An Analysis of Fire Safety in Residential Buildings through Fire Statistics

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ABSTRACT

This paper focuses on the matters concerning residential fires in the City of São Paulo through the analysis of data collected in a four-years period (1994-1997) by the Fire Department of State of São Paulo using an improved collecting system. It aims at pointing out the method used to analyze the particular problems detected in the City of São Paulo, in order to contribute to the development of such studies in other megacities located in developing countries with situation similar to the ones met in São Paulo. This situation is mainly caused by the lack of a systematic analysis of fire statistics and its application on fire prevention and protection activities such as public education, inspection, development and revision of standards and codes, improvements in fire services, etc.

KEYWORDS: Fire statistics, fire data analysis, residential fires.

INTRODUCTION

The City of São Paulo, capital of São Paulo State, is one of the cities with the highest population of the world, accounting for approximately 10 million of the 15 million inhabitants that comprehends the São Paulo Metropolitan Area. In a total area corresponding to 0.6% of

the São Paulo State, approximately 30% of the State's population dwell today in the City of São Paulo.

The industrialization process throughout this century has made the city of São Paulo the most economically important area through its progressive expansion to neighboring cities.

The fast economic growth in main cities of developing countries was noticeable and brought serious consequences, such as the intense migration to these cities. A considerable amount of low-income population was marginalized in this process, due to the lack of dwellings and basic infrastructure to satisfy the demand together with the lack of resulting labor qualifications.

The City and State of São Paulo present several problems that are typical of megacities and, among those, firesafety problems in its buildings are focused here.

Construction techniques inherited from Portugal, our colonizers, used predominantly masonry. Early in this century, reinforced concrete structures enclosed with brick walls were introduced. This type of construction presents great advantages when related to fire safety in this country, where natural catastrophes such as earthquakes and typhoons do not occur. Although these construction techniques have good fire resistive and fire spread control characteristics, fire safety has not been a matter of concern in this country throughout its history.

One of the first high-rise buildings in São Paulo, with 32 floors, was built in 1934 and it is the landmark of the introduction of reinforced concrete structure in Brazil. Since that, all high-rise structures were built without any concern about fire safety until two great tragedies in São Paulo: the Andraus Building fire (1972 - 16 deaths) and Joelma Building fire (1974 - 180 deaths).

As a consequence of those great fires, the first municipal building regulation concerned with firesafety was established in São Paulo in 1975, based on European and American standards and codes. The São Paulo State Fire Department had required very light fire safety countermeasures since 1962, and it was only able to establish more comprehensive and strict fire protection requirements in 1983.

Although fires in high-rise buildings have been of great concern in São Paulo, this megacity has several fire problems in all kinds of structures. An essential tool to analyze firesafety is the fire statistics, which are generally poor in developing countries due to several factors. This paper focuses on the first extensive analysis of fire data from a recently improved data collection system.

THE ANALIZED DATABASE

Due to the organization of the fire services in Brazil, which are totally independent by State, the collection and comparison of fire data collected by different systems, in order to get a wide, national view of the firesafety situation in the country has been quite impossible.

By the initiative of the São Paulo State Fire Department, that has been improving its fire data collecting system since 1991 [1],[2], a Brazilian standard for collecting fire data was

elaborated and approved in 1997 as Brazilian Standard NBR 14023/97 [3]. Representatives of several State's Fire Departments participated in the Standard's definition and are now working on the implementation of the system nationwide.

The São Paulo State Fire Department has been collecting data based on the principles of the Standard for some years and its database is analyzed here [4],[5]. The analysis aims at giving a better understanding of the fire problems in São Paulo and the evaluation of the system implementation. Some data were analyzed for a four-year period (1994-1997) and other, for a three-year period (1995-1997), due to the changes made to the database during the 1994-1995 period.

Some data are shown in Tables 1 and 2 to illustrate the fire situation in the City (Capital) and State of São Paulo.

TABLE 1. Total of fire incidents in the State and City of São Paulo (1994-1997)

Type of fire	Place	1994	1995	1996	1997
All types *	City	7,071 (22%)	6,445 (23%)	6,385 (23%)	6,980 (20%)
	State	32,738 (100%)	27,678 (100%)	28,268 (100%)	35,210 (100%)
Structure	City	3,545 (36%)	4,075 (24%)	3,937 (31%)	3,954 (28%)
	State	9,834 (100%)	16,726 (100%)	12,724 (100%)	13,979 (100%)

*All type of fires include structural, vehicle, wildfires, etc.

Today's fire data system of this Fire Department collects more data than the minimum standardized data established in the Brazilian Standard, and includes detailed information about some activities, due to the particularity and complexity of the situations found in São Paulo State. This fire data refers to the activities carried out throughout the State by fire stations located, essentially, in major urban areas and industrial zones that does not cover 100% of the State's territory. However, the fire stations are located in municipalities where 70% of the State's population lives, and it is, therefore, considered that most of the population is protected.

TABLE 2. Fires (average of 4 years) and the population[6] in São Paulo City and State

	Fires	Population	Fire/1,000 inhabitants
Capital	6,720 (22%)	9,800,997 (30%)	0.69
Interior	24,254 (78%)	22,868,107 (70%)	1.06
State	30,974 (100%)	32,669,104 (100%)	0.95

The distribution of fire incidents in buildings in the State and Capital (City of São Paulo), respectively, are presented for the 1995-1997 period in Figure 1, according to building occupation, where "others", which represents 8% or less, includes: public buildings, hospitals and, passengers and cargo terminals.

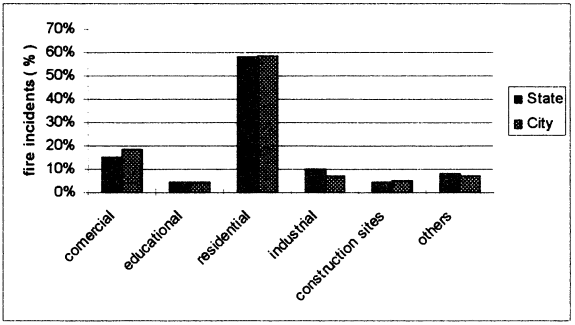

FIGURE 1. Distribution of fire incidents in buildings in the State and City of São Paulo (sum of 3 years: 1995-1997)

The area damaged by fire in buildings, which is collected in order to size the fire loss, is presented in Figure 2. This Figure shows that residential buildings represent the major fire damaged area, emphasizing the importance of improving this analysis. The area damaged by fire is defined in the Fire Department's Manual as "area damaged by the incident and its consequences, in square meter".

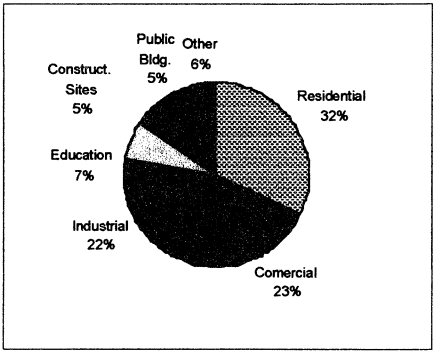

FIGURE 2. Distribution of fire damage area in the City of São Paulo (sum of 3 years: 1995-1997)

Based on the data related to the fire causes in the City of São Paulo (the sum of 3 years), already focusing on the participation of residential fires in total structure fires, it is possible to see that some causes are typically generated by domestic activities, as it can be seen in Table 3. It was noticed that approximately 50% of all fire causes are unknown or not reported.

TABLE 3. Main causes of fires in the 1995-1997 period in São Paulo City

Causes	All Types of Fires	Structure Fires	Residential fires
Carelessness at cooking	1,164	1,146	986
Inadequate electrical installation	1,932	1,441	804
Arson	2,576	995	512
Negligence with candles	452	435	370
LPG leakage	382	354	265
Children play	576	270	186
Other known causes	2,639	1,579	644
Unknown / not verified	10,089	5,746	3,086
Total	19,810	11,966	6,853

THE PROFILE OF RESIDENTIAL BUILDINGS AND RESIDENTIAL FIRES

As it has been already observed in Figure 1, the residential fires constitute almost 60% of the total number of structure fires in the State of São Paulo, as well as in the City of São Paulo. An analysis to understand the phenomenon was carried out and is presented here.

The analysis is based on the fire data of the City of São Paulo, as it is possible to consider that almost all fire incidents were assisted by the Fire Department in this area, due to the number and strategic location of fire stations.

To analyze the firesafety of residential buildings it is necessary to know what are the actual living conditions of the population in the city. Table 4 shows the families distribution, by type of building construction and by social-economic groups in the City of São Paulo [7] in 1994.

The families were classified in four social-economic groups, according to their living conditions, varying from *A*, meaning good living conditions, to *D*, meaning poor living conditions. The method applied for this classification is called PCV (*Survey on Life Conditions*) method and its is composed by the evaluation of four parameters: housing, education, employment and income.

The *housing* parameter considered in its evaluation the construction material used to build the dwelling, the available inner space and how it is used by the dwellers, while the *education* parameter considered the level of education of the head of the family and of a second member with the highest education level. Additionally, the *employment* parameter identified the position of the head of the family and of a second family member in the labor market, considering the labor quality, the stability, the unemployment level and the average income. Finally, the forth parameter, that is *income*, considered *per capita* income of the family compared to the minimum living expenses.

In a survey carried out in 1994 using the PCV method, 25.8% of the families in the city of São Paulo were classified as *A*, 35% as *B*, 15.8% as *C* and 23.4% as *D*.

TABLE 4. Distribution of families, by type of building construction in the City of São Paulo in 1994

Type of construction	Social-economic Groups (%)			
	A	B	C	D
Shanty houses or towns	--	--	15.1	13.5
Slums	--	--	15.1	10.3
Single-family masonry	60.6	87.3	65.9	70.5
Multistory buildings	39.4	12.7	3.9	5.7

It is clear, in Table 4, that most of the population in the City still live in single-family masonry houses, followed by reinforced concrete multistory buildings. Shanty houses / towns (small, badly built houses, usually made from pieces of wood or metal or cardboard), and slums (very poor and crowded urban areas where the buildings are in an extremely bad state and the living conditions are very low) can be seen in the lower two groups. The estimated population in shanty houses and towns in 1991 (last Population Survey by IBGE [6]) was about 650,000 inhabitants in the City of São Paulo, which is a considerable number of people living in a high fire risk situation.

The firesafety requirements in residential occupancies in the City are portable fire extinguishers and fire hoses/hydrants for multistory (multi-family) buildings and none for single-family houses.

As a first step, the residential fires were analyzed by type of construction for the 1995-1997 period, as shown in Table 5.

TABLE 5. Residential fire by type of construction (1995-1997)

Type of construction	1995	1996	1997
Shanty house	156	154	147
Shanty town	41	33	29
Slums	61	48	61
Single-family houses	1,462	1,471	1,378
Multistory buildings	606	565	555
Others*	30	27	29
Total	2,356	2,298	2,199

*Non-conventional dwellings: cars, wagons, tents, etc.

Figure 3 shows the distribution of the total fire cases registered in the 1994-1997 period, by type of construction, where it is possible to see that more than half of the fires occurred in single-family houses and 25% occurred in multistory residential buildings.

By analyzing the same fire incidents by month and by days of the week for the 1995-1997 period, it was clear that there is not a significant variation in the number of cases along those periods. On the other hand, the profile of fire occurrences over the hours of the days adopted a

considerable variation according to the activities developed inside the houses, as can be seen in Figure 4.

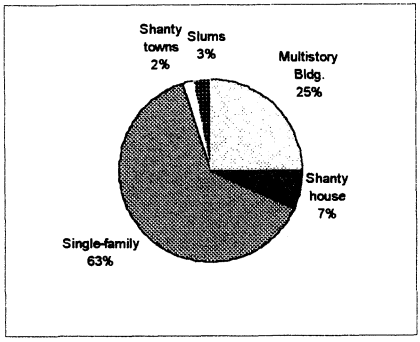

FIGURE 3. Distribution of residential fires by type of construction (1995-1997)

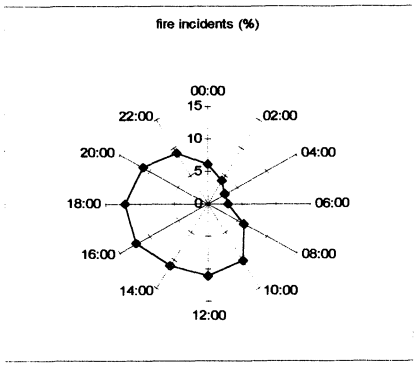

FIGURE 4. Residential fires by hour of the day (1995-1997)

The damaged area, that reached approximately 141,500 m^2 in the 1995-1997 period, resulted in an average of 20.6m^2 per fire in residential fire in the City of São Paulo. Table 6 shows the average of fire damaged area by type of construction in the 1995-1997 period.

TABLE 6. Fire damaged area by type of construction in the 1995-1997 period

Type of construction	Average damaged area per fire, in m^2	Sum of 3 years, in m^2
Shanty houses	24.7	11,275 (8.2%)
Shanty towns	250.2	25,770 (18.8%)
Slums	21.8	3,716 (2.7%)
Single-family houses	18.0	77,451 (56.4%)
Multistory buildings	6.2	19,117 (13.9%)

The fires in shanty towns are responsible for only 18.8% of the total damaged area by residential fires, although each of those fires spread, in average, for about 250 m^2. The fires in single-family houses, on the other hand, represent 56.4% of the total damaged area, having less serious consequences, in average.

By analyzing the fire damaged area by type of construction, it is possible to consider that fires in shanty towns have greater consequences than in any other type of construction. This situation is caused not only by the high fire-load concentration in this type of building, but also by the high density of those areas, together with the extremely poor living conditions. Besides that, other factors, such as the lack of water supply for fire-fighting and the difficult access of the fire fighters and apparatuses to control the fire inside shanty towns, make matters worse.

The situation in single-family houses and multi-story buildings are the opposite to the one described above. Although there is a great number of fires in these types of buildings, the damage caused is much less, generally due to the multi-compartimentation of the spaces inside the residential units by masonry walls and reinforced concrete slabs. The fires are generally confined to the space of origin. The average of fire damaged area is much less in multi-story, multi-family residential buildings and it can also be related to the smaller proportion of its inner spaces than in single-family houses.

The use of the "fire damaged area" as an input data for the estimation of direct economic losses due to fire in buildings is also expected, however, the definition of an adequate method of estimation is still under consideration due to the variations caused by the unstable economy of this country. Additionally, some problems related to the lack of a clear method for an appropriate estimation of fire damage area must be corrected.

The main known fire causes are presented below, in Table 7. About 45% of fire causes in residential buildings in the City of São Paulo have been recorded as "unknown", "not investigated" or "other causes" in the 1995-1997 period, which can influence negatively the results of the analysis carried out here. However, it does allow a primary analysis of the situation.

TABLE 7. Fire causes in residential buildings (1995-1997)

Cause	Total number of fire incidents	(%)
Carelessness at cooking	986	(14.4)
Inadequate electric wiring	804	(11.7)
Arson	512	(7.5)
Negligence with candles	370	(5.4)
LPG leakage	265	(3.9)
Children play	186	(2.7)
Criminal actions / vandalism	142	(2.1)
Overheating of appliances	135	(1.9)
Carelessness at smoking	112	(1.6)
Balloons	82	(1.2)
Carelessness at handling of flammable liquids	22	(0.3)
Accumulation of grease on appliances	21	(0.3)
Negligence on welding works	21	(0.3)
Other known causes	109	(1.6)
Unknown / not investigated	3,086	(45.0)
Total	6,853	(100.0)

It is very important to emphasize the meaning of the correct recording of fire data by the fire-fighters. In the case of fire causes, some fundamental matters need to be solved to improve the quality of its data and this is directly related to an appropriate infrastructure for fire investigation, supported by qualified personnel and laboratories.

Through the analysis of known fire causes at residential buildings in the 1995-1997 period, the carelessness at cooking is outstanding and it can be related to situations such as: leaving cooking pans unattended, proximity of cooking table to combustible materials, etc.

The second largest fire cause is the inadequate electric wiring, which can reflect the lack of skilled labour for the installation of electrical wiring, very common at poor housing, or overload / bad conditions of old electrical wiring due to the increasing use of household appliances.

The negligence with candles also represents a considerable cause of fires, due to its constant use to light the houses in the lack of public electrical supply and also for lighting religious images and altars at home. The LPG leakage from portable gas cylinders used to supply cooking units at home is also a very serious fire cause. This is related not only to the lack of maintenance of its components, but also to the bad conditions of installation and storage. Overheated appliances also cause fire and they can be related to factors such as the bad quality of equipment or to consumer disorientation.

Besides the causes discussed above, those related to intentional human acts such as arson, criminal acts and vandalism, are considerable too. The play of children with fire is also representative.

The places of fire origin in residential buildings are shown in Table 8. Concerning fire incidents, the kitchen is the most critical place inside a house, where the carelessness at cooking occurs, followed by the bedroom (≅22%) and, by the living room (≅5%), where the carelessness with candles and smoking of cigarettes are present, together with overheating of appliances and inadequate electrical wiring.

The "whole building", which means the situation where all domestic activities are carried out by its inhabitants in one single space, is the place of fire origin of 7.4% of all fire incidents. This kind of space normally is fully loaded with combustible materials and different sources of ignition, typically found at shanty towns and slums.

Fires in places such as backyards and courtyards, by the ignition of combustible garbage or other materials stored in that open space, results from children play, vandalism or other causes.

TABLE 8. Places of fire origin in residential buildings (1995-1997)

Places of fire origin	Total number of fire incidents	(%)
Kitchen	1,962	(28.6)
Bedroom	1,483	(21.6)
Backyard	582	(8.5)
Whole building	507	(7.4)
Living room	358	(5.2)
Garage	257	(3.8)
Laundry room	217	(3.2)
Other places	1,487	(21.7)
Total	6,853	(100.0)

FATAL VICTIMS OF RESIDENTIAL FIRES

The City of São Paulo had 37% of all deaths in structure fires in the State in the 1995-1997 period, and residential fires caused 90% of the fatal victims during the same period. The casualties registered by the Fire Department only include those occurred during the fire, not considering the deaths that occurred later in injured victims.

The number of victims by type of construction in the 1995-1997 period for the city of São Paulo are shown in Table 9.

TABLE 9. Deaths in residential fires in the City of São Paulo (1995-1997)

Type of construction	Number of deaths		
	1995	1996	1997
Shanty houses	2	4	3
Shanty towns	1	4	1
Slums	0	3	0
Single-family houses	10	3	10
Multistory buildings	0	0	1
Total	13	14	15

More than 50% of the total number of deaths in residential fires occurred in single-family houses in the 1995-1997 period, and it is proportional to the frequency of fire incidents.

Today, there are few possibilities of more detailed analysis, due to lack of adequate procedures to investigate and record fire deaths by the fire departments' staff. This is an item of the fire data collecting system that has to be improved in the near future.

From the available data it is possible to conclude that most of the casualties occurred during the night with adult male, followed by unattended children below age 12. Children are the main victims of fires in slums and shanty houses/ towns because they are usually locked at home during the day, when parents go to work.

CONCLUSION

This first analysis of the São Paulo Fire Department's fire database was very important to get an overview of firesafety in the City of São Paulo and to evaluate its data collection system. Through this study, it was possible to detect problems and propose some basic improvements to get more reliable data, as presented below:

- it is necessary to improve the consciousness and the preparation of fire service staff, as well as to improve the fire investigation techniques;
- fire incidents with fatal victims should be investigated more thoroughly, by qualified personnel using detailed procedures;
- injured victims rescued alive at the fire scene should be followed up for a specified period after the fire incident, in order to evaluate the effectiveness of the rescue activity;
- a method should be developed for the calculation of fire loss in different kinds of occupancy and type of construction.

On the other hand, the analyzed data showed that the main causes of residential fires are located in the kitchen and/or related to electrical wiring. These causes can be understood as a result of the population's lack of consciousness in its daily activities and the unqualified contractors for carrying out electrical services.

The database today represents an evolution in the fire data collecting system, however, several improvements should be considered for a more reliable evaluation of the fire causes and its consequences in São Paulo.

Finally, it is necessary to expand the standardized fire data collecting system not only in the State of São Paulo, but also throughout the country, in order to get a national fire data system.

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