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PRESCRIPTIVE CODES VS. PERFORMANCE-BASED CODES: WHICH ONE IS THE BEST FIRE SAFETY CODE FOR THE BRAZILIAN CONTEXT?

RODRIGO MACHADO TAVARES*

OPTSEG - Optimal Safety Engineering (www.optseg.com), Research Department, GEDIPE - Grupo de Estudos sobre DInâmica de PEdestres, F. 13, Mackworth House, Augustus Street, Regent's Park, NW1 3RE, London, UK

* email: rodrigotmj@gmail.com

Abstract - In Brazil, the fire safety codes are based on a prescriptive approach; however a considerable number of fire accidents have shown that these codes might not have been providing the fire safety as they should have. In fact, nowadays, most developed countries, such as some North-European countries (like the UK and Sweden), Australia, New Zealand, the USA, Canada and Japan have already started to change their fire safety codes from a prescriptive approach to a performance-based one. The performance-based codes attempt to provide clearer guidance than the prescriptive codes taking into consideration the actual growing complexity of the architectural designs, which introduces more fire risks. This is one of the main reasons why most of the mentioned countries are in an advanced stage of development and implementation of performance-based codes. Nevertheless, in the Brazilian context, many difficulties are found for the implementation and development of such types of fire safety codes. Some of these difficulties which could be mentioned are: the perception of the fire risks and the laws. Both of them are considered the crucial barriers for the development and implementation of performance-based codes. In reality, these two issues can be associated with what here has been called here as “fire safety culture”. Furthermore, the objective of this paper is to promote the discussion on “which is the best practice for fire safety in Brazil: the prescriptive codes or the performance-based ones?”

Key-words: Fire Safety Codes; Prescriptive Codes; Performance-Based Codes; Fire Safety Culture; Perception of Fire Risks.

1.0 AN OVERVIEW OF THE BRAZILIAN FIRE SAFETY CONTEXT

All of the Brazilian safety regulations and codes are prescriptive in nature **[1]**. Most of these regulations are both extensive and complex, making their interpretation difficult. In reality, Brazil has a national fire code, which consists of a general document and does not contain detailed fire safety requirements **[1]**. Therefore, the detailed fire safety regulations that are regional and applied on a daily basis vary from city to city.

São Paulo is considered to have the most advanced fire code within Brazil and is often used as a model for other city codes. For example, the building code for the city of Recife, in the Northeast of Brazil, is based on the São Paulo code, using the same categorisation of occupancy and many similar sections pertaining to detection systems, fire alarms, maximum travel distances, exit dimensions, number of exits, etc. However, there are also numerous differences between the codes; for instance, while in São Paulo the unit passage width is 60 cm **[2]**, in Recife it is 55 cm **[3]**. These fire codes determine a set of recommendations, which must be followed. For example, the Recife building code specifies that all buildings with a built area greater than 2,000m^2 must have a fire alarm **[4]**. Nevertheless, most of the buildings in Recife do not have any form of fire alarm (automatic or manual). Indeed, the code enforcement situation in Recife appears relaxed, with many public buildings not having smoke detectors, alarm systems or even evacuation procedures in place. This situation can be assumed for much of Brazil. There is much room for development in the areas of fire safety research, education and code development in Brazil (and in Latin-America generally). The “fire safety culture” could probably explain this situation.

The predominate activity in fire research in Brazil is concerned with structural fire resistance (primarily the analysis of concrete failure under elevated temperatures, given that vast majority of construction involves concrete with internal structures of steel) **[5-7]**, explosion research and fire risks analysis **[8]**. It is also important to observe that this is primarily aimed at industrial applications, rather than improving a theoretical understanding of the issues of fire safety in buildings, which include evacuation.

In addition, in Brazil, for the last few years, a strong interest in developing a better understanding of human behaviour and its impact on aircraft evacuation has been apparent **[9]**. Along with a growing interest in fire and evacuation modelling, especially by aircraft manufacturers and energy supply companies, which have been becoming more concerned in fire safety in their power plants.

Nevertheless, in spite of this "apparent" development of the *fire safety culture*, mentioned previously, these efforts are focused on the industrial sectors; therefore excluding the majority of residential or office structures in daily use.

The larger cities in Brazil (e.g., Rio de Janeiro, São Paulo, Belo Horizonte, Recife, Florianópolis, etc) are characterized by their high-rise buildings, which are essentially sky-scrapers built using concrete. Some of these cities have been the scene of numerous serious fire incidents. For instance, in São Paulo, in 1972, the fire in the Andraus building killed 16 people and 330 were injured **[10]**. And also in São Paulo, in 1974, a fire in the Joelma building killed 189 people and more than 320 were injured **[11]**. In Rio de Janeiro, in 1986, another fire in the Andorinha building killed 21 and more than 50 were injured **[10]**.

The investigations of these fires and others in Brazil have shown that the number of fatalities might be reduced if the occupants were aware of the procedures that should have been followed in an emergency fire situation.

It is also relevant to observe that this lack of awareness might represent the perception of fire risks, not only individually, but collectively speaking (i.e., fire safety culture). Based on this statement, two considerations can be raised, namely: the occupants were unaware of the procedures because they neglected these procedures; and also the occupants were unaware of the procedures because these procedures were not clear to them. As mentioned before, in a way or another, this might be the consequence of the fire safety culture; which influences the individual behaviour and clearly the collective behaviour (i.e., the entire society) and vice-versa. (This will be discussed in further details in section 5 of this paper.)

2.0 HISTORICAL ANALYSIS OF THE DEVELOPMENT AND IMPLEMENTATION OF FIRE SAFETY CODES IN BRAZIL

As mentioned previously, Brazil has witnessed fires in enclosed environments along its history as a new country. Some of these fires have caused big impacts, which generated social and economic losses to the nation.

As consequence of these disasters involving fires, fire safety codes started to be developed and improved. The creation of the ABNT (Associação Brasileira de Normas Técnicas – Brazilian Association of Technical Regulations) in 1940 represented an important step in the safety process and more particularly in the fire safety context. Furthermore, the ABNT became a starting point for the development of safety codes in general in Brazil which enabled the technological progress in many sectors and also the effective participation of the nation in the international safety regulations committee **[12]**.

In the 50's, the fire safety codes in São Paulo requested that designers should provide to the local fire brigades the architectural plans of the building. The fire brigade authorities were then responsible to analyse these plans for defining where the extinguishers should be installed **[13]**.

In the 60's, the laws n. 6.235 of 25th of August of 1961 and n. 8.563 of 31st of December of 1964 were approved. These laws specified the parameters for installation of fire hydrants and extinguishers. These laws were very basic and reactive in nature instead of being preventive and proactive laws. They were used until the beginning of the 70's when two major catastrophic fires occurred in buildings located in the centre of São Paulo city: the fire in the Andraus Building in 1972 and the fire in the Joelma Building in 1974.

These two fires have caused hundreds of deaths and injured people, as mentioned in the previous section, which have shocked the public opinion and raised the discussion on fire safety in buildings. Several failures on the fire safety of these buildings, not only in terms of physical devices but also in terms of fire safety procedures, were observed. These buildings facilities did not have emergency stairway; neither fire-walls; nor emergency

signage or emergency routes. Besides that, for the Joelma building, the fire spread vertically through the external glass windows of the entire building.

On the other hand, these two major fires made the society more aware about the fire risks within enclosures and their consequences. For this reason, the "Departamento de Defesa Civil" (department of civil defence) dedicated to study and propose alternatives for providing the safety of the population, including the prevention of fires, was founded within the Economy and Planning Secretary of the São Paulo state. This served as a model to the other states in Brazil.

On the 30th of September of 1975, the law n.684 was published. This law authorized the government to establish associations with the local authorities in the cities in order to improve the fire safety measures in terms of prevention and extinction of fires. This law has also replaced the previous laws (i.e., n. 6.235 and n. 8.563), since they have shown to be inefficient during the fires which occurred in the Andraus and the Joelma buildings.

In 1976, in the state of Rio de Janeiro, the state law n.897 of 21st of September of 1976 established the fire safety protection regulations addressing issues such as: "panic" behaviour of occupants, installation of sprinklers systems, installation of fire doors, definition of emergency stairways, installation of extinguishers, fire safety in car park buildings and fire safety in assemblies. This law was official until the 15th of March of 1994, when some improvements of this law was made according to the resolution n.142.

In 1978, probably as consequence of the fire in the Joelma building, the "Normas Regulamentadoras – NR" (regulation laws and standards) was defined through the law n. 3.214 of 8th of June of 1978. Amongst the different NR's, the NR 23 was defined. The NR 23 was dedicated to fire protection. In general, the NR 23 defines issues such as: revetment of walls and doors; construction of fire-walls; occupants' circulation within the enclosure facilities; protections of the corridors and the emergency exits; use of emergency signage and besides that the NR 23 has also defined the legal penalties to the building designers/engineers responsible to the fire safety of it if they did not follow these measures **[14]**.

In 1981, another fire has occurred in the Paulista avenue in São Paulo city. The fire happened in the Grande Avenida building, a 23 multi-storey building. Because of this fire, 17 people died and 53 were injured. This fire has shown that the existent law should be updated. And in 1983, the state law n.20.811 was established. This law defined several issues, such as: the use of emergency stairways; fire-walls and fire-doors; emergency routes etc.

In 1986, a fire occurred in the building of the CESP (Companhia Energética de São Paulo – company for the energy supply for São Paulo) in São Paulo. During this fire, one of the towers of the building burnt from the first floor to the top floor because of the vertical propagation of the fire. Probably because of this, the law n. 38.069 was established. In this law, the definition of how to define and build fire-resistant materials was presented.

In the early 90's, the foundation of the "Comitê Brasileiro de Segurança contra Incêndio" (Brazilian Committee for Fire Protection) represented another important step for the fire safety in the Brazilian context. This committee was responsible for the definition of several aspects within the fire safety, namely: the development of the fire design; analysis and evaluation of constructive materials resistance performance to fire; methodology for laboratory tests; terminology of fire safety concepts etc.

During the subsequent years after the establishment of the mentioned laws, it was observed that the number of fires was still growing in Brazil. The Figures 1 and 2 present graphs which show this increase in the two major states in Brazil, namely São Paulo and Rio de Janeiro.

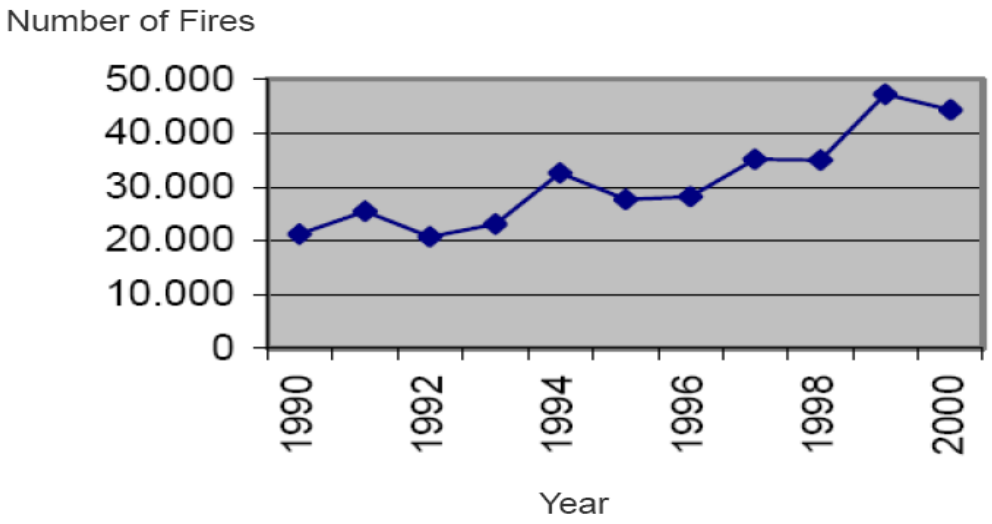

Figure 1: Number of Fires in São Paulo from 1990 to 2000 (based on the São Paulo fire brigade statistics)

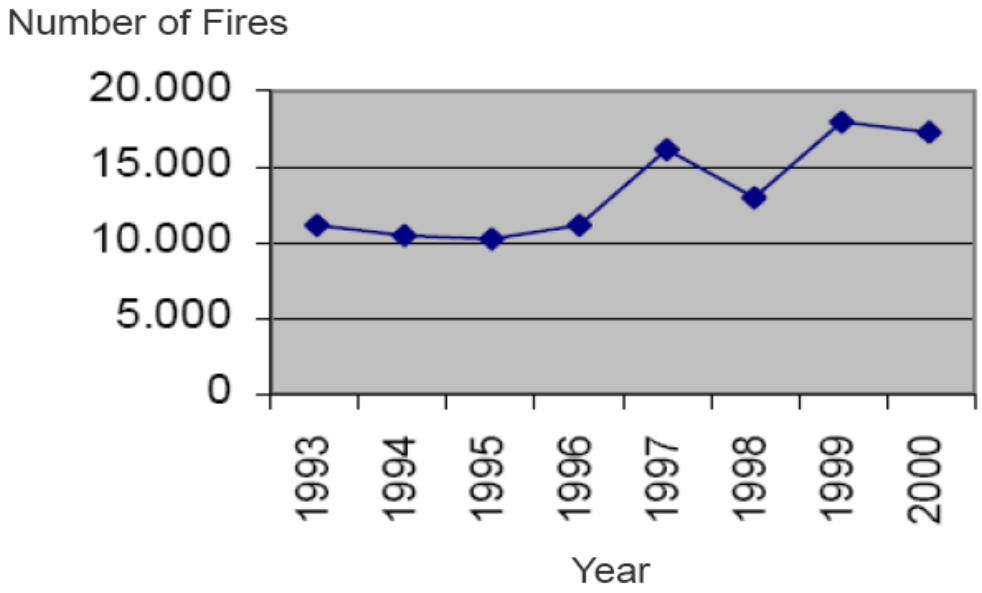

Figure 2: Number of Fires in Rio de Janeiro from 1993 to 2000 (based on the Rio de Janeiro fire brigade statistics)

Because of the increase in the number of fires over these years, new laws, laws n. 46075 and 46076, were created in 2001. Some important issues which were covered more emphatically were: smoke control, safer means of escape through the definition of maximum travel distance and the avoidance of dead ends and also means of rescue. Besides that, the need of training for the building staff in case of emergency evacuation situations was discussed in these new laws **[16]**. (Nevertheless, regarding the evacuation training, it is important to observe that evacuation trials are still rarely performed in Brazil **[15]**).

Based on that, it is true to conclude that the fire safety codes in Brazil are a result of past fires experiences. In other terms, along its history on fire safety, Brazil clearly has showed a reactive posture in terms of fire safety rather than a preventive and proactive approach.

And additionally, despite these new laws, the fire safety in Brazil seems to have not improved much since then. Accidents involving fires (and also explosions) in commercial buildings, small and medium shops, shopping malls, night clubs, metro undergrounds and even Churches have being occurring since these new laws were established.

For instance, on the 11th of January of 2001 in Rio de Janeiro, a fire occurred during the filming of a TV show for children by the biggest TV-company in Latin-America. During that day, 300 people, including several children were in the studio. In total, 26 people were injured, 7 severely. The studio was full of combustible materials, such as: polyethylene; polymers; polychlorethane etc. The emergency exit was locked. During the fire, no fire alarm was activated neither any sprinkler system **[16]**.

More recently, on the 17th of July of 2007, a fire occurred in one of the terminals of the Santos Dummont Airport in Rio de Janeiro. The fire started in the 3rd floor of the terminal and the smoke spread quickly through the terminal. With this many flights needed to be cancelled **[17]**.

And again in 2007, on the 25th of December, a fire occurred in the "Hospital das Clínicas", one of the major public hospitals in São Paulo. The fire started from a short-circuit in the basement of the hospital and the smoke spread quickly to the other floors. Surgeries needed to be stopped, patients needed to be removed from the hospital facility and two people threw themselves from the 1st floor. A building close to the hospital needed to be evacuated too, given its proximity to the hospital **[18]**.

These fires have not caused any deaths and injuries, but have resulted in several other direct and indirect losses, such as interruptions of local transport system; interruptions on the telephone line system; stress to the local society and negative image for national and international tourism. Therefore, fire safety is a crucial factor within emerging economy nations like Brazil.

3.0 THE MAIN CHARACTERISTICS OF THE PRESCRIPTIVE AND PERFORMANCE-BASED CODES

Nowadays, most developed countries, such as some North-European countries (like the UK and Sweden), Australia, New Zealand, the USA, Canada and Japan had already started to change their fire safety codes from a prescriptive approach to a performance-based one **[19-22]**. The performance-based codes attempt to provide clearer guidance than the prescriptive codes taking into consideration the actual growing complexity of the architectural designs, which introduces more fire risks. This is one of the main reasons why most of the mentioned countries are in an advanced stage of development and implementation of performance-based codes.

There are a large number of papers in the literature about fire safety codes; therefore this paper is not concerned with explaining specific details of such codes. For this reason, in this section, only a brief summary is presented regarding the main features of these fire safety codes.

The prescriptive codes, as the name suggests, prescribe sets of measures to reach the fire safety in enclosures. Nevertheless, these codes do not explain how to reach the fire safety, since they do not provide clear guidance on how to develop and assure it.

As a consequence of it, the costs of fire designs based on prescriptive codes usually have the tendency to be high. And besides that, in some cases, the recommendations suggested by the prescriptive codes do not provide for the safety of the occupants. The Table 1 presents the main advantages and disadvantages of the prescriptive codes.

Differently from the prescriptive codes, the performance-based codes are more flexible and dynamic, since, as the name suggests, they are based on the performance of all the main aspects (i.e., fire; enclosure and occupants) and their interactions: fire-enclosure; fire-occupants; occupants-enclosure and occupants-occupants. With that, the criteria to develop the fire design are defined by the designer/engineer **[19]**. The Table 2 presents the main advantages and disadvantages of the performance-based codes.

Table 1: The main advantages and disadvantages of the prescriptive codes

Advantages	Disadvantages
Direct analysis, i.e., direct interpretation of the requirements	Specific recommendations which sometimes are not clear
Fire safety engineers with more specific qualifications and/or skills (such as evacuation modeller; CFD modeller etc) are not required	The codes structure is complex
	It is more difficult to develop safe design with reduced costs, and there is no flexibility in terms of requirements completion
	They are not much open to technological innovations or alternative solutions

Table 2: The main advantages and disadvantages of the performance-based codes

Advantages	Disadvantages
The establishment of the fire safety objectives is clearly defined and the fire safety engineer has the freedom to define the criteria and methodology to achieve them	It is difficult to define the quantitative criteria (i.e., performance criteria)
They are flexible for introducing innovative solutions	Training might need to be necessary, especially during the first phases of implementation
Harmonic to the international codes	It is difficult to analyse and evaluate the “equivalent project”
They enable the development of fire design with the reduction of the costs	There are difficulties in validating the methodologies used when defining the quantitative criteria
Introduction of new technologies in the fire safety market	

It is clear to see that the performance-based codes do provide more advantages when compared with the prescriptive codes.

In spite of this “worldwide movement towards performance-based codes”, in Brazil, the fire safety codes are based on a prescriptive approach. The possible reasons why this is happening will be discussed in section 5 of this paper. In the next section, some other countries experiences in developing and implementing the performance-based codes are briefly explored.

4.0 EXPERIENCE OF SOME COUNTRIES IN DEVELOPING AND IMPLEMENTING THE PERFORMANCE-BASED CODES

According to what was mentioned previously, some countries have already started to change their fire safety codes from a prescriptive approach to a performance-based one. It is important to observe also that before this process starts to take place, a “transition process” is required. In this transition process, the performance-based codes development will be evaluated to check if it will provide at least the same fire safety which the previous prescriptive code used to provide. This evaluation is commonly called as “equivalent code”. This is a very important step indeed. If the equivalent code shows that the future performance-based code will not provide the sufficient fire safety guidance, then the code will need to be revalidated. Figure 3 illustrates this process.

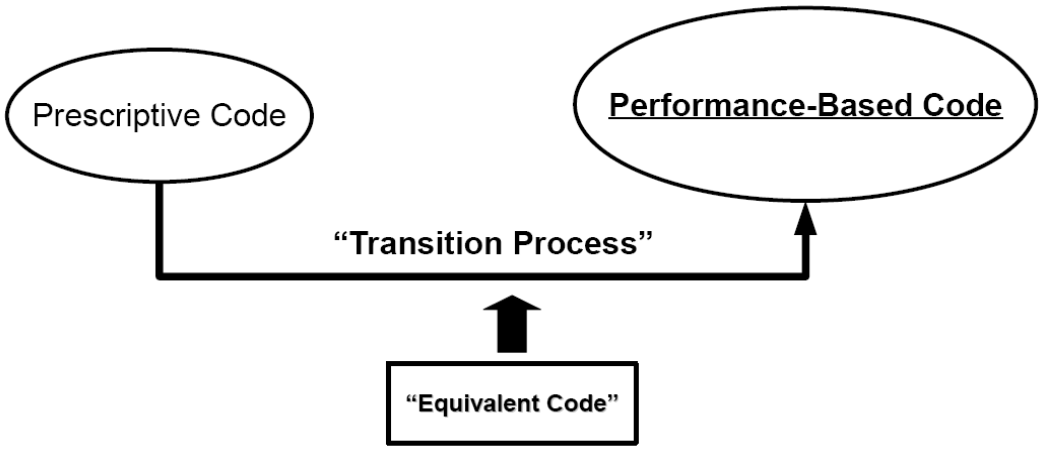

Figure 3: The transition process during the change from a prescriptive code to a performance-based code

This process is not as direct and trivial as it seems to be. In fact, there are many factors which influence directly and/or indirectly on the success of the development and implementation of performance-based codes. For instance, some factors can be mentioned such as: fire safety education (which is associated with the perception of fire risks); nation history on fire/emergency accidents; types of law; enforcement of law and also socio-political context of the nation. It is interesting to observe that these factors are in a way or another associated with the fire safety culture (this issue will be discussed later on this paper).

The countries mentioned before, (i.e., the UK, Sweden, Australia, New Zealand, the USA, Canada and Japan) which are in advanced stage of developing and implementing the performance-based codes, have been already victims of fires which have caused big economic losses.

Despite that each country has its own identity and inner culture, it is possible to establish, in general terms, some basic conditions; which can be taken as criteria for evaluating if the performance-based codes were well implemented or not, see Table 3.

Table 3: Some criteria for evaluating if the performance-based code is well implemented or not well implemented

Well Implemented	Not Well Implemented
There is perception of fire risks by the society	There is no perception of fire risks by the society and/or the perception of fire risks by the society is not "adequate"
The fire safety codes are central; i.e., there is only an unique regulation for the country	There are several fire safety codes in the country, which vary from state to state and/or from city to city
There is a government support	There is no government support

A brief analysis of the experience of some of the mentioned countries previously in developing and implementing performance-based codes will suggest that Japan has been succeeding in this process; while the USA has been passing through some problems in this matter.

In the Japanese experience, it is possible to see that the performance-based codes are being well implemented because the mentioned criteria in table 3 are observed in their national context. For example, in Japan they have a federal department, the Ministry for Construction. This ministry is responsible to evaluate, develop and implement the performance-based codes **[23]**.

Another factor which also does help Japan in this process is their small national territory which makes easier the use of a central fire safety code for the whole country.

Besides that, probably the Japanese experience on emergency situations along its history because of earthquakes might have helped to develop perception of risks of accidents, which include fires.

Differently from Japan, in the USA, the development of fire safety codes is the responsibility of public and private sectors. Additionally, the fire safety codes vary from state to state, like their laws in general. Furthermore, the USA is probably the only country, amongst the most developed countries, that does not have substantial government support for the fire safety issue in buildings **[23]**. Probably this is why the USA when compared with the other developed countries, in terms of development and implementation of the performance-based codes, are still behind them.

Clearly, the USA has been contributing largely to the fire safety community on a global scale. Their research centres and universities as well as their specialized big companies have been promoting the development of new technologies in fire safety and the understanding of fire through science. The NFPA (National Fire Protection Association); the NIST (National Institute of Standards and Technology); the SFPE (Society of Fire Protection Engineers) amongst others show their importance for the fire safety community.

Nevertheless, in reality, fires are still a major problem in the USA. According to the USA government, in 2005 it was estimated that 3.677 people died (fire kills more people in the USA than all other natural disasters together) and 17.925 were injured in fires. And the estimated value of economical losses because of fires is US$ 10,7 billion **[24]**.

5.0 DIFFICULTIES IN IMPLEMENTING PERFORMANCE-BASED CODES IN BRAZIL

Based on what was discussed in the previous section, it is clear to observe that the difficulties in Brazil for developing and implementing performance-based codes are immense. For example, there is no support by the government to specific guidance in terms of fire safety. Besides that, despite having a national fire code just like its national constitution; as mentioned previously, the specific and detailed fire safety regulations are regional (vary from state to state) and quite often they also vary from city to city. Additionally, similarly to the USA, its vast territory (8.547.403km2 **[25]**; which is divided in 27 states spread along its 5 main regions) makes more difficult the implementation of performance-based codes.

Furthermore, Brazil is a new nation (508 years, but it started to be populated in the end of the 19th century when urbanization started to take place effectively), which used to be a rural country and became, in a very short period of time, an urban and industrialized society. This sudden change generated, amongst other problems, an increase of fire risks. Just in order to provide an idea, the population for the whole country was estimated as 9.94 million people in 1872 **[26]**; and in 2007 the population size was estimated as 191.8 million **[27]**. This means that the population size increased by 182 million people in 135 years; and it is still growing. It is also important to mention that the main cities, like São Paulo (population estimation: 19.3 million **[26]**), Rio de Janeiro (population estimation: 11.6 million **[26]**) and Recife (population estimation: 3.8 million **[26]**), are densely populated and this is where the big fires happen.

Apart from these mentioned factors, the main direct factors which represent difficulties for the development and implementation of performance-based codes in Brazil are:

- the existent fire safety codes are not well known;
- the existent fire safety codes are not applied efficiently;

And there are other factors which can be also mentioned as “indirect barriers” for developing and implementing performance-based codes in Brazil, namely:

- the “fire safety culture” is not appropriate;
- the fire safety industry is attached to a prescriptive approach;
- most of the engineering and architecture undergraduate courses do not cover fire safety engineering in their curriculums;
- there are very few research groups dedicated to fire safety engineering;
- there is a lack of specialists in fire safety engineering.

Regarding the fire safety culture, this is a complex issue to analyse, since it involves the perception of fire risks and this is associated with fire education. In Brazil, safety culture (which includes fire safety culture) over its

history of accidents in general, is not a major matter for the public sector. Consequently, the private sector is influenced by this posture and as a final result the whole society is influenced by that. It seems that “bad things” need to happen for then some kind of safety measure to be done, as discussed in section 2 of this paper. This posture generates a fire safety culture within the Brazilian context, which seems to be not appropriate, since the society is not aware of the fire risks. The fire safety culture is an issue which should be more explored. (The author has started to collect data based on evacuation trials in order to understand human behaviour in emergency situations within the Brazilian society comparing with the British society **[15]**. A similar study was also conducted in which comparisons between the Brazilian and the Japanese societies were made based on evacuation trials **[28]**. These kinds of studies are potentially helpful in order to bring some light on this issue of fire safety culture).

In summary, taking into consideration all these issues as well as the historical of fire safety codes in Brazil, as discussed in section 2 of this paper, it is correct to say that Brazil might not be prepared yet to develop and implement performance-based codes. And it is also relevant to mention that those countries (which are in advanced stage of development and implementation of performance-based codes) do have a solid history on fire prevention. And additionally, their previous prescriptive codes were well implemented and properly used. And this does not seem to be the case observed in the Brazilian context as discussed along the previous sections of this paper. These factors can be described as the main reasons why Brazil does not follow the “worldwide movement towards performance-based codes”.

6.0 CONCLUSIONS

Therefore, “which is the best practice for fire safety in Brazil: the prescriptive codes or the performance-based ones?” For the reasons explained in this paper, the most adequate fire safety code in Brazil at the current moment is the prescriptive code. Without any doubts, the fire safety codes which follow a performance-based approach are a better practice and a natural path to be followed; however for Brazilian fire safety context, this is not the best practice yet.

First of all, the prescriptive codes in Brazil should be improved and their use should be reinforced strictly.

Besides that, the perception of fire risks (which is associated with the fire safety culture) does impact on the development and application of legislation in general **[29]**, including the fire safety codes. And as discussed before, the fire safety culture in Brazil does not seem to be in harmony with a performance-based approach, where the freedom given to the fire safety engineers/designers could have negative consequences based on the lack of enforcement of the law. And also, the fire safety community in Brazil is not yet prepared to deal with the disadvantages which the performance-based codes have, such as the requirement of fire safety engineers with more specific qualifications and/or skills (such as evacuation modeller; Computational Fluid Dynamics modeller etc), see table 2.

In general terms, a first step for developing a fire safety culture in Brazil is to promote fire education in schools (for educating the future generation) and in the media (for educating the society as a whole). Something similar has been already started in relation to other issues such as sexual transmitted disease, social violence, drugs and drinking and driving, and the results have shown to be positive. Just like these issues, fires do also generate big social and economical losses, which are not desirable in an emerging economy country like Brazil. This is a challenging task indeed, nevertheless it is necessary to start to improve the fire safety in Brazil and for a future development and implementation of performance-based codes.

In this process, academia does play an important role.. In fact, some fire experts in Brazil, some of them with international experience in the fire safety community, have started to contribute their efforts to this process. A recent book was published in portuguese adapted to the Brazilian context by these experts **[24]**. This book covers the principal topics found in fire safety engineering: from human behaviour in fires to fire dynamics. This represents a good start point.

It is expected that this paper could bring some light on how to improve fire safety in Brazil and also in similar fire safety cultures, eg. other nations in Latin-America. It is also expected that some more studies should be conducted in the Brazilian society in order to collect more data on fire safety, since there is little or no data in this area from Brazil.

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