

# Fire Incident Characteristics of a Densely Populated Oriental Urban City

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## ABSTRACT

Hong Kong is a small but densely populated oriental city with limited natural resources. The fire engineering approach to formulating fire safety strategies for buildings requires information on the number and characteristics of fires that occurred in different types of buildings. In this paper, fire incident statistical data collected by the Hong Kong Fire Services Department for years 1991 to 2001 is analysed. It is found that residential buildings constituted 75% of the total number of building fires, however fire risk appears to be the highest in buildings classified as Places of Public Assembly, using the number of fatalities and injuries per fire as an indicator. The statistical data seems to imply that quality of maintenance of equipment and power supply in privately built shopping arcades, commercial premises and residential buildings is lower than the same buildings owned by the government. Apart from the fire engineering perspective, the fire statistics seems to also reflect to some degree the social make-up and work pattern of the society of Hong Kong, for example, more fires due to carelessness occurred in buildings with lesser educated occupants, and relatively uniform temporal distribution of fires in most parts of the day in private commercial buildings due to significant amount of overtime and overnight work.

**KEYWORDS:** fire statistics, fire data analysis, fire safety, Hong Kong

## INTRODUCTION

Hong Kong, a Special Administrative Region of China since 1997, is a densely populated oriental urban city situated at the south-eastern tip of the mainland of China; it has just over 1,100 square kilometres in area with a population of 6.8 million in mid-2003 [1], i.e., 6,181 persons/sq. km. It consists of Hong Kong Island, Kowloon Peninsula (its northern side connects to the mainland China), Lantau Island, and a number of smaller outlying islands, all centered around a harbour, the Victoria harbour.

Just after World War II, the city was re-built and many buildings were constructed with timber, mostly of low rise nature up to 4 storeys high. A flood of immigrants from China before and after the world war led to a shortage of accommodation in Hong Kong, resulting in many single storey shelters, constructed with timber slats or sheet metal, cluttered together on the hillside. Coupled with the use of naked flame using wood or kerosene as fuel for cooking, these shelters were a major fire hazard.

As a result of a large fire on the Christmas night of 1953 in the Shek Kip Mei squatter area which rendered over 53,000 people homeless overnight [2], the Government embarked a series of public housing construction that aimed to provide low cost accommodation to these people. From that time construction was carried out by the Resettlement Department and was gradually expanded to work by 3 separate Hong Kong

Government agencies, which were the Resettlement Department, Government Low Cost Housing and Housing Authority, who tended to look after the needs of separate groups based upon their income or their residency status.

Abundant mountainous areas in Hong Kong places enormous pressure on the efficient land use of the remaining relatively flat terrains, and there were successive generations of land reclamation into the Victoria harbour. Land is thus a premium in Hong Kong.

Nowadays, most Hong Kong residents live in high rise apartments of concrete construction, with the number of public housing and private residential buildings being approximately on a 1 to 1 ratio. Accompanying with the economic growth in Hong Kong that started in the 1970's, the fuel for household cooking in these high-rise residential buildings has changed from wood and barrelled kerosene to bottled LPG and finally to centralised town gas reticulation.

Other enhancements on fire safety over the past three decades included the introduction of automatic fire sprinkler systems, since the first publication of the Codes of Practice for Minimum Fire Service Installations and Equipment (FSI Code) in 1964, for certain types of buildings, including bowling alleys and dressing rooms, scenery docks, stages and stage basements of theatres, underground garages & car parks over 1,000 ft<sup>2</sup>, any room or compartment of a building over 250,000 ft<sup>3</sup>, departmental stores or shops over 250,000 ft<sup>3</sup>, basements for storage over 5,000 ft<sup>2</sup>, non-domestic floors of composite buildings over 15 storeys in height, and godowns & warehouses as required by the Hong Kong Fire Services Department.

Buildings that required to be provided with automatic fire sprinkler systems were extended after 1973 to all commercial buildings and the commercial portions of composite buildings over 30 m in height or over 10 storeys, whichever is the lesser, and for all industrial buildings including godowns over 2 storeys in height. Currently in Hong Kong, all buildings with a floor area of over 230 m<sup>2</sup> will require to be provided with an automatic fire sprinkler system, with an exception being residential buildings where fire sprinklers are not required regardless of the building height and floor areas.

Although fire safety has been improved over the years in Hong Kong, there are still almost 6,000 building fires occurring each year. This paper examines the fire incidents statistics for Hong Kong from 1991 to 2001, collected and provided by the Hong Kong Fire Services Department, with a view to identifying if further improvements can be made with respect to the level of fire safety in this densely populated city.

The statistics include number of fire occurrence, deaths and injuries, causes of fires, and times of fires categorised by building types that consist of restaurants, hotels, residential buildings developed by the government (housing estates), private residential buildings, quarters for the married government officers, commercial buildings within the housing estates, privately developed commercial buildings, shopping arcades within housing estates, privately developed shopping arcades, factories built by the government and private developers, institutional buildings, and construction sites.

## **FIRE OCCURRENCE BY BUILDING TYPES**

In the years 1991 to 2001, there were on average 5,921 building fires in Hong Kong per year (Table 1). The distribution of building fires when categorised by building type is lop-sided, with 49.5% in private domestic buildings, 25.7% in public housing estates and 0.3% in Government Married Officer's Quarters (Fig. 1). In other words, residential

building fires accounted for 75% of all building fires in Hong Kong during this 11 year period, followed by commercial building fires which accounted for merely 11% of the total. Such relatively frequent occurrence of fires in residential buildings is also observed in the fire incident statistics of the UK [3], Australia [4], USA [5], Japan [5], and the State and City of São Paulo [7].

Table 1. Number of fires in Hong Kong by premises type (1991-2001).

Type of premises	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Average	% average
Restaurant	225	96	188	218	191	215	233	183	178	185	177	189.9	3.2%
Hotel	11	13	3	4	7	5	17	4	12	10	13	9.0	0.2%
Housing Estate - Domestic	1909	1834	2136	1771	993	1141	987	1531	1494	1531	1416	1522.1	25.7%
Private Domestic Building	2221	2390	2394	2444	3325	3644	3903	3183	3034	2915	2815	2933.5	49.5%
Gov't Married Officer's Quarters	27	16	13	12	19	10	6	14	15	20	12	14.9	0.3%
Housing Estate - Commercial	40	15	20	36	48	28	33	70	60	33	39	38.4	0.6%
Private Commercial Premises	609	596	419	919	563	602	722	614	668	541	531	616.7	10.4%
Housing Estate - Shopping Arcade <sup>a</sup>	-	-	-	-	13	4	2	30	13	22	41	17.9	0.3%
Shopping Arcade <sup>a</sup>	-	-	-	-	53	62	50	52	21	28	27	41.9	0.7%
Factory Building - Private	418	361	334	256	287	320	247	190	163	160	143	261.7	4.4%
Factory Building - Gov't Built	12	5	0	8	10	9	4	5	4	5	6	6.2	0.1%
Places of Public Assembly <sup>a</sup>	-	-	-	-	18	18	27	12	5	18	23	17.3	0.3%
Institute Building	105	34	13	52	115	173	168	183	180	112	175	119.1	2.0%
Construction Site	198	150	115	93	131	164	141	132	123	100	106	132.1	2.2%
<b>Total</b>	<b>5775</b>	<b>5510</b>	<b>5635</b>	<b>5813</b>	<b>5773</b>	<b>6395</b>	<b>6540</b>	<b>6203</b>	<b>5970</b>	<b>5680</b>	<b>5524</b>	<b>5920.5</b>	<b>100.0%</b>

<sup>a</sup>Data from 1995-2001 only

The terminology in Table 1 for describing the type of premises is faithfully reproduced from the raw data and may be confusing to readers who are not familiar with the situations in Hong Kong. An explanation of what the terms represent is given as follows.

- Restaurant: Usual definition.
- Hotel: Usual definition.
- Housing estate - domestic: Residential buildings developed by the Housing Authority of the Hong Kong government.
- Private domestic building: Residential buildings developed by private developers.
- Gov't married officer's quarters: Residential buildings developed by the Hong Kong government for civil servants who are married and whose job nature requires them to be on shift (e.g., firefighters and police officers)
- Housing estate - commercial: Office/commercial areas in buildings developed by the Housing Authority of the Hong Kong government.
- Private commercial premises: Office/commercial buildings by private developers.
- Housing estate - shopping arcade: Shopping centres developed by the Housing Authority of the Hong Kong government.
- Shopping arcade: Shopping centres developed by private developers.
- Factory building - private: Factory buildings developed by private developers.
- Factory building - gov't built: Factory buildings developed by the government.
- Places of public assembly: cinemas, sports hall and the like.
- Institute building: hospitals, universities, primary and secondary schools and the like.

- Construction site: work site or structure still under construction with no occupation permit granted by the Hong Kong Buildings Department yet.

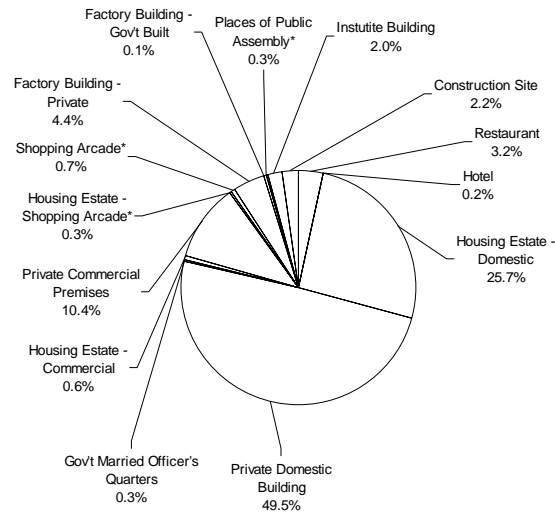


Fig. 1. Distribution of building fires in Hong Kong by premises type (1991-2001).

### DEATHS AND INJURIES

In the years 1991 to 2001, the reported number of fire injuries and deaths in residential premises (first three rows in Table 2) is the highest among all premises types, with a total average of 281.3 injuries and 16.1 fatalities on an annual basis.

Commercial premises (4<sup>th</sup> and 5<sup>th</sup> rows in Table 2) have the second highest number of fire injuries and deaths, with a total annual average of 79.0 injuries and 6.1 fatalities respectively. This is followed by private factory buildings with an annual average of 35.5 injuries and 0.5 fatalities. In contrast, shopping arcades within Housing Estate, government built factory buildings, and hotels had virtually no fatalities, and had only 0.1, 0.3, and 0.8 injuries respectively as the annual average.

Table 2. Averaged number of fire fatalities and injuries in Hong Kong by type of premises per annum (1991-2001).

Type of premises	Avg No. of fires p.a.	Avg No. of fatalities p.a.	Avg No. of injuries p.a.
Private Domestic Building	2933.5	9.0	179.5
Housing Estate - Domestic	1522.1	7.0	100.9
Government Married Officer's Quarters	14.9	0.1	0.9
Private Commercial Premises	616.7	5.0	77.0
Housing Estate - Commercial	38.4	1.1	2.0
Factory Building - Private	262.6	0.5	35.5
Factory Building - Government built	6.2	0.0	0.3
Restaurant	189.9	0.2	26.5
Institute Building	119.1	0.3	21.8
Shopping Arcade <sup>a</sup>	41.9	0.1	11.9
Housing Estate - Shopping Arcade <sup>a</sup>	17.9	0.0	0.1
Construction Site	132.1	0.4	9.3
Places of Public Assembly <sup>a</sup>	17.3	2.4	3.3
Hotel	9.0	0.0	0.8
<b>Total</b>	<b>5921.5</b>	<b>26.1</b>	<b>469.9</b>

<sup>a</sup> Data from 1995-2001 only

Whilst the statistics in Table 2 indicate that most fire fatalities and injuries occurred in residential type buildings, it alone is not an appropriate life safety risk indicator because the statistics might simply be due to that there were more fires occurred in residential buildings than other types of buildings. A relatively more accurate description of the fire risk would be the number of fatalities and injuries per fire, as shown in Table 3.

Table 3. Averaged number of fire fatalities and injuries per fire in Hong Kong by type of premises per annum (1991-2001).

Type of premises	Avg No. of fires p.a.	Avg No. of fatalities per fire p.a.	Avg No. of injuries per fire p.a.	Avg No. of fatalities & injuries per fire p.a.
Places of Public Assembly <sup>a</sup>	17.3	1.40E-01	1.90E-01	3.31E-01
Shopping Arcade <sup>a</sup>	41.9	3.41E-03	2.83E-01	2.87E-01
Housing Estate - Shopping Arcade <sup>a</sup>	17.9	0.00E+00	8.00E-03	8.00E-03
Private Commercial Premises	616.7	8.11E-03	1.25E-01	1.33E-01
Housing Estate - Commercial	38.4	2.84E-02	5.21E-02	8.06E-02
Housing Estate - Domestic	1522.1	4.60E-03	6.63E-02	7.09E-02
Government Married Officer's Quarters	14.9	6.10E-03	6.10E-02	6.71E-02
Private Domestic Building	2933.5	3.07E-03	6.12E-02	6.42E-02
Institute Building	119.1	2.29E-03	1.83E-01	1.85E-01
Factory Building - Private	262.6	2.08E-03	1.35E-01	1.37E-01
Factory Building - Government built	6.2	0.00E+00	4.41E-02	4.41E-02
Restaurant	189.9	9.57E-04	1.39E-01	1.40E-01
Hotel	9.0	0.00E+00	9.09E-02	9.09E-02
Construction Site	132.1	2.75E-03	7.02E-02	7.30E-02
<b>Total</b>	<b>5921.5</b>			

<sup>a</sup> Data from 1995-2001 only

On a combined fatalities and injuries per fire incident basis, it can be seen from Table 3 that the places of public assembly has the highest number of fatalities and injuries per fire (0.331), followed by public and private buildings shopping arcades combined (0.295), public and private commercial premises combined (0.214), all residential buildings, i.e., public & private residences plus government married officer's quarters combined (0.202), Institute buildings (0.185), private and government factories combined (0.181), restaurants (0.140), hotels (0.091) and construction sites (0.073).

Such ranking order may be due to relatively large number of occupants in the places and public assembly and shopping arcades, the fire emergency management procedures in those types of buildings, and the fire protection measures provided, however the quality and depth of the current statistics does not enable further analysis.

It is interesting to note that whilst residential buildings is the only building type that is not provided with automatic sprinkler systems, the number of fatalities and injuries per fire in this building type is not particularly high when compared to other building types. This may be due to the way the residential apartments have been constructed, where each apartment is virtually a fire rated enclosure, thus significantly limiting the spread of fire and smoke from an apartment to other apartments and the public corridors.

It is also of interest to examine three types of buildings that were built by both the government and private developers, i.e., shopping arcades, commercial buildings, and residential buildings. It is found that for shopping arcades, the ratio of the averaged number of fatalities and injuries per fire in private shopping arcades to that in public shopping arcades is 35.8, whereas the ratio is only 1.7 for commercial buildings and 1.1 for residential buildings. In addition, the number of fires that occurred in these three types of privately built premises are significantly more than that government built counterparts as illustrated in the second column of Table 2 and Table 3.

## CAUSES OF FIRE

The causes of fire in shopping arcades, commercial premises and residential buildings are presented graphically in Fig. 2a & 2b, Fig. 3a & 3b, and Fig. 4a & 4b respectively. The statistics indicate that for shopping arcades and commercial premises, general electrical faults, careless handling or disposal of ignition sources, and suspicious circumstances are the dominant causes of fires. For residential buildings, stove overcooking, careless handling or disposal of ignition sources, general electrical faults and suspicious circumstances are the dominant causes of fires. It is worth noting that for these three building types, the percentage of fire cause under the category of suspicious circumstances in Housing Estates premises is about 1.5 to 4 times of that in private buildings, which may be more of a social problem than a technical problem.

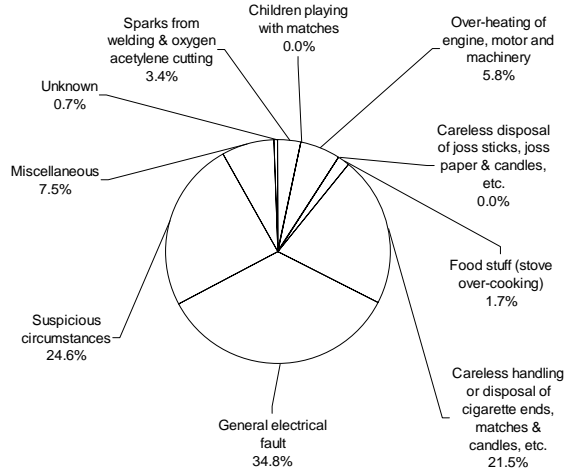


Fig. 2a. Causes of fire in private shopping arcades (1995-2001).

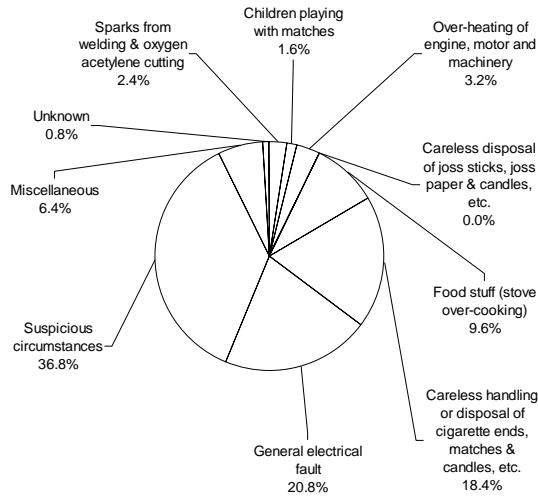


Fig. 2b. Causes of fire in housing estate shopping arcades (1995-2001).

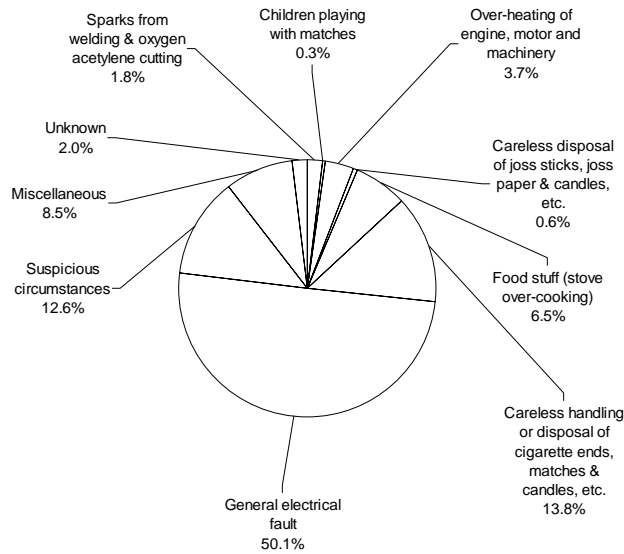


Fig. 3a. Causes of fire in private commercial premises (1991-2001).

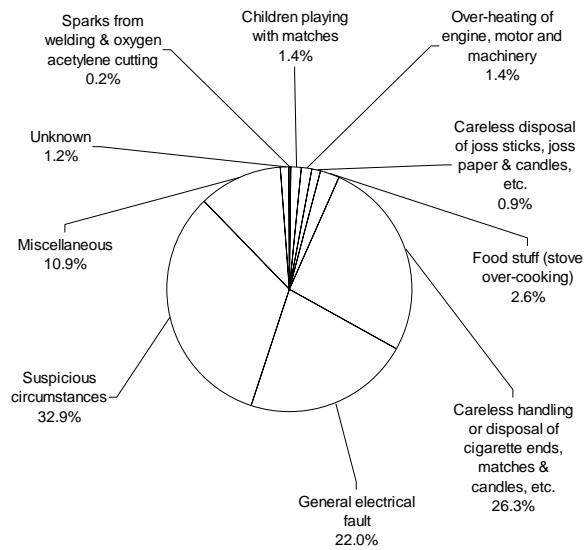


Fig. 3b. Causes of fire in housing estate commercial premises (1991-2001).

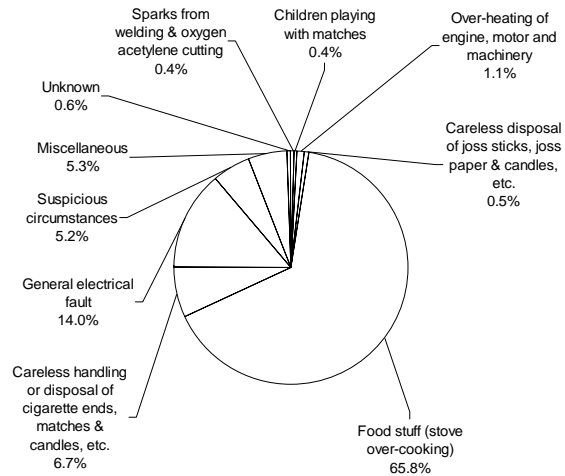


Fig. 4a. Causes of fire in private residential buildings (1991-2001).

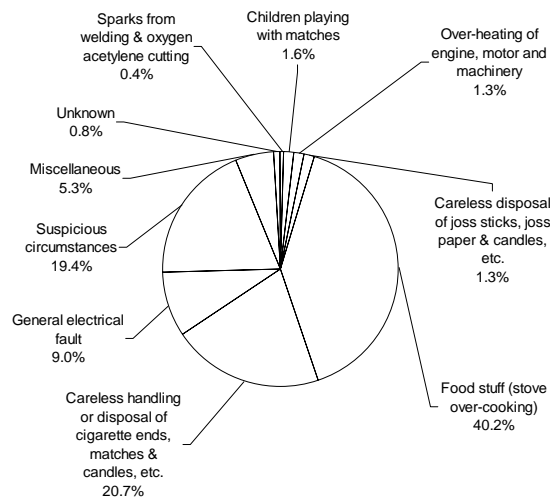


Fig. 4b. Causes of fire in housing estate residential buildings (1991-2001).

Apart from the cause of fires under the suspicious circumstances category, a comparison of the distribution of other causes of fires is made for the three types of buildings.

For Shopping Arcades, there were more fires due to general electrical faults and machinery overheating in privately built shopping arcades than that in Housing Estate counterparts (34.8% vs 20.8% and 5.8% vs 3.2% respectively, about 1.5 times and 1.8 times resp.), whereas the opposite applied for fires due to stove over-cooking (about 5.5 times more in Housing Estate shopping arcades, 1.7% vs 9.6%). The contribution from 'children playing with matches' to fire starts is also found to be more frequent in Housing Estate shopping arcades.



For Commercial Premises, there were also more fires due to general electrical faults and stove over-cooking in privately built commercial premises than that in Housing Estate commercial premises (50.1% vs 22.0% and 6.5% vs 2.6% respectively, about 2 times and 2.5 times resp.), however there were many more fires due to careless disposal of ignition sources such as cigarette ends and matches, and children playing with matches in Housing Estate commercial premises than that in the privately built ones (26.3% vs 13.8% and 1.4% vs 0.3% respectively, about 2 times and 4.5 times resp.).

For Residential Buildings, stove over-cooking was the dominant cause of fires in both privately built and government-built residences, however there were more fires due to this cause in private residential buildings than that in Housing Estate ones (65.8% vs 40.2%, about 1.5 times). There were also more fires due to general electrical faults in private residential buildings than Housing Estate counterparts (14.0% vs 9.0%, about 1.6 times), but there were far more fires due to careless disposal of cigarette ends and matches, and of joss sticks and candles, and to children playing with matches in Housing Estate residential buildings than the private ones (20.7% vs 6.7%, 1.3% vs 0.5% and 1.6% vs 0.4% respectively, about 3 to 4 times).

A comparison in the distribution of causes of fires in these three types of buildings between privately built and government built ones is summarised in Table 4.

Table 4. Relative contribution on cause of fires in shopping arcades, commercial premises and residential buildings.

<b>Cause of fire</b>	<b>Privately Built</b>	<b>Government Built</b>
General electrical faults	More	Less
Overheating of machinery	More	Less
Careless disposal of ignition sources	Less	More
Children playing with matches	Less	More
Stove over-cooking	More in commercial and residential, less in arcades	Less in commercial and residential, more in arcades

The first two causes of fire in the summary above may imply that the quality of maintenance of equipment and power supply in privately built shopping arcades, commercial premises and residential buildings is not as good as that in the government built ones, probably due to lesser resources spent by the private operators and property management on maintenance so as to maximise profit. The following two causes may be somewhat related to the educational level of the residents and users of those buildings, however no definitive conclusions can be drawn based on the currently available statistical details. With respect to stove over-cooking, there is not a clear trend between privately and government built buildings, and any attempted explanations can only be conjectures only.

### **TIMES OF FIRE**

Fire starts are expected to be associated to a large degree with the extent of activities within the respective buildings, because generally when there are occupants, there will be a higher usage of energy sources such as electricity for equipment, machinery, lighting etc. and open flames for cooking. The times at which fire calls for shopping arcades, commercial premises, and residential buildings are received by the Hong Kong Fire Services Department are plotted in Fig. 5a to 7b respectively.

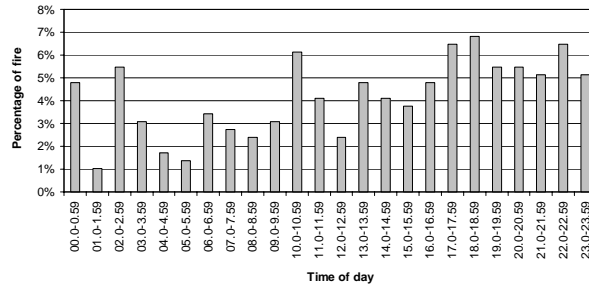


Fig. 5a. Times of fire in private shopping arcades (1995-2001).

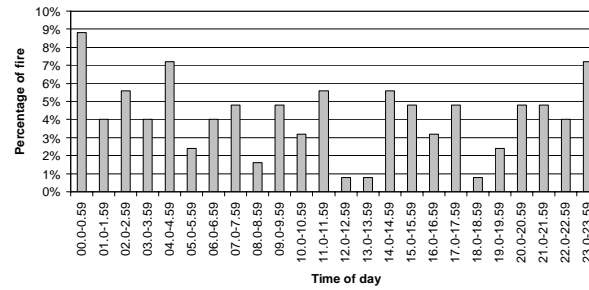


Fig. 5b. Times of fire in housing estate shopping arcades (1995-2001).

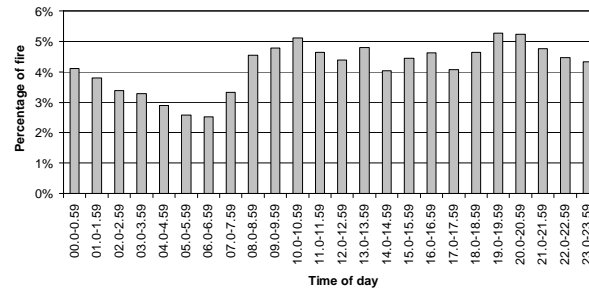


Fig. 6a. Times of fire in private commercial premises (1991-2001).

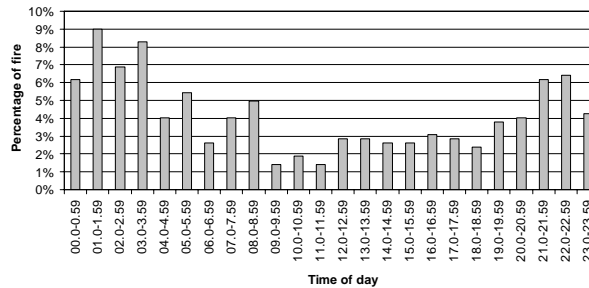


Fig. 6b. Times of fire in housing estate commercial premises (1991-2001).

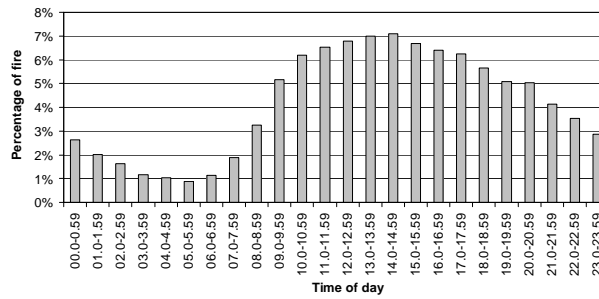


Fig. 7a. Times of fire in private residential buildings (1991-2001).

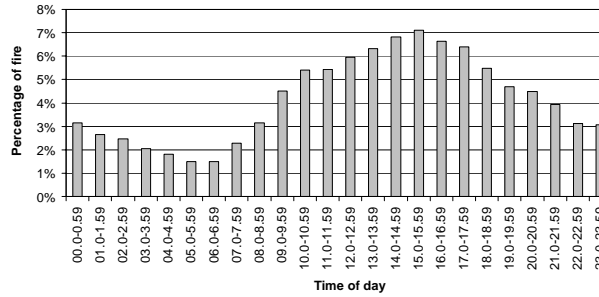


Fig. 7b. Times of fire in housing estate residential buildings (1991-2001).

The variation of the number of fires by time of alarm in private shopping arcades in Fig. 5a shows that the arcades were relatively 'quiet' during early mornings with consistently more fires in the evenings, whereas in Housing Estate shopping arcades, Fig. 5b shows a somewhat different trend with the number of fires during the early morning hours similar to that in the evenings, with particular dips around the lunch time period.

In commercial premises, the trend on the number of fires by time of alarm in privately built buildings is quite clear in Fig. 6a that there were more fires during the normally occupied hours, with lesser fires in the early mornings. The number of fires being fairly constant also in the evening hours up to midnight seems to reflect fairly accurately the amount of office workers overtime practised in Hong Kong over the last decade. It is however intriguing for the trend on the number of fires by time of alarm in Housing Estate commercial premises in Fig. 6b that shows there were many more fires in the early mornings (midnight to 4am) than the normal office hours, which may perhaps be related to fires associated with suspicious circumstances or arson, however the definitive causes of such trend can only be determined with more detailed statistics on the fire incidents as well as nature of those commercial premises and associated demographics.

The trend on the number of fires by time of alarm for both privately built and government built residential buildings is very similar, with a dip in the early mornings (most people still asleep), an increase after dawn (people getting up and preparing for the activities of the day), and a decrease towards midnight (people reducing activities and going to sleep). The slight difference is that the increase of the number of fires in private residential buildings is much sharper than that in Housing Estate residential buildings in the early morning, probably due to a much larger workforce living in the private buildings.

## CONCLUSIONS

It is found that Hong Kong share a common statistic with the UK, Australia, USA, Japan, and the State and City of São Paulo, i.e., residential building fires constitute a larger proportion of building fires than other building types combined.

Whilst about 75% of fires occurred in residential buildings, the highest fire risk appear to be in buildings classified as Places of Public Assembly, using the number of fatalities and injuries per fire as an indicator.

There were three groups of buildings built by both the government and private developers, i.e., shopping arcades, commercial premises and residential buildings. The fire incident statistics for these buildings seems to indicate the following:

- (a) There were many more fires classified as suspicious, as well as more fires due to careless disposal and handling of ignition sources, in government buildings than private buildings, which may be partially associated with the demography and educational level of the occupants therein.
- (b) The quality of maintenance of equipment and power supply in private buildings is generally inferior to that in government buildings, possibly due to lesser resources spent by private property management on maintenance to maximise profit.
- (c) The times of fire appears to reflect the trend of activities and working pattern of occupants on a daily basis, i.e., generally more activities led to more fires.

## REFERENCES

- [1] Hong Kong Special Administrative Region, "Hong Kong in Figures, 2004 Edition," Census and Statistics Department, March (2004).
- [2] T. Fung, "The Housing Challenge Ahead: Hong Kong," The International Housing Conference, Hong Kong Housing Authority, Hong Kong, 1996, <http://www.housingauthority.gov.hk/housconf/dhspeech.htm>.
- [3] Watson, L., Gamble, J., and Schofield, R., "Fire Statistics United Kingdom 1999," Home Office Research, Development and Statistics Directorate, Building Research Establishment, Hertfordshire, 2000.
- [4] NSW Fire Brigades Statistics, Australian Incident Reporting System (AIRS), 1994-1998.
- [5] Federal Emergency Management Agency, "A Profile of Fire in the United States, 1989-1998 (12th edition)," U.S. Fire Administration, 1999, <http://www.usfa.fema.gov/downloads/pdf/publications/fa-214.pdf>.
- [6] Sekizawa, A., "International Comparison Analysis on Fire risk among the United States, the United Kingdom, and Japan," *Fire Safety Science – Proceedings of the Fourth International Symposium*, International Association for Fire Safety Science, 1994, pp. 961-969.
- [7] Ono, R., and Da Silva, S.B., "An Analysis of Fire Safety in Residential Buildings through Fire Statistics," *Fire Safety Science – Proceedings of the Sixth International Symposium*, International Association for Fire Safety Science, 2000, pp. 219-230.