distribution function (CDF) of X is denoted by $F_X(x;\theta)$. The Kolmogorov-Smirnov statistic (K-S statistic) of $F_X(x;\theta)$ is given by

$$D(\theta) = \max_{1\le i\le N}\left|F_X(x_i;\theta) - \frac{i}{N}\right|.$$

2.2 Grid Search

Grid search is a traditional algorithm of performing hyper-parameter optimization which is a simple exhaustive searching through a manually specified subset of the hyper-parameter space of learning algorithm.

In this paper, we use grid search for minimizing the K-S statistic in order to obtain a set of parameters. Then, we improve the parameters by using PH-transform. The algorithm of grid search has 5 steps as shown in section 3.

2.3 PH-transform

In casualty insurance, a risk is a non-negative random loss X defined by its cumulative distribution function,

$$F_X(t) = \Pr(X \le t)$$

or survivor function,

$$S_X(t) = 1 - F_X(t).$$

The proportional hazards transform is based on the following mathematical definition.

Definition 2. Give any random variable X with survivor function $S_X(t)$, the equation

$$S_Y(t) = [S_X(t)]^{\frac{1}{\rho}}, \rho > 0.$$

Define another random variable Y with survivor function $S_Y(t)$. The mapping $S_X \longmapsto S_Y$ called the proportional hazards transform (PH-transform).

In this paper, we use PH-transform to change cumulative distribution function form for improving the better K-S statistics.

2.3 Distributions are used in experiment

In this section, we present some properties of experiment as location, scale and shape parameters of the Rayleigh, logistic, Gamma, Pareto, log-logistic, normal, Weibull, log-normal, and exponential distributions as seen in (Sinsomboonthong, 2015).

2.3.1 Rayleigh distribution

The probability density function of the Rayleigh distribution has a scale parameter σ. The probability density function is given by

$$f_X(x;\sigma) = \frac{x}{\sigma^2}e^{-\frac{x^2}{2\sigma^2}}, \quad x \ge 0. \tag{1}$$

The cumulative distribution function is in the form

$$F_X(x;\sigma) = 1 - e^{-\frac{x^2}{2\sigma^2}}, \quad x \ge 0. \tag{2}$$

2.3.2 Logistic distribution

The logistic distribution has a positive real scale parameter σ. The probability density function is given by

$$f_X(x;\ \sigma) = \frac{1}{\sigma}\frac{e^{-\left(\frac{x}{\sigma}\right)}}{\left(1 + e^{-\left(\frac{x}{\sigma}\right)}\right)^2}, x \in \mathbb{R}. \tag{3}$$

The cumulative distribution function is in the form

$$F_X(x;\ \sigma) = \frac{1}{1 + e^{-\left(\frac{x}{\sigma}\right)}}, x \in \mathbb{R}. \tag{4}$$

2.3.3 Gamma distribution

The Gamma distribution has a positive shape parameter α and a positive scale parameter β. The probability density function is given by

$$f_X(x;\alpha,\beta) = \frac{1}{\beta^\alpha\Gamma(\alpha)}x^{\alpha-1}e^{-\frac{x}{\beta}}, x \ge 0, \tag{5}$$

where $\Gamma(\alpha)$ is the Gamma function evaluated at α. The cumulative distribution function is in the form

$$F_X(x;\alpha,\beta) = \frac{\gamma\left(\alpha,\frac{x}{\beta}\right)}{\Gamma(\alpha)}, x \geq 0, \quad (6)$$

where $\gamma\left(\alpha,\frac{x}{\beta}\right)$ is the lower incomplete Gamma function.

2.3.4 Pareto distribution

The Pareto distribution has a positive shape parameter α and a positive scale parameter β. The probability density function is given by

$$f_X(x;\alpha,\beta) = \frac{\alpha\beta^\alpha}{x^{\alpha+1}}, x \geq \beta. \quad (7)$$

The cumulative distribution function is in the form

$$F_X(x;\alpha,\beta) = 1 - \left(\frac{\beta}{x}\right)^\alpha, x \geq \beta. \quad (8)$$

2.3.5 Log-logistic distribution

The log-logistic distribution has a real location parameter μ and a positive real scale parameter σ. The probability density function is given by

$$f_X(x;\mu,\sigma) = \frac{1}{\sigma}\frac{1}{x}\frac{e^z}{(1+e^z)^2}, x \geq 0. \quad (9)$$

where $z = \frac{\ln(x)-\mu}{\sigma}$. The cumulative distribution function is in the form

$$F_X(x;\mu,\sigma) = \left(1 + \left(\frac{x}{\mu}\right)^{-\sigma}\right)^{-1}, x \geq 0. \quad (10)$$

2.3.6 Normal distribution

The normal distribution or, as it is often called, the Gaussian distribution is the most important distribution in statistics which has a real location parameter μ and a positive real scale parameter σ. The distribution is given by

$$f_X(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2},\ x \in \mathbb{R}. \quad (11)$$

The cumulative distribution function is in the form

$$F_X(x;\mu,\sigma) = \frac{1}{2}\left(1 + \operatorname{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right), x \in \mathbb{R} \quad (12)$$

where $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}}\int_0^t e^{-x^2}dx$.

2.3.7 Weibull distribution

The Weibull distribution has a positive real shape parameter α and a positive real scale parameter β. The distribution is given by

$$f_X(x;\alpha,\beta) = \frac{\alpha x^{\alpha-1}}{\beta^\alpha}e^{-\left(\frac{x}{\beta}\right)^\alpha}, x \geq 0. \quad (13)$$

The cumulative distribution function is in the form

$$F_X(x;\alpha,\beta) = 1 - e^{-\left(\frac{x}{\beta}\right)^\alpha}, x \geq 0. \quad (14)$$

2.3.8 Log-normal distribution

The log-normal distribution has a real location parameter μ and a positive real scale parameter σ. The probability density function is given by

$$f_X(x;\mu,\sigma) = \frac{1}{\sigma x\sqrt{2\pi}}e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}, x > 0. \quad (15)$$

The cumulative distribution function is in the form

$$F_X(x;\mu,\sigma) = \frac{1}{2} + \frac{1}{2}\operatorname{erf}\left[\frac{\ln x - \mu}{\sqrt{2}\sigma}\right]. \quad (16)$$

2.3.9 Exponential distribution

The exponential distribution has a scale parameter β. The probability density function is given by

$$f_X(x;\beta) = \frac{1}{\beta}e^{-\frac{x}{\beta}}, x \geq 0. \quad (17)$$

The cumulative distribution function is in the form

$$F_X(x;\beta) = 1 - e^{-\frac{x}{\beta}}, x \geq 0. \quad (18)$$

2.4 Maximum Likelihood Estimator

The Maximum Likelihood Estimator (MLE) is a method for estimating a parameter based on a random sample. The basic idea is to choose a value for the parameter that maximizes the probability of the observations that actually occurred in the random sample. Although this approach is most fruitful in the context of continuous population random variables with parameters that take values along a continuum of real numbers, it also works for discrete random variables and parameters taking

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discrete values. In this paper we use the MLE to estimate the initial parameter for some distributions as following definition as seen in (Leonard and Mark, 2015).

Definition 3. Let X be a population random variable with a parameter θ. Assuming X is continuous, the density function as $f_X(x;\theta)$ in order to emphasize the dependency on θ as well as x. The likelihood function is given by

$$L(\theta; x_1, x_2, \dots, x_n) = \prod_{i=1}^{n} f_X\,(x_i; \theta) \qquad (19)$$

taking logarithm in (19), $\ln L(x;\theta)$, is called log-likelihood function that solved by taking derivative of $\ln L(x;\theta)$ with respect to the parameter θ, and setting it equal to zero in order to solve for θ. The value of θ that obtained from maximizing the function $\ln L(x;\theta)$ is exactly that the same value of θ, is called Maximum likelihood estimator.

3. Results and Discussions

This experiment uses some of fire data of an insurance company in Thailand. The purpose of this paper is to improve Minimum K-S estimator using PH-transform technique and we have two operations of experiment. The first operation, we minimize K-S statistic value using grid search technique for nine distributions. The data consist of the claim size as shown in Table 1. We used MLE to compute the initial parameters. After that, we calculate the K-S statistic as shown in Table 2. Next, Minimum K-S estimator estimates parameters that minimizes the K-S statistic. Minimum K-S estimator is a numerical optimization method that moves from the initial parameter to a better solution. The Minimum K-S estimator using grid search algorithm can describe as following:

Step 1: Compute the K-S statistic from the initial parameters a, b or d where a is scale parameter, b is location parameter and d is shape parameter.

Step 2: Randomly change the parameter value. We can do this by choosing constant r_1, r_2 or r_3 (real number) and let $a' = a + r_1, b' = b + r_2$, and $d' = d + r_3$.

Step 3: Compute the K-S statistic value with a, b or d.

Step 4: Compare the K-S statistic value which were obtained by step 1 and 3. If the K-S statistic value of the step 3 is greater than step 1, then repeat step 2 with set $a = \acute{a}, b = \acute{b}$ and $d = \acute{d}$. Otherwise, we choose a new constant r_1, r_2 or r_3 then go on to step 2.

Step 5: Repeat step 2 to step 4 until the K-S statistic value remains constant. The results are shown in the following Table 3.

Table 1. The claim size of fire insurance in Thailand (million).

Times	Claim size	Times	Claim size	Times	Claim size
1	35.5	**17**	26.7	**33**	69.9
2	26.4	**18**	32.4	**34**	122.7
3	64.9	**19**	76.5	**35**	158.9
4	127.3	**20**	33.2	**36**	33.1
5	57.7	**21**	25.7	**37**	60
6	21.8	**22**	60.2	**38**	104.3
7	67.3	**23**	132.2	**39**	29.2
8	48.5	**24**	20.9	**40**	63.1
9	23.6	**25**	65.8	**41**	90
10	22.3	**26**	55.3	**42**	27.2
11	84.6	**27**	33	**43**	22.4
12	21.4	**28**	22.1	**44**	27.5
13	51.5	**29**	24.2	**45**	57.2
14	20.7	**30**	44.4	**46**	34.2
15	40.1	**31**	20.4	**47**	53.2
16	29.3	**32**	30.8		

Table 2. The K-S statistic by computing from initial parameter.

Distribution	Parameters			K-S statistic value
	Scale	Location	Shape	
Rayleigh	43.02991	-	-	0.22218
Logistic	18.25640	-	-	0.87754
Gamma	16.89217	-	3.02242	0.16515
Pareto	20.40000	-	1.34604	0.11675
Log-logistic	0.34005	3.72054	-	0.12438
Normal	33.11345	51.05532	-	0.19137
Weibull	1.69222	-	57.75607	0.15542
Log normal	0.57106	3.75845	-	0.14337
Exponential	51.05532	-	-	0.30811

In Table 2 - 3**,** we found that K-S statistic of distributions in Table 3 is better than K-S statistic of distributions in Table 2, except the exponential distribution. We use 200 situations of simulation for our criteria in Table 3.

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Table 3. Minimum K-S estimator.

Distribution	Parameters			K-S statistic value
	Scale	Location	Shape	
Rayleigh	36.05355	-	-	0.12705
Logistic	36.99975	-	-	0.44620
Gamma	11.35555	-	3.85453	0.10397
Pareto	20.78183	-	1.24468	0.08111
Log-logistic	0.37615	3.72054	-	0.11197
Normal	20.14758	41.34690	-	0.12797
Weibull	1.62774	-	57.75607	0.14661
Log normal	0.68813	3.75845	-	0.11888
Exponential	25.77485	-	-	0.52554

In our second experiment, we consider Minimum K-S estimator with PH-transform technique for the same distributions as we used in the first experiment. The PH-transform technique is in the form

$$F_Y(t) = 1 - S_Y(t) = 1 - \left(S_X(t)\right)^c.$$

The K-S statistic of $F_Y(t;\theta)$ is given by

$$D(\theta) = \max_{1 \le i \le N} \left| F_Y(t_i;\theta) - \frac{i}{N} \right|.$$

PH-transform technique algorithm is described as following:

Step 1: Compute the K-S statistic with PH-transform technique for the parameters $c = 1, a, b$ or d (a is scale parameter, b is location parameter and d is shape parameter) is obtained from Table 3.

Step 2: Randomly change the parameter value. We can do this by choosing constant r (real number) and let $\acute{c} = c + r$.

Step 3: Compute the K-S statistic value with a, b or d of Table 3 and $\acute{c}$.

Step 4: Compare the K-S statistic value which were obtained from step 1 and 3.

If the K-S statistic value of the step 3 is greater than step 1, then repeat step 2 with set $c = \acute{c}$, a, b or d of Table 3. Otherwise, we choose a new constant r then go on to step 2.

Step 5: Repeat step 2 to step 4 until the K-S statistic value remains constant.

The methodology of the Minimum K-S estimator as shown in Figure 1. In Table 4, we obtained that Minimum K-S estimator with PH-transform method in Table 4 is better than K-S statistics of distribution in Table 3, except logistic distribution and normal distribution.

Table 4. List of parameters by Minimum K-S estimator with PH-transform technique for nine distributions.

Distribution	parameters				K-S statistic value
	Scale	Location	Shape	c	
Rayleigh	36.05355	-	-	0.00245	0.12698
Logistic	36.99975	-	-	0.00014	0.44620
Gamma	11.35555	-	3.85453	0.00077	0.10392
Pareto	20.78183	-	1.24468	0.00008	0.08110
Log-logistic	0.37615	3.72054	-	0.00130	0.11193
Normal	20.14758	41.34690	-	0.00001	0.12797
Weibull	1.62774	-	57.75607	0.00046	0.14659
Log normal	0.68813	3.75845	-	0.00022	0.11887
Exponential	25.77485	-	-	0.72173	0.30005

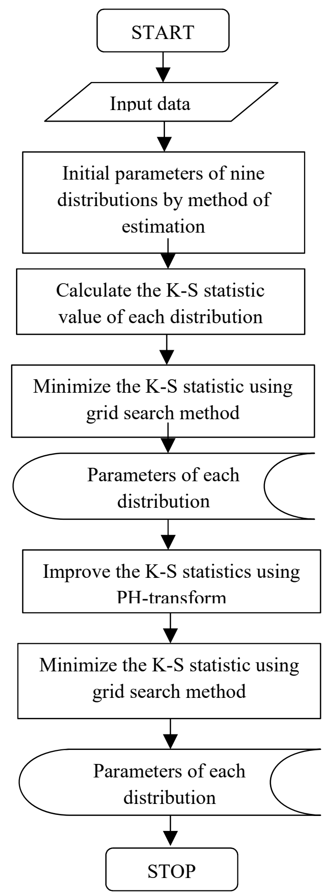

Figure 1. Methodology flow chart for Minimum K-S estimator.

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4. Conclusions

In implementing the Minimum K-S estimator, PH-transform technique can improve Minimum K-S estimator with two operations of experiments. The algorithms give better the Minimum K-S estimator for seven distributions; Rayleigh distribution, logistic distribution, gamma distribution, Pareto distribution, log-logistic distribution, normal distribution, Weibull distribution, log-normal distribution, and exponential distribution while the Minimum K-S estimators of normal distribution and logistic distribution are unchanged. For future research, Minimum K-S estimator can be applied with other algorithm such as E-M algorithm, Markov Chain Monte Carlo (MCMC) algorithm, etc. Its applications are used in actuarial science instance, we can use our tool to estimate parameter vector of the claim severities for Weibull distribution as in (Khotama, et al., 2015), other biostatistics, and biomedical research.

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Maximizing the retention level for proportional reinsurance under α-regulation of the finite time surplus process with unit-equalized interarrival time

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Abstract: The research focuses on an insurance model controlled by proportional reinsurance in the finite-time surplus process with a unit-equalized time interval. We prove the existence of the maximal retention level for independent and identically distributed claim processes under α-regulation, i.e., a model where the insurance company has to manage the probability of insolvency to be at most α. In addition, we illustrate the maximal retention level for exponential claims by applying the bisection technique.

Keywords: Probability of insolvency, Proportional reinsurance, Maximal retention level.

1. Introduction

Recently, an insurance business is a widely popular and highly interesting investment. An investment has risk as also insurance business. Moreover, the main interested in the view of an insurer is the occurring quantity of risk based upon capital which is affected by claim severities (the outflow of capital) and the premium rate (the inflow of capital).

In this paper, we assume that all of the random variables are defined in a probability space $(\Omega, \mathrm{F}, \Pr)$. The considered model is assumed that claim happens at the time n, for all $n = 1, 2, 3, \ldots$, called *claim arrivals*, and Y_n represents a claim size at the time n. In addition, the constant c_0 is assumed to be the premium rate for one unit of time. Therefore, the quantity is the insurer's balance (or surplus) at the time n with the constant $u \ge 0$ as the initial capital is define by

$$U_n(u, c_0) = u + c_0 n - \sum_{k=1}^{n} Y_k \tag{1}$$

Furthermore, we assume that the claims are controlled by choosing the retention level $b \in [L, 1]$ of proportional reinsurance, that is the claim amount y, the insurer pay $b \cdot y$ and reinsurer pay $(1-b) \cdot y$. Moreover, level $b = 1$ is the action without reinsurance, and the level $b = L$ is the smallest retention level that the insurer can be chosen or accepted. The premium rate of one unit of time for the insurer and reinsurer are calculated by the expected value principle as follows:

$$c_0 = (1+\theta_0)\mathrm{E}[Y],$$

and

$$\begin{aligned} c(b) &= (1+\theta_0)\mathrm{E}[Y] - (1+\theta_1)(1-b)E[Y], \\ &= \{b(1+\theta_1) - (\theta_1 - \theta_0)\} E[Y], \end{aligned}$$

where θ_0, θ_1 are the safety loadings of the insurer and the reinsurer, respectively such that $\theta_1 \ge \theta_0 \ge 0$. We note that $c(1) = c_0$ and assume that $c(L) > 0$. Therefore, the surplus process for the insurance model with proportional reinsurance is given by

$$U_n(u, c_0, b) = u + nc(b) - b\sum_{k=1}^{n} Y_k \tag{2}$$

for all $n = 1, 2, 3, \ldots$, where $u \ge 0$ is the initial capital, $c(b)$ is a net premium rate of insurer with the retention level $b \in [L, 1]$ and $\{Y_n : n \in \mathbb{N}\}$ is a claim size process. The probability of insolvency at one of the time $1, 2, 3, \ldots, n$ with respect to the retention level b is defined by

$$\Phi_n(u, c_0, b) = \Pr(U_k(u, c_0, b) < 0 \text{ for some } k = 1, 2, 3, \ldots n).$$

The survival probability for one time unit $1, 2, 3, \ldots, n$ is denoted by

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$$\varphi_n(u,c_0,b) = 1-\Phi_n(u,c_0,b) \qquad (3)$$

Commonly, an application of the process (1) is used to describe the behavior of the surplus in the case of motor insurance, because traffic accidents are occurred every day. The process (1) is uncomplicated; so many researchers have studied the subject and the results. For example, Chan, W.S. and Zhang, (2006) considered a case of discrete time surplus process and proposed another approach to deriving recursive and explicit formulas for the ruin probabilities with exponential claim severity Y_n. Sattayatham, et. al. (2013) generalized the recursive formula of the probability of insolvency, introduced the minimum initial problem, and controlled the probability of insolvency so that it was not greater than a given quantity. Klongdee, (2013) studied the model (2) in the case $n=1$ under the α-regulation, introduced the maximum retention level for proportional reinsurance and gave an example of the existence of a maximal retention level by using exponential claims.

In this research, we study the model (2) and propose the existence of a maximal retention level for proportional reinsurance in the finite-time surplus process with unit-equalized inter-arrival time, then we maximize it for exponential claims under α-regulation. Moreover, we define the maximal retention level, denoted by

$$\mathrm{MaR}_\alpha(\Lambda_n,u,c_0) = \max\{b\in[L,1]:\Phi_n(u,c_0,b)\le\alpha\} \qquad (4)$$

2. Results

In this section, we consider the finite time surplus process with an unit-equalized inter-arrival time in the equation (2), the claim process $\{Y_n : n\in\mathbb{N}\}$ constitutes a sequence of nonnegative random variables which are assumed to be independent and identically distributed (i.i.d), i.e., $\Pr(Y_1\le y)=\Pr(Y_k\le y),\ k=2,3,4,...,$ and Y_i, Y_j are mutually independent where $i\ne j$.

We define the total claim size process $\{\Lambda_n : n\in\mathbb{N}\}$ by

$$\Lambda_n := Y_1+Y_2+Y_3+\cdots+Y_n,$$

for all $n\in\mathbb{N}$. The survival probability at the time N as mentioned in (3) can be expressed as follows

$$\varphi_N(u,c_0,b) = \Pr\left(\Lambda_k \le \frac{u+kc(b)}{b}, k=1,2,3,\ldots,N\right)$$

$$=\Pr\left(\bigcap_{k=1}^{N}(b\Lambda_k-u-kc(b)\le 0)\right)$$

$$=\mathrm{E}\left[\prod_{k=1}^{N}\mathrm{I}_{(b\Lambda_k-u-kc(b)\le 0)}\right],$$

where I_A is an indicator in set A.

Lemma 2.1 Let N be a positive integer, $b\in[L,1]$ and c_0 be a non-negative real number .If $\{Y_n : n\in\mathbb{N}\}$ is an i.i.d claim size process, then $\varphi_N(u,c_0,b)$ is left continuous in b. In addition, $\Phi_n(u,c_0,b)$ is also left continuous in b.

Proof Sine $\mathrm{I}_{\{\omega: b\Lambda_n(\omega)-u-nc(b)\le 0\}} = \mathrm{I}_{(-\infty,0]}(b\Lambda_n-u-nc(b))$, $n=1,2,3,\ldots,N$,

$$\varphi_N(u,c_0,b) = \mathrm{E}\left[\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}(b\Lambda_n-u-nc(b))\right].$$

By the monotone convergence theorem, we have

$$\lim_{\delta\to b^-}\varphi_N(u,c_0,\delta) = \lim_{\delta\to b^-}\mathrm{E}\left[\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}(\delta\Lambda_n-u-nc(\delta))\right]$$

$$=\lim_{\delta\to b^-}\mathrm{E}\left[\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}\left(\Lambda_n-\frac{u-nc(\delta)}{\delta}\right)\right]$$

$$=\mathrm{E}\left[\lim_{\delta\to b^-}\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}\left(\Lambda_n-\frac{u-nc(\delta)}{\delta}\right)\right]$$

Sine $\mathrm{I}_{(-\infty,0]}\left(\Lambda_n-\frac{u-nc(\delta)}{\delta}\right)$ is left continuous on δ, $n=1,2,3,\ldots,N$, so that

$$\lim_{\delta\to b^-}\varphi_N(u,c_0,\delta) = \mathrm{E}\left[\prod_{n=1}^{N}\lim_{\delta\to b^-}\mathrm{I}_{(-\infty,0]}\left(\Lambda_n-\frac{u-nc(\delta)}{\delta}\right)\right]$$

$$=\mathrm{E}\left[\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}\left(\Lambda_n-\frac{u-nc(b)}{b}\right)\right]$$

$$=\mathrm{E}\left[\prod_{n=1}^{N}\mathrm{I}_{(-\infty,0]}(b\Lambda_n-u-nc(b))\right]$$

$$=\varphi_N(u,c_0,b).$$

Therefore, $\varphi_N(u,c_0,b)$ is left continuous in b. Moreover, we can conclude that $\Phi_N(u)=1-\varphi(u)$ is also left continuous.

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Lemma 2.2 Let a, b and α be real numbers such that $a \le b$. If f is increasing and left continuous

on $[a,b]$ and $\alpha \in [f(a), f(b)]$, then there exists $d \in [a,b]$ such that

$$d = \max\{x \in [a,b] : f(x) \le \alpha\}.$$

Proof The proof is similarly to Lemma 2.1 in Sattayatham, et.al. (2013).

The maximum retention level for proportional reinsurance is defined by (4) and the proof of $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$ was then done using the following Theorem 2.1.

Theorem 2.1 Let N be a positive integer and c_0 be a non-negative real number. If $\Phi_n(u, c_0, b)$ is increasing in b and $\alpha \in [\Phi_N(u, c_0, L), \Phi_N(u, c_0, 1)]$, then there exists $b^* \in [L,1]$ such that

$$b^* = \mathrm{MaR}_\alpha(\Lambda_n, u, c_0).$$

Proof We consider quantity $\Phi_n(u, c_0, 1)$ in the following cases:
Case 1 $\Phi_n(u, c_0, 1) \le \alpha$, $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0) = 1$.
Case 2. $\Phi_n(u, c_0, 1) > \alpha$. By Lemma 2.1, we have $\Phi_n(u, c_0, b)$ is left continuous. Using Lemma 2.2, there exists $b^* \in [L,1]$ such that

$$b^* = \max\{b \in [L,1] : \Phi_N(u, c_0, b) \le \alpha\}.$$

This is, $b^* = \mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$.

Lemma 2.3 Supawan, (2015), let n be positive integer and $\{Y_n : n \in \square\}$ be an i.i.d exponential claim process. If

$$u \ge \max\{n(\theta_1 - \theta_0) E[Y_1], 0\},$$

then $\Phi_n(u, c_0, b)$ is an increasing function in $b \in (0,1]$.
From the results of Theorem 2.1 and Lemma 2.3, Theorem 2.3 follows:

Theorem 2.3 Let N be a positive integer and c_0 be a non-negative real number. If $\Phi_n(u, c_0, L) \le \alpha$ and $u \ge \max\{n(\theta_1 - \theta_0)\mathbf{E}[Y_1], 0\}$, then

$$\mathrm{MaR}_\alpha(\Lambda_n, u, c_0) = \max\{b \in [L,1] : \Phi_n(u, c_0, b) \le \alpha\}$$

exists.

Proof If $\Phi_n(u, c_0, 1) \le \alpha$, we have $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0) = 1$. On the other hand, if

$\Phi_n(u, c_0, 1) > \alpha$, we have $\alpha \in [\Phi_n(u, c_0, L), \Phi_n(u, c_0, 1)]$. By Theorem 2.1 and Lemma 2.3, we have

$$\Phi_n(u, c_0, K) = \lim_{b \to K^-} \Phi_n(u, c_0, b) \le \alpha,$$

where $K = \sup\{b \in [L,1] : \Phi_n(u, c_0, b) \le \alpha\}$. It follows that $K = \mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$.

3. Numerical example

In this section, we compute the maximal retention level, $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$, by applying the bisection technique for the decreasing and left continuous function as mentioned in next theorem which can be proved similarly to Theorem 2.8 in Sattayatham, (2013).

Theorem 3.1 Let N be a positive integer, $\alpha \in (0,1)$ and $L \le a_0 < b_0 \le 1$. Let $\{a_n : n \in \square\}$ and $\{b_n : n \in \square\}$ be a real sequence such that for each $n \in \square$,

$$a_n = a_{n-1} \text{ and } b_n = \frac{b_{n-1} + a_{n-1}}{2}, \text{ if } \Phi_N\left(u, c_0, \frac{a_{n-1} + b_{n-1}}{2}\right) > \alpha$$

$$b_n = b_{n-1} \text{ and } a_n = \frac{a_{n-1} + b_{n-1}}{2}, \text{ if } \Phi_N\left(u, c_0, \frac{a_{n-1} + b_{n-1}}{2}\right) \le \alpha.$$

If $\alpha \in [\Phi_N(u, c_0, a), \Phi_N(u, c_0, b)]$, then

$\lim_{n \to \infty} a_n = \max\{a \in [L,1] : \Phi_n(u, c_0, a) \le \alpha\}$ and

$$0 \le b_n - \mathrm{MaR}_\alpha(\Lambda_n, u) \le \frac{b_0 - a_0}{2^n}.$$

Next, we give an example to illustrate applications of the maximal retention level for exponential claims under α-regulation i.e., a model where the insurance company has to manage the probability of insolvency to be at most α. We assume that $\{Y_n : n \in \square\}$ is an i.i.d exponential claim size process such that Y_1 has an exponential with intensity $\lambda > 0$, i.e., $E[Y_1] = \frac{1}{\lambda}$. Thus, the recursive formula of probability of insolvency of the discrete time surplus process with a retention level b of proportional reinsurance is the form

$$\Phi_n(u, c_0, b) = \Phi_{n-1}(u, c(b), b) + \frac{\left[\frac{\lambda}{b}(u + nc(b))\right]^{n-1}}{(n-1)!} \cdot e^{-\frac{\lambda}{b}(u + nc(b))} \cdot \frac{u + c(b)}{u + nc(b)} \quad (5)$$

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for all $n = 1,2,3,...$ (Supawan, et al., 2015).

We estimate the numerical illustrations of the main results and approximate the maximal retention level $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$ in the finite-time surplus process with unit-equalized inter-arrival time (2) by using the Theorem 3.1 in the case of $\{Y_n : n \geq 1\}$ a sequence of i.i.d. exponential distribution with the intensity $\lambda = 1$. We choose parameter combinations $\theta = \theta_0 = \theta_1 = 0.1$ in which $c(b) = b(1.1)\mathrm{E[Y]}$ and $\theta = \theta_0 = \theta_1 = 0.2$ in which $c(b) = b(1.2)\mathrm{E[Y]}$ and setting $u = 2, 4$ by using $\alpha = 0.05$ and $\alpha = 0.01$ respectively. As a result, we get the table of the maximal retention level b as below:

Table 1. Maximal retention levels $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$ in the finite-time surplus process with unit-equalized inter-arrival times with exponential claim ($\lambda = 1$).

	$u = 2$ and $\alpha = 0.05$		$u = 4$ and $\alpha = 0.01$	
N	$\theta = 0.1$	$\theta = 0.2$	$\theta = 0.1$	$\theta = 0.2$
5	0.899835	1.000000	0.819065	0.893983
10	0.764282	0.946663	0.716041	0.800137
20	0.698472	0.882411	0.645468	0.745491
30	0.678359	0.866225	0.617395	0.727946
40	0.669302	0.860026	0.602708	0.720351
50	0.664413	0.857143	0.593949	0.716547
60	0.661471	0.855640	0.588291	0.714460
100	0.656667	0.853776	0.578148	0.711719
200	0.654469	0.853361	0.572905	0.711063
300	0.654120	0.853345	0.572002	0.711035
400	0.654028	0.853344	0.571756	0.711033
500	0.653997	0.853344	0.571674	0.711033
1000	0.653978	0.853343	0.571620	0.711033

Table 1 shows the approximation of the maximal retention level $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$ with b as mentioned in Theorem 3.1, choosing $a_0 = 0$ and $b_0 = 20$, and $\Phi_n(u, c_0, b)$ computed by applying the bisection technique and using equation (5). The numerical results in Table 1 show maximal retention level $b = 0.899835$ for $u = 2$, $\alpha = 0.05$, $N = 5$ and $\theta = 0.1$ etc.

Figure 1 we run numerical experiments to compare the retention level b and probability of insolvency for the finite-time surplus process with unit-equalized inter-arrival times. Here, we choose parameter combinations $u = \{1, 2, 3, ..., 6\}$, $N = 100$, $\alpha = 0.01$, $\alpha = 0.05$ and $\theta = 0.2$. The numerical results in Figure 1 show that the intersection of various values of α and u are the maximal retention level b.

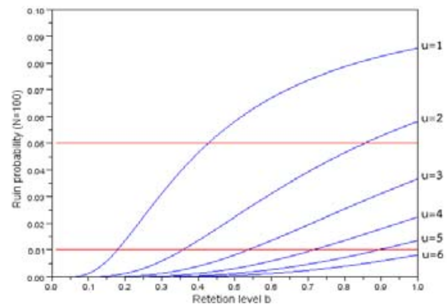

Figure 1. The relationship between proportional reinsurance b and $\Phi_n(u, c_0, b)$ with exponential claim ($\lambda = 1$).

4. Conclusions

In this paper, we consider a reinsurance problem for an insurer under the surplus process for a reinsurance model (4) in which we focus on the proportional reinsurance. We give the claim process $\{Y_n : n \geq 1\}$ which constitutes a sequence of nonnegative random variables which are assumed to be independent and identically distributed (i.i.d). The main result of the paper is the argument for the existence of the maximal retention level for independent and identically distributed claim processes under α-regulation, i.e., a model where the insurance company has to manage the probability of insolvency to be at most α. Finally, numerical examples of the maximal retention level, $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$, for exponential claims by applying the bisection technique to support the main result. In future works, we will study the maximal retention level, $\mathrm{MaR}_\alpha(\Lambda_n, u, c_0)$, for this excess-of-loss reinsurance and alternate case.

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Latent fingerprints on different type of screen protective films

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Abstract: The purpose of this research was to study the quality of latent fingerprint on different types of screen protective films including screen protector, matte screen protector, anti-fingerprint clear screen protector and anti-fingerprint matte screen protector by using black powder method in developing latent fingerprints. The fingerprints were performed by 10 volunteers whose fingers (right index, right thumb, left index and left thumb) were stubbing at different types of screen protective films and subsequently latent fingerprints were developed by brushing with black powder. Automated Fingerprint Identification System (AFIS) counted the numbers of minutiae points from 320 latent fingerprints. Anti-fingerprint matte screen protective film produced the best quality of latent fingerprint with an average minutiae point 72.65, followed by matte screen protective film, clear screen protective film and anti-fingerprint clear screen protective film with an average minutiae point of 155.2, 135.0 and 72.65 respectively. The quality of latent fingerprints developed between a clear and a matte surface of screen protective films showed a significant difference (sig>0.05), whereas the coat and the non-coat with anti-fingerprint chemical revealed a non-significant difference (sig<0.05) in their number of minutiae points.

Keywords: Screen protective film, Latent fingerprints, Black powder method, Anti-fingerprint coating.

1. Introduction

Physical evidences are an important role for crime scene. To resolve the lawsuit, investigating, collecting and recognizing those evidences are required. Fingerprints often and still are respected to be one of the valuable kinds of physical evidence in identification (Samuel, 2008). Two fingerprints have never been found alike in many billions of humans. In addition, fingerprints are relatively persistent when they compare with other visible human characteristics such as facial features, which tend to change with age (Adebisi, 2008). Latent fingerprint marks at crime scene may be found on many surfaces such as guns, knives, woods, glasses and smartphones which different surface (Rozman et al., 2014)

Fingerprint powder is widely used crime scene technician to detection and collection latent fingerprints that left behind crime scene. Powder methods is commonly used due to low cost, easy to develop latent print on many surface types and doesn't require much expertise (Low et al., 2015).

Nowadays, Smartphone and its application have been involved in our daily lives and offer much benefits (Smith, 2012). Smartphone is not just for calling but can do so many things including listening to music, scheduling appointments, controlling the equipment and so on which can be done by touching a finger on the smartphone. In some situation, smartphone is used for a tool in the crime such as for remoting bomb and to communicate between the terrorists. So smartphone is an important object that investigators, which usually used for collecting the fingerprint, evidenced to identification of person.

However, screen protective film is first accessory which choose by phone user for protect smartphone. Screen protective film will install on the screen of smart phone for protecting them from scratch and fingerprint which effectively to quality of the fingerprint due to the surface and chemical coating of protective film (Luis, 2014).

Screen protective film were produced and developed to respond the demand of consumers, so screen protective films were having many difference types. The most widely available, economical and easy to purchased type of screen protector, which used in this study is standard or clear screen protectors are usually thin and has shiny and smooth surface. Anti-glare and/or matte screen protectors have a matte finish to diffuse sunlight. Anti-fingerprint screen protective films are screening protective film that coating with hydrophobicity and oleophobicity chemicals.

The quality of latent print from development depends upon the surface of the object (Badiye and

Kapoor, 2015), so this article is part of a study the quality and the difference of latent fingerprints deposited onto different types of screen protective

film by using black powder dusting method for latent fingerprint detection and using Automated Fingerprint Identification System (AFIS) to determine number of minutiae.

2. Materials and Methods

2.1 Preparation of screen protective films for sample collection

In this research, 4 types of screen protective film were used including clear screen protective, anti-fingerprint clear screen protective, matte screen protective and anti-fingerprint matte screen protective. All types of films were made from polyethylene terephthalate (PET), clear types have a smooth surface and matte types have a matte finish, and anti-fingerprint types were made from polyethylene terephthalate with anti-fingerprint coating (Luis, 2014). Twenty films of each type were used. Almost of films have the size about length 5.44 inches and width 2.64 inches and each film was divided into 4 equal parts for repost the fingerprint mark of right index finger, right thumb finger, left index finger and left thumb finger, 4 figures that always developed for each touch-screen sample. After that installed films onto glass plate.

2.2 Latent fingerprint development

Three hundred and twenty mark of latent fingerprints from 10 volunteers - 5 men and 5 women deposited fingerprints. The volunteers were stabbed right index finger, right thumb finger, left index finger and left thumb finger onto 4 types of film with 2 films per types (duplication) at room temperature. Black powder was applied on stabbed fingerprint surface with a light-brushing action by rabbit hair, lifted with a tape and placed on a white backing card (Sodhi and Kaur, 2001).

2.3 Latent fingerprint examination

Collected latent fingerprints were counted the number of minutiae points by used Automated Fingerprint Identification System (AFIS) from SPEX Forensic Company, New Jersey, USA (Kenneth et al., 2011). The statistics were used to compare quality of appearance of latent fingerprint. The statistics were used in this experiment is *t*-test to compared and analyses the difference of latent fingerprint appearance

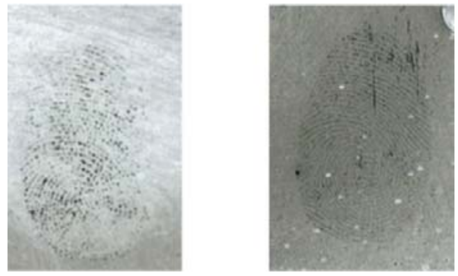

Figure 1. Latent fingerprints developed from clear screen protective films.

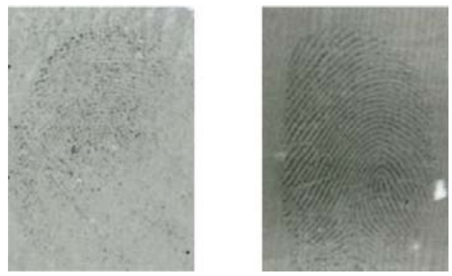

Figure 2. Latent fingerprints developed from anti-fingerprint clear screen protective films.

Figure 3. Latent fingerprints developed from matte screen protective films.

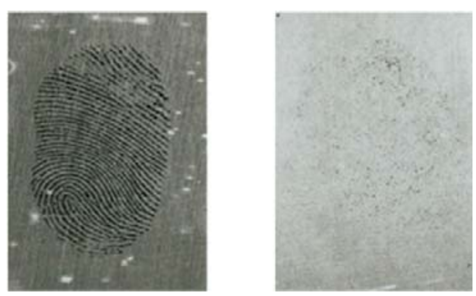

Figure 4. Latent fingerprints developed from anti-fingerprint matte screen protective film.

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3. Results and Discussion

The result of the experiment, the visualization of latent fingerprints from each type of screen protective films has both of clear and faint fingerprints as show in Figure 1-4. Because of, the visualization of latent fingerprints was not depending on only surface but have many factors such as distortion, smearing and substance transferred to the surface etc. (Ulery et al., 2016). The number of minutiae points on each type of screen protective films from right index finger, right thumb finger, left index finger and left thumb finger of 10 volunteers which counted by used Automated Fingerprint Identification System (AFIS) as show in table 1. Anti-fingerprint matte screen protective film had the best quality of latent fingerprint, with average of the minutiae point 72.65 follow by matte screen protective film, clear screen protective film and anti-fingerprint clear screen protective film with average of the minutiae point 155.2, 135.0 and 72.65 respectively.

An independent sample *t*-test was conducted to compare the quality of latent fingerprint on different type of screen protective films, which compare between clear and matte surface, and between coating and non-coating with anti-fingerprint chemical as show as in Table 2-3.

The result from table 2 showed that comparison of the quality of latent fingerprints on clear surface and matte surface screen protective films. There was a significant difference (sig < 0.05) in the number of minutiae point. These results suggest that surface have an effect on the quality of latent fingerprints on screen protective films, which the numbers of minutiae points of matte surface screen protective films were more than clear surface screen protective films. Because of matte surface screen protective films were rough due to manufacturing process for anti-glare property (Marco et al., 2014). So the black powder from brushing and the secretions from the finger may be easily extracted to the surface.

Table 1. The total number of minutiae of each volunteer, counted by AFIS.

Screen protective films Type	Volunteer										$\bar{x}$
	1	2	3	4	5	6	7	8	9	10	
Clear	140.5	191.5	224	108	104	126	120	114.5	105.5	116	135.0
Anti-fingerprint Clear	7	180.5	114	100.5	29.5	66	79	68	66	16	72.65
Matte	133.5	209.5	172	190	248.5	175.5	123.5	86	103	110.5	155.2
Anti-fingerprint Matte	180	183	166	257	159.5	162	141.5	123	151	89	161.2

Table 2. Independent-sample *t*-test comparing matte and clear surface

Surface	N	Mean	SD	*t*	*p* value
clear	20	103.8250	55.19207	-3.355	.002
matte	20	158.2000	46.97323		

The comparison of the quality of latent fingerprint on anti-fingerprint coating and non- coating by used independent sample *t*-test method which analyze by used the number of minutiae points. There was no significant difference between the coating and non-coating with anti-fingerprint chemical (p>0.05) as shown in table 3.

The result suggest that anti-fingerprint coating haven't an effect on the quality of latent fingerprints on screen protective films, which the numbers of minutiae points of did not coating with anti-fingerprint chemical screen protective films were more than anti-fingerprint coating screen protective films in case of clear surface screen protective films, which anti-fingerprint clear screen protective films were coated with chemical for hydrophobicity and oleophobicity to self-cleaning, or easy-to-clean property (Wu et al., 2011). But in case of matte surface screen protective films the numbers of minutiae points of coating with anti-fingerprint chemical screen protective films were then did not coating type may be the anti-figure print coating did not have the effect to the rough.

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Table 3. Independent-sample *t*-test comparing coating and non-coating with anti-fingerprint chemical

Anti-fingerprint	N	Mean	SD	*t*	*p* value
coating	20	116.9250	64.90930	10576	.123
Non-coating	20	145.1000	46.66640		

4. Conclusions

It is concluded from the result that the quality of latent fingerprint with the numbers of minutiae point of developed from different types of screen protective films were found anti-fingerprint matte screen protective is the best appearance of fingerprint films followed by matte screen protective film, clear screen protective film and anti-fingerprint clear screen protective film respectively. Surface conditions may one of dependent factors, which affected to the quality of latent fingerprints on screen protective films, which matte surface screen protective films were more than clear surface screen protective films, however, anti-fingerprint coating may not relate to the quality of latent fingerprints on screen protective films. For the future research will be conducted on appropriate method using for each type of screen protective films and affecting factors related to quality of latent fingerprint.

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