Evaluating Probability to Amend Prescriptive Fire Codes to Performance based Fire Codes in India

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ABSTRACT

Over the last few decades, the worldwide fire protection community has made large strides in improving building fire safety. Advancement in fire safety technology with the help of development of design using analysis tools had not only helped us understanding fire dynamics in a better way but also had transformed the conventional approaches. These changes had certainly contributed in improving building and fire codes. This paper will provide an overview of prescriptive fire codes and performance based fire codes and identifies some potential factors which might drive India to consider a transition to performance based codes which is already receiving a widespread acceptance in most of the countries in the world.

Keywords  
Fire Codes, Prescriptive codes, Performance based codes, Building codes

INTRODUCTION

Building codes are law or regulation that sets forth minimum requirements for design and construction of buildings and structures; these are adopted with the aim to establish health, well-being and safety of society. (Cote A.E., 2008). These set of rules also attempt to represent society’s compromise between optimum safety and economic feasibility. (Worcester Polytechnic Institute, 1999). These are to be applied by various professionals like architects, engineers, constructors & regulators but are also used for various purposes by the safety personnel, environmental scientist, real estate developers, insurance agencies and others. Though professionals, builders and building owners regularly determine their own requirements, however the minimum requirements as mentioned in the code of the regulating authorities of that area must be followed. Aspects obeyed are like structural design, sanitation, interior finish, fire protection, and means of egress. These building codes become law of a particular jurisdiction when formally enacted by the appropriate government or private authority.

There are two general types of building codes pertaining to fire safety & fire protection. The first type is ‘Specification or prescriptive codes’ that spell out in details what materials can be used, the size of building size, and how components should be assembled as presently being followed in India and is majorly followed in the world. Second type is ‘Performance based codes’ which is a contemporary approach where an objective is determined and is verified by confirming pre-established performance criteria based on engineering analysis. Here the builders and designers are free to select construction techniques and materials providing it meet the requirements of performance criteria.

Though the prescriptive codes is followed in most of the countries of the world, whereas others countries had already transformed to performance codes which claims to have better advantages.

OBJECTIVE

The objective of this study is delineated as under;
1. Understanding Prescriptive fire codes & Performance based fire codes.
2. The basic advantages and disadvantages of both the codes.
3. To explore methods for India to transform from Prescriptive to Performance based fire codes.
PRESCRIPTIVE CODES

The majority of building codes and fire safety standards used today are considered prescriptive. Prescriptive codes get their names from the fact that they specifically advise or ‘prescribe’ what is to be done in a given case. This approach to building design is embodied in the National Codes and International Codes, which have the status of guidelines, and are developed over the years by empirical judgment of few fire professionals, learning the weakness of the building against fire.

Prescriptive codes determine the minimum fire safety requirements based on occupancy and are generic in nature. They also specify certain construction features, limiting dimensions, or protection system without mentioning that how these prescriptions are achieving the desired fire safety goals. The level of safety or overall loss potential is also not defined in prescriptive codes. (NFPA Inhouse Task Group (PBCS), 1995)

Important codes being followed by various countries in the world have given elaborate fire safety requirement for the buildings. Few of these codes which are based on this approach are NFPA 101 Life Safety code, U.K. Approved document ‘B’, Japanese Building Safety Law which are being comprehended by various other countries in order to prepare the model code for themselves. If all the requirements mentioned in codes are fulfilled then the fire officials may consider that the building has complied with the prescribed provisions within the scope of active fire protection and treat it as safe. Though there is no clear reasoning behind the requirements along with the aim of the code.

In spite of the fact these regulations have contributed in improving fire safety levels in the buildings, the provisions are considered exorbitant and complex as these requirements as quoted in the previous example are supplemented with various product & implementation practices sometimes leading to the use of ‘rule of thumb formula’. This so called ‘rule of thumb formula’ being formulated by the so called ‘experts’ converts the whole complex procedure so simple and easy to implement because of the virtue of its generic nature.

Thus, we may say prescriptive based fire codes are product bias and also they more rely on visual inspection and enforcement. Whereas mostly these are easy to implement, very easier to verify and provide assurance to the designer or builder as they are usually developed around well-established products and practices.

This approach not only limits the flexibility of the designer along with curbing down his or her innovation, but also incurs high cost on its application.

Further, these prescriptive fire safety codes are not quantified to determine what level of fire safety is achieved in the buildings and what level of fire safety must be attained.

Advantages of Prescriptive Codes

Prescriptive codes are laid down in a manner that directs exactly how a building is to be constructed. This is an advantage when the construction of a building is underway because there is no analysis to conduct, the designers merely have to categorize the building appropriately and follow the applicable codes (Babrauskas, 2000).

Another advantage to prescriptive codes is that they provide an acceptable level of fire safety in buildings following common ‘standard’ design patterns. Prescriptive code lay down the exact requirement in each case with minimum interpretation.

These codes are very easy to implement as there is no integral analysis which is required to enforce them. Therefore, fire safety professionals with more specific qualifications and skills are not required as the officials can easily check certain measurements and specifications as per the checklist or guidelines mentioned in the codes or standards.

All the above factors make it simple to decide that has the code been met or not. However, the prescriptive codes are not perfect which explains the requirement of exploring another approach.

Disadvantages of Prescriptive codes

The major disadvantage of prescriptive codes is the lack of flexibility. This inflexibility leads to numerous other drawbacks. The designs created are most of the times tends to be high on cost factor due to the fact that prescriptive codes may not permit the use of any cheaper alternate design solutions. These detailed requirements tend to make it easier for the designers and builders to design more ‘standard’ buildings, but
falls outside the more complicated buildings which do not offer design flexibilities. The high-risk occupancy such as sports arenas, multiplex, mixed occupancy, skyscrapers or large atria which are mostly in trend, merely cannot be built considering this approach because codes do not cover them. Because of the vast sizes of these buildings, emergency planning for such special cases requires to take into account the complexities that are assumed to be covered in these codes and these issues therefore makes the implementation of prescriptive codes either very difficult or most of the times impossible (Hadjisophocleous and Bénichou, 2000).

PERFORMANCE BASED CODES
As discussed earlier that the prescriptive codes suitably work well for ‘typical’ or ‘standard’ building design, they can be inappropriate for the buildings having modern designs, and when the regulatory infrastructure is incapable of addressing any other alternative solution this can hinder the progress of rapid development, Urbanization, densification and the desire to have a ‘world class’ buildings. To counter this many developed nations have already shifted from prescriptive–based to performance based regulations & design approach and have adopted them in their regulatory codes and becoming the pioneers in enforcing the Performance-Based Codes. This ‘Worldwide movement towards performance based codes is because they provide more advantages than the prescriptive codes.

A performance-based code is defined as an approved formal document that illustrates requirements for health, safety, and amenity in a building through a set of flexible defined societal goals, functional objectives, and performance requirements (Wong, 2008). These codes are designed having fire safety solutions where fire safety solutions are devised to achieve ‘specified goal’ for ‘specified use or application’ (NFPA Inhouse Task Group (PBCS), 1995).

The use of an alternate solution allows the fire safety engineer to design the building using fire engineering rather than relying on prescriptive ‘empirical based’ rules. Some codes contain performance requirements and but fire safety engineer can put forward alternative solutions to satisfy the requisite standard or even better solution. In case, if the building does not comply with the regulatory fire safety provisions, performance based design could find another appropriate and convenient option.

Fire Engineering relies on the principles of fire science, human behaviour and risk management. The key components of performance based approach consist of design fire, safety criteria and fire models. The objective fire safety planning is specified and several fire models can be established for a predetermined condition for design of fire. The prescribed technical standards are taken into consideration for the conformity whether the desired level of fire safety is achieved or otherwise. This process requires the fire safety engineer or designer to think through the issue of;
Fire ignition growth and spread
The location of people in the building and their state
How people will become aware of a fire and what they might do
How quickly people can get out
How fire might develop
How smoke will be generated and could spread
How the smoke and fire might affect people
How the building material will respond to the fire

These considerations will allow a fire safety solution to develop suited to the particular building and its use.

Performance Based Design Process
As described by In-house task group of National Fire Protection Association on performance based codes and standards is a design process in which solutions with regards to fire and safety are designed to achieve specified goal for a specified use or application. This process enables performance-based documents to be enforced and ensures that the goals are met.

Before discussing the various steps of performance based procedure in order to appreciate in a better way, following important terminologies are to be understood which are related to the same.

Fire Safety Goal
The purpose or objective towards which the effort is directed is termed as ‘Goal’. When the goal is based with regard to fire safety we may term it Fire Safety Goal. The goal should be nonspecific and must be qualitative based. These goals should also be potentially measurable even if the exact scale is not identified. Thus, goals may be expressed in terms of impact on people, property, or the environment, or in terms of mission continuity. This goal may be manifested in different ways, the six categories of fire safety goal which could be expressed in a performance based document is as mentioned below in the figure 2.

Fig2: Categories of Fire Safety Goal

Performance Objective
The fire safety objectives of performance-based codes and standards are expected to be more specific than fire safety goals i.e. ‘more quantitative rather than qualitative’. The performance objective is the link between the fire safety goals & performance criteria. Thus, we may say that performance objective helps us to define the sequence of actions needed to attain the overall fire safety goal. The basic difference between the fire safety goals and objectives, the performance objective precisely speaks about the issues that need to be addressed.
Performance Criteria
The performance criteria follow the performance objectives for individual products, systems, assemblies, or areas and measuring them into engineering term. They are directly “measurable” (i.e., by experimentation, analysis and/or calculation)

It is a standard, rule, or test on which a judgment or decision can be made in order to confirm that the performance objective is achieved and subsequently attaining the associated fire safety goals.

<table>
<thead>
<tr>
<th>Examples of Performance Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention of structural damage</td>
</tr>
<tr>
<td>No life loss in the room of fire origin</td>
</tr>
<tr>
<td>Separating occupants from fire effects for “a specified period of time”.</td>
</tr>
<tr>
<td>Containing the fire to the room of origin</td>
</tr>
</tbody>
</table>

Fig3: Examples of Performance objectives

Safety Factor
It is the conservative adjustment made to the actual value achieved after any experiment or analysis for the sake of safety to counter any ambiguity in the methods and possibilities employed for measuring the performance.

Fire Scenario
Once the potential hazards inside the building are identified, the worst credible fires are assumed fire scenarios. Depending upon the characteristic of the building contents and the enclosure, a design fire is determined for analysis.

Fire Model
Fire models are calculation tools that contain engineering and scientific principle. As these principles are complex in nature therefore they are packaged as a computer model. These computer modeling programs are predominantly used in performance based fire safety design for improved and faster computation methods. However apart from computer model these principles could also be verified by using hand calculations and mathematical formulae. Relevant input data are compared through Proposed Solution.

Proposed Solution
A proposed design aimed to achieve the predefined goals and objectives known as proposed solution and are needed to comparison with the relevant input data so that the results may be calculated and actual variance is analysed.

Verification
Here verification means that the proposed solution or design achieves the level of safety as demonstrated by ‘qualified people using correct methods’ once compared with the input data. If it matches the predefined level of safety then the process is said to be verified or if it does not, then the input data is corrected to get the required result and anomalies are further rectified to match the desired result.

Performance Based Design Procedural Steps
There are 9 steps required to be followed to establish any performance based code or standard as described by (NFPA Inhouse Task Group (PBCS), 1995). (See figure 4 below)
Fig4: Procedural steps for establishing performance based codes

STEP-1: Establish Fire safety goals

STEP-2: Evaluate the condition of the occupants, building contents, process equipment or facility

STEP-3: Identify potential hazards

STEP-4: Define appropriate fire scenarios

STEP-5: Establish performance objective & performance criteria

STEP-6: Select suitable calculation method (eg. Fire models)

STEP-7: Develop a proposed solution

STEP-8: Assess the proposed solution

STEP-9: Obtain approval of the proposed solution
Advantages of Performance based codes

Though initially during the beginning of the codes as recorded in history, Codes of Hammurabi were the oldest performance based codes and slowly kept on revising with the experience after each fire and became what we call prescriptive codes. But now in the new millennium the codes are transforming back to performance based codes due to its various advantages. These advantages can be summarized as follows (Hadjisophocleous, Be’ nichou and Tamin, 1998):

- Stating clear fire safety goals and allowing the designer to achieve those by whatever means.
- The designer is allowed to have innovative design solutions in order to achieve the recognized performance requirements.
- The technical barrier to trade is eliminated for smooth flow of industrial products.
- This approach harmonizes with International codes.
- It encourages the use of new knowledge as it becomes available.
- Due to applying performance based codes the design becomes more flexible and cost effective.
- It assists in prompt introduction of new technologies to the market place.
- Eliminating the complexities of existing prescriptive codes.

Disadvantages of Performance based codes

The disadvantages of Performance based codes are largely associated with the design fire scenarios. The development process of fire scenarios requires the engineer to consider several features of the building and its occupants. Frequently it is required by the engineer to make suppositions about these features as well as other required inputs in the fire model. These assumptions have integral doubts that can affect the validity of the design fire if not properly planned. Implementation of performance based codes can be a question due to the independent nature of the codes. The specific requirements will vary for each building and will most of the times need exhaustive analysis by officials with adequate training and experience.

Advantages
- Tailoring fire safety measures to risk and specified goals.
- Freedom to define performance criteria
- Harmonic to international code.
- Cost effective
- Permit innovative solutions
- Enable introduction of new technology
- Not product bias
- Flexible

Disadvantages
- Enforcement is difficult
- Difficulty in designing performance criteria & fire scenerio
- Require high level skills

Fig5: Advantages and disadvantages of performance based fire codes
Prescriptive codes V/s Performance based codes

As per International code council (2000) prescriptive codes are defined as “The minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from the fire hazards attributed to build environment.

David Nuss (1994) penned it as a rigid set of requirements and regulatory system that has difficulty in accommodating the new materials, new designs and new expectations on both cost and safety”. Prescriptive codes attain the basic purpose of safety be the use of particular requirements which are based on construction types and occupancy classification as stated by Brain Meachem in Fire risk and hazards research application symposium in 1998. Though initially during the beginning of the codes as recorded in history, Codes of Hammurabi were the oldest performance based codes and slowly kept on revising with the experience after each fire and became what we call prescriptive codes. But now in the new millennium the codes are transforming back to performance based codes due to its various advantages.

Jack Snell (1993), an engineer at National Institute of Science and Technology described performance based codes as those which allows the designer to use innovative solutions in order to achieve already clearly defined fire safety goals, thus all solutions are permitted which fulfills the requirements of those codes. Puchovsky (1997) further clears about these safety goals when he states that these are based on desired levels of safety or risk and that too is defined at very incipient.

While comparing the two codes Richard Custer and Brain Meachem (1997) states that codes and standards are more generic and are based on occupancy type or past history having no supportive scientific data. These minimum standards may be sufficient for some buildings but may differ in some others. Scott Nacheman (1999) attests this thought further explains the reason behind this is that process of code development has been essentially reactive on the event rather than being proactive in predicting the same. On contrary the aim of performance based code design is meant to deliver a fire safety solution in order to attain specific fire safety goals for a specific use or application (Milosh Puchvsky (1997). Armstrong, Bowman and tubs (1997) mentioned advocated performance based codes due to its proactive characteristic in building standard magazine. This make absolutely clear that the present prescriptive codes and standards are inappropriate as the fire safety and protection level is not clear.

Fig6: Advantage comparison (Prescriptive V/s Performance Based Codes)
When compared in terms of the methodology, the prescriptive codes set forth only the minimum requirements for protection and also these requirements made are generally based on the occupancy whereas, the performance based codes involved entire fire building system interaction considered by the fire safety engineering concepts which exceeds individual code requirements. Armstrong et al (1997) clarify in simple manner that in prescriptive codes design the building is viewed as an individual component whereas on other hand performance based design view it as a system which makes it better during comparison (see figure 6).

**HOW TO TRANSFORM PRESCRIPTIVE CODES TO PERFORMANCE BASED CODES IN INDIA: INDIA’S SCOPE**

As the advantages of performance based codes are more over the prescriptive ones there is a worldwide shift from prescriptive codes to performance based codes.

In our country though exhaustive life & fire safety provisions have being included and described in Part -4 of National Building Code of India-2005, the provisions being only recommendatory and hardly gets implemented except in few states where these have been made mandatory by amending building-bye-laws.

Indian codes are generally prescriptive in nature and set minimum requirements related to fire & safety that are generic by occupancy. Once these ‘minimum requirements’ as guided by the code are fulfilled then local fire officials treat the building as a safe building.

Although this discussion on advantages on performance based codes over the prescriptive codes is relatively recent in India, which has emerged due to the expansion of infrastructural development in the country. In most of the cases designer faces difficulties in complying with the codes in the newer buildings which are large and complicated such as multiplex, sports arenas, mixed occupancies. These buildings require performance based design to meet its goal and objective. For instance, our prescriptive based Indian code requirement of travel distance may mandate for a particular class of occupancy, performance based approach may include evacuate or relocate or defend in place strategy for sufficient time so that occupants are not exposed to likely untenable environment.

Another drawback of Indian codes is that it does not easily amalgamate with the new revisions when the new revisions are to be executed in the building and make the situation again complex. For example, the buildings which were constructed before 90’s lacked in segregation but with evolution in the fire safety industry and better revised codes this issue had been addressed in the newer building. Many old buildings can be seen having unsegregated lift lobbies from other areas, whereas the revised code requires to have segregation by 2 hrs fire doors in order to prevent ‘funnel and flue effect’ which may be created, inducing an upward spread of fire to prevent spread of fire and smoke (clause 4.2.9 NBC part -4). Irony is that though as per new code the older buildings does not match the compliance but still the building gets ‘no objection certificate’ from the local authorities and given the same status from fire safety point of view as it is given to the new one. This ‘level of safety’ is therefore not quantified nor can it be determined in the present codes. The verification is only based on the assessment done by the ‘local fire officials’ responsible to the risk assessments as per the required frequency in their respective jurisdiction. They ignore such anomalies as it had been overseen by their predecessors in the darkness of unawareness.

One must admit that the newer revised codes (NBC-part 4; 2005) has the basic essence of performance based codes i.e. it has basic goal and defined objectives which are mostly based of the fire safety engineering logics but somehow the only evaluation of these codes is to completely follow them. This process makes them very rigid, product bias and ambiguous most of the times. Therefore, and alternative method shall be incorporated in the codes based on engineering approach in order to verify the goals, objectives and performance criteria and make it more flexible and worthy.

The similar methodology had been adopted Australian Building Codes Board and had successfully incorporated performance based into their system. The Australian Building code (BCA90) was fundamentally prescriptive similar to Indian national building code, although with the amendments, about fifth of BCA90 clauses were considered to be performance based. BCA 96 included the technical requirements of BCA90, with a ‘performance hierarchy’ built around them.
This performance hierarchy consists of four levels (see figure 7 below):

![Hierarchy chart of Australian Building Code](image)

**Fig.7: Hierarchy chart of Australian Building Code**

a) Objectives: The objectives of the community generally refer to the need to protect people and property and protect adjoining buildings.

b) Functional statements: This refers how a building could be expected to satisfy the objectives or community expectations.

c) Performance requirements: Suitable level of performance must be met by building functional statement.

d) Building solutions: In order to develop a building solution to achieve the performance requirements, two methods can be followed:

a. Deemed-to-satisfy Provisions. These include examples. Of materials, components, design factors, and construction methods which, if used, will result in compliance with the performance requirements of the BCA96. The deemed-to satisfy provisions are, with minor variations, the prescriptive provisions from the BCA90.

b. Alternative Solutions. An approval authority may still issue an approval if it differs in whole or in part from deemed-to-satisfy provisions described in the BCA if it can be demonstrated that they comply with the relevant performance requirement.

This ‘performance hierarchy’ as developed in Australia shall be taken as model for Indian codes and revised accordingly. This four-tier performance method is already tested and tried method and it provides opportunities for the use of fire safety engineering method as a prime means to demonstrate the compliance with the performance –based code if the Deemed-to-satisfy solutions in present code are not specific as they are in few cases discussed earlier in the paper.

National building codes of India has the potential to transform its existing codes which are more of prescriptive in nature to performance code if this above mentioned approach is introduced and existing codes are revised however in order to properly implement them the system had to undergo certain changes (see figure 8).
Fig.8: The Transition process during change from a prescriptive code to performance based code

START

Existing Codes
Consisting following:
- Defined objectives
- Defined Functional statement
- Designed Performance requirement

Need For Quantification analysis

Yes

Design based on Fire Safety Approach

Define Objective & Design Parameters

Evaluate
- Fire Growth
- Smoke Spread
- Detection & Suppression
- Occupant Response/Evacuation
- Building Member failure
- Fire spread
- Fire department response

Modify Fire safety Options

Results & documentation approval of design

End

No

Design based on Fire Safety Approach

Yes

Performance Criteria to satisfy the design & ensure ‘Equivalency’ to existing codes

Satisfaction of performance criteria

End
The fire safety regulations in India are regional (vary from state to state and to quite extent vary from even from city to city) something similar to the USA. Vast territory in India (3,287,263 km²) there are 29 states and 7 union territories which makes the implementation of performance based codes extremely difficult. Therefore first and foremost requirement in transition process of existing codes to the performance based codes is creation of a uniform, nationally-consistent building code which combines building and fire-safety regulations into one guideline is of utmost importance. At present National building code in India serve only as model code which provide guidelines for regulating building construction and fire safety activities to various state municipalities and urban development authorities. Moreover these codes shall have status of mandatory nature which should be applicable in any part of the country.

In the entire Constitution of India there are just two words “Fire Service” which is listed in schedule 12 that is referred to under Article 243 W which deals with devolution of powers, authorities and responsibilities to Municipalities, etc., by the state legislature. Second important change required is to establish a central based regulatory authority to enforce newly applied codes.

Finally, for enforcing and implementing the fire codes, a qualified manpower having competent fire protection engineering education is vital and understanding of performance based approach is to be inculcated in the syllabus. In our country, the only institute which is conducting fire based courses is National Fire Service College which produces handful professionals every year. The approach today in education is more of reactive based when it comes to fire safety. Thus, another step towards the transition process is establishing a certification program on performance based codes to produce standardized fire protection engineers who are well versed with the concept and application of the concept. There is a urgent requirement of more proactive approach and better understanding of fire risk to appreciate the probability of risk, understand required performance criteria and take necessary alternative solution and validate them.

**CONCLUSION**

The need to transform India built Fire & safety laws and regulations towards achieving safe, habitable, fully protected buildings to avoid loss of life and property cannot be over-emphasized. As there is no doubt that fire protection techniques have to be based on the fire behaviour characteristics of different materials and structural elements in the building along with other active measures to suppress it and control from spreading. The activities pursued by the occupants of any building must also be taken into consideration for assessing the extent of hazards, and methods shall be devised to control these identified hazards. All these are being taken care by well enforced fire codes & laws.

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Most of the countries are shifting from prescriptive to performance based approach due to obvious advantages over the prescriptive approach. Where prescriptive approach is rigid and tend to be very expensive on the budget, performance based approach proves to be very flexible giving liberty to the designers to use alternative solution in order to meet the objectives and goals and also likely to be more cost effective.

In India the National building code is basically a perceptively developed code based on prescriptive approach and can’t be quantified, but also at few of the places its directives are based on engineering approach which gives the code a little essence of performance based to an extent. Hence the importance of transforming the present code in India so as to enable quantification of the performance requirement where the code is silent on the matter and is purely prescriptive. For this we may take Australia as our role model and use their ‘performance hierarchy’ approach model and amalgamate with the existing codes to make it better and fill the required gap where the prescriptions are not based on engineering approach. This will make the code more flexible as now the designer will be able to use the alternative solutions to match the performance requirement. Therefore, if a revision is done where any alternative approach if required could be used, will make the codes more effective and prudent.

Finally, in order to enforce this code effectively this code shall be uniform code having a mandatory status which shall be enforced centrally by separate jurisdiction. Also fire protection engineering shall be encouraged and establish various certification programs to produce standardized fire protection engineers as the presently there are handful of professionals being delivered by only fire college in India.

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