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Research on cost-benefit evaluation model for performance-based fire safety design of buildings

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Abstract

One of the most important functions of performance-based fire safety design method is to evaluate the economic efficiency of different schemes so that to make the fire safety investment more reasonable. It should begin with the calculation of cost budgets and benefits when evaluate the investment efficiency. Costs for improving building fire resistance and installing fire engineering projects are included in the investment budgets. However, the investment benefits are mainly about the reduced losses after the enhancement of the building fire safety level. Based on the performance-based fire safety design method, applying principles of economics and construction budget, the model described above will be built in this paper to provide scientific guides for fire safety investment.

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Keywords: performance-based fire safety design; cost-benefit analysis; cost budget; loss estimation

Nomenclature

C_{BC}	cost of building structure	c_{idoor}	cost of door i
C_{DOOR}	cost of doors	c_{jwin}	cost of window j
C_{WIN}	cost of windows	c_{kwall}	cost of wall k
C_{WALL}	cost of walls	c_{lother}	cost of other component l
C_{Other}	cost of columns, beams, floors and roofs	C_{EG}	cost of fire protection engineering projects
n	amount of doors	$C_{INSTALL}$	cost of fire protection installation projects
m	amount of windows	$C_{MAINTAIN}$	cost of fire protection maintaining projects
p	amount of walls	F	an investment in a year future
q	amount of others	A	an investment in each year future
y_C	probability of damage	x_C	maximum value of factor causing damage
DL	direct loss of building in a fire	L	total losses of building in a fire
IL	indirect loss of building in a fire	A_T	areas damaged by temperature (m^2)
A_S	areas damaged by smoke (m^2)	A_W	areas damaged by water (m^2)
P_{TD}	probability of temperature damage	P_{SD}	probability of smoke damage

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P_{WD}	probability of temperature damage	$A_{overlap}$	areas damaged by three factors(m^2)
G	an increasing amount of investment in each year future (Yuan)		
$P_{overlap}$	probability of damage caused by three factors		
ω_W	density of possessions' value caused by water (Yuan/m^2)		
ω_T	density of possessions' value caused by temperature (Yuan/m^2)		
ω_S	density of possessions' value caused by smoke (Yuan/m^2)		
P	present worth of each investment in the future		
A_{FDS}	areas enclosed by FDS temperature curve and time axis		
$A_{STANDARD}$	areas enclosed by standard fire temperature curve and time axis		

1. Introduction

Performance-based fire safety design method has developed greatly since it was come up in 1970s. The USA, Canada, Australia, New Zealand and some other developed countries have applied performance-based codes for managing their fire safety problems. First, this kind of design method can overcome limitations when conduct architectural design. At the same time, one of the most important functions of this method is to select the most worthwhile designing scheme which can not only protect fire safety but also expend most reasonably, avoiding the problem of investing inappropriately. Vaughan Beck came up with the concept of cost-benefit evaluation model early in 1979 in his research on fire risk evaluation model called FiRECAM [1]. In addition, British Standard DD240 Fire Safety Engineering in Building [2], Fire Engineering Guidelines of Australia [3] and New Zealand [4] and regulations of some other countries have mentioned the analysis of economy of fire risk for recent years. It proves that the cost-benefit evaluation is an important part of performance-based fire safety design method. However, safety itself is mainly taken into consideration when evaluated, but the economic effectiveness of investment is always ignored in our country. With the advancement of Scientific Outlook on Development, fire safety investments ignoring cost-benefit may not be sustainable. Hence, it is necessary to carry out the evaluation of investment cost-benefit when using the method of performance-based fire safety design. And it will form the basis for the decision-making of fire safety investment.

2. The theory of investment cost-benefit in fire safety and the frame of evaluation model

2.1. The theory of investment cost-benefit in fire safety

Cost is the price of essential productive factors put into producing activities, which includes the price of labour force, capital and so on. In general, total costs of fire safety in buildings are the prices of productive factors put into building to control or restrain fire risk. Correspondingly, benefit regards to the income brought by cost [5], as to fire safety investment in buildings, its benefit can be divided into two part, one is decrease benefit and the other is value-added benefit. Decrease benefit is the reduced fire losses caused by fire safety investment, and value-added benefit is the increasing part of income from higher production efficiency caused by fire safety investment. Generally speaking, because of the abstract of value-added benefit, although its contribution to the society cannot be ignored, there isn't proper way to calculate it. Therefore, benefits discussed in this paper are all about decrease benefits.

2.2. The frame of fire safety investment cost-benefit evaluation model

According to the cost and benefit theory from micro economics discussed above, it can be inferred that this cost-benefit model is composed of three parts, one is cost budgets sub-model, one is benefit estimation sub-model, another is analyzing sub-model. For the cost-benefit evaluation in performance-based fire safety design, the cost is due to the improvements of construction fire resistance and the installation of fire safety engineering projects. Meanwhile, the decrease benefits are from these two aspects too. So, figure 1 shows the elementary frame of cost-benefit evaluation model:

3. The cost budgets model of building fire safety design

In general, the cost budgets model of building fire safety design can be divided into two parts on the basis of products which are investment in hardware and investment in software. In detail, it can be described by figure 2 and Eq. (1):