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Cost-Benefit Analysis of Urban Fire Stations Management

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***Abstract*—With rapid urbanization and population density in China, the urban infrastructure of fire fighting can be difficult to meet the increasing demands of urban public safety. By comprehensively analyzing cost input and benefit output of urban fire stations, this paper attempts to apply benefit-cost ratio (BCR) model for the dynamic cost-benefit analysis of urban firefighting investment. Several key strategies have been proposed for China urban fire stations management, emphasizing reasonable allocation on cost input and scientific promotion on benefit output.**

Keywords-cost; benefit; urban; fire stations; management

I. INTRODUCTION

No one can deny the fact that fire is a hazard. As a common, disastrous phenomenon, fire gives rise to destructive consequences and threats obviously. Because of the quick speed of spread and intensity, physical properties are instantly ruined with dense flames, aggressive smoke, and the crackling of combustion. As to human beings, survivors not only suffer from the anguish when fire scorches them, but also experience the fear when recalling such disaster ceaselessly. With high-profile incidents spring up, more and more concerns have been engendered about uncontrolled fire, which results in great loss of life and property. According to the data compiled by the NFPA (National Fire Protection Association), the annual total cost of fire in the U.S. is between 45–50 billion dollars [1].

With fast development of national economy and living standards, China has witnessed a period of rapid urbanization and population density. Certainly, the urban infrastructure of fire fighting can be difficult to meet increasing demands of urban public safety. In the field of the urban public security, fire disaster is a serious accident with high incidence rate and is harmful to people's lives, property and social security [2]. Overall, number of fire cases and the death-toll are inclined to go downward. On the contrary, property damage is experiencing a growing trend. For many fires, a considerable number of greater losses could be avoided by a timely manner to attack the fire [3]. However, the protection effects cannot be so satisfied, often resulted from the improper fire station management, such as scattered resource allocation, poor scheduling and many other kinds of hysteresis. Owing to the lower level of economic development and technological constraint, China fire station investment is far less than the United States, Japan, Australia and other developed countries [4][5]. In this sense, the imbalance between input and output of fire stations tends to exacerbate continuously.

Under the above-mentioned circumstance, based on the theory of cost-benefit analysis, this paper focuses on the cost input and benefit output of urban fire stations. Since fire stations management is of great importance as the consequences of an indoor or outdoor fire are catastrophic, this paper sheds light on such innovative concepts so as to provide some feasible measures to enhance the urban firefighting level.

II. COST INPUT OF URBAN FIRE STATIONS

Fire protection as an important lifeline of the city has always been paid attention to the protection of works in China [6] and fire protection planning is an important part of urban planning [7]. Compared with some foreign standards of urban fire protection planning and fire station construction, the development of urban fire station in China still stays on a backward level. The basic requirements of cost input of urban fire stations were very comprehensive, including a series of expenses, such as location requisition, building construction, apparatus installment, daily operation, etc [8].

A. Location Requisition Cost

In general, location requisition refers to the territory property, infrastructure arrangement, and early development of fire stations. All these activities will lead to a certain amount of expenditure, which are depreciated within time-limit. Where to locate fire stations has a preliminary impact on accomplishing firefighting task and protecting peoples' life and property safety. As the responsible zoning of fire stations, geographical features, urban road system and fire management districts should also be taken into great consideration.

B. Building Construction Cost

Construction costs are mainly used for all kinds of buildings in fire stations, including basic construction and moderate decoration. For example, the fire station buildings should be set up in the well designed feature, emphasizing the special function which can facilitate the fire engine to access and leave conveniently. Thus, it is essential to determine the construction style of fire stations to improve work efficiency. In addition, this kind of costs is viewed as one-time expenses, which will also be devalued.

C. Apparatus Installment Cost

Due to the complicated tasks of fire stations, the requirements of fire apparatus are comparatively intense. Generally, the function of fire apparatus could be divided

into two categories, such as fire fighting and safety protection. Tackling different emergencies needs appropriate apparatus, including fire engines, extinguishing equipment, safety equipment, etc. However, fire apparatus is incapable to exert anticipated efficiency from beginning to end. When calculated, it could be depreciated as well.

D. Daily Operation Cost

Daily operation cost is a changeable parameter, including the expenses of fire fighters, daily consumption and livelihood expenditure. All these costs should be adjusted at least to meet the basic needs of operation management in fire stations. Then, firefighting strength could be intensified under a sound operation environment sustainably.

If the overall cost input of fire station is C_i, then according to the hypothesis above, the cost input analysis model of urban fire stations can be calculated with equation (1) as follows:

$$C_i = \sum_{i=0}^{n} (Cl_i + Cb_i + Ca_i + Cd_i) \tag{1}$$

i — the specific year;

n — the operation tenure (per year) of urban fire stations;

Cl_i — the location requisition cost of urban fire stations , which is depreciated within time-limit;

Cb_i — the building construction cost of urban fire stations , which is depreciated within time-limit;

Ca_i — the apparatus installment cost of urban fire stations , which is depreciated within time-limit;

Cd_i — the daily operation cost of urban fire stations.

III. BENEFIT OUTPUT OF URBAN FIRE STATIONS

Generally speaking, earthquakes, hurricanes, and floods are beyond human control, being regarded as acts of God. Fortunately, fire hazard is considered to be manageable, and loss of life can be avoidable through efficient firefighting measures. The ultimate benefit output of fire station management is to ensure survival and reduce loss. When it comes to the benefit, people's life and surviving property saved by urban fire stations cannot be neglected [9].

A. Rescued People's Life Value

It is undeniable that people's life value is the most priority beyond anything else. The primary task of fire fighting is to rescue more lives as many as possible. The value of survivors rescued by the firefighting activities can be measured in the following three methods, which are universally applied in this field. Firstly, varied expenses of casualties and loss are included with the loss-oriented objective. Secondly, premium is viewed as a symbol of life value according to worth of life insurance. Thirdly, the economic value is estimated on individual with extended life-span.

B. Saved Property Value

Fire fighting actions can protect and save the property and loss directly and indirectly. On one hand, direct property value can be prevented from being destroyed in fire hazard through effective fire control. On the other hand, indirect loss resulting from industrial standstill can be avoided if the fire has been extinguished completely and effectively. Normally, the value of such property can be measured by its actual value or insured value.

If the overall benefit is B_i, then the benefit output analysis of urban fire stations can be calculated with certain equation in (2).

$$B_i = \sum_{i=0}^{n} (RL_i + SP_i) \tag{2}$$

i — the specific year;

n — the operation tenure (per year) of urban fire stations;

RL_i — the valuation of rescued people's life of urban fire stations;

SP_i — the valuation of saved property of urban fire stations.

In addition, SP_i is the sum of direct property value and indirect loss decline. Q is introduced as a factor identified with the importance of casualties and loss. So, the indirect loss decline is calculated in equation (3) as follow:

$$SP_i = SPd_i + Q \times SPd_i \tag{3}$$

SPd_i — the direct property value saved by urban fire stations;

$Q \times SPd_i$ — the indirect loss decline saved by urban fire stations.

IV. APPLICATION OF COST-BENEFIT ANALYSIS ON URBAN FIRE STATIONS

A. Basic Dyanmic Model of Cost-Benefit Analysis

Cost- Benefit Analysis (CBA) is the framework of an analytical method based on the discount ratio, which to evaluate the effectiveness of investment on the public engineering or profit projects and efficiency of resource allocation [10]. The key point of this method is to define cost and quantify the benefit effectively. The basic theory of CBA can be traced back to Welfare Economics Theory of the 19th century. Some economist has defined the public project social benefit standard is the sum of project' net benefits and consumer surplus, which was described in his thesis Measurement of Public Project Utility for the first time [11]. In china, the methods of feasibility study and CBA have been widely applied in the project decision-making since 1970s.

In essence, CBA presents precise and comprehensive information on project future earnings and cost to decision-makers by scientific research and statistical analysis. With these detailed information, decision-makers rank the project with low cost, adopt the project only when benefits are over costs, or to justify the unreasonable project, which may

improve decision-making efficiency. Through providing a systematic approach to check the results of immediate and long-term, decision-makers who are concerned about efficiency are tempted to make more fully rational decision-making, against cognitive errors. In compliance with the changing tendency of cost and benefit, different methods are adjusted mathematically. If the cost and benefit keep fluctuating, dynamic cost-benefit analysis models have been used in decision-making.

1) Net Present Value Model

With time elapsing, money will be depreciated definitely. On the basis of a certain point of time, net benefit during the specific year has been transferred to the sum of net present value. According to economics theories, if the net present value (NPV) is beyond zero, the investment is regarded as an effective and efficient one. On the contrary, the project is considered a failure. In other words, the NPV of a project is the sum of discounted values of a stream of net cash flows generated by a project during its life period and if NPV>0, the project can be accepted [12].

2) Internal Rate of Return Model

Generally, internal rate of return (IRR) refers to the discount rate, which is equivalent to the sum of net present cost and benefit. The utmost affordability of loan interest rate and investment reimbursement is embodied by internal rate of return. The higher internal rate of return is, the better of economic benefit could be obtained in the end. If IRR of a capital project is greater than the cost of capital, investment in the project should be made. If IRR is less than the cost of capital, the project should be rejected [13]. As for individual project, IRR must be beyond the bottom-line of prospective rate of return and at least higher than the loan interest rate as well. When compared with several projects, the plan with the highest IRR is assumed to be the optimal one among these options.

3) Net Equivalent Annual Benefit Model

Through discount rate, net equivalent benefit of a certain project during specific year can be depreciated into average net annual benefit, reflecting the consequences of the plan which has been carried out already. Pay back period is the length of time required to recover the initial cash outlay on the project. The method also serves as a proxy for risk. The faster the investment is recovered, the less risk to which the firm is exposed [14]. If the net equivalent annual benefit is beyond zero, multiple plans could be adopted. When it comes to many optional plans, the project with the highest net equivalent annual benefit deserves to be the best choice.

4) Benefit-Cost Ratio Model

Frankly speaking, benefit-cost ratio (BCR) is viewed from the standpoint of the popular value concept. Benefit-cost ratio refers to the ratio of present value of benefits to initial investment costs. There are various factors influencing the ratio, such as the role of credit, direct and indirect costs, the quality of output, etc. If benefit outputs are over the cost inputs, namely, BCR value is greater than one, the project can be financially feasible. When compared with some other projects, the optimal project should be the one with the highest BCR. Proposals are decided regarding the optimal solution for a given situation. Consequently, recommendations are made to improve the sustainable development of benefits.

B. Application of Benefit-Cost Ratio Model in Fire Stations Management

In view of the above-mentioned, cost input and benefit output of fire stations can be assumed to be varying with time value. So, a dynamic analysis of cost-benefit is preferred, with such objective and reasonable viewpoint. Considering the specific characteristics of fire stations management, cost input is regarded to be more complicated and extendable, and benefit output lacks stability and publicity as well. In this sense, BCR (Benefit-Cost Ratio) model is applied to the cost-benefit analysis of fire stations.

Together with the equation (1) and (2), BCR value of urban fire stations can be represented by the following equation (4):

$$BCR_i = \frac{\sum_{i=0}^{n} B_i}{\sum_{i=0}^{n} C_i} \tag{4}$$

i — the specific year;

n — the operation tenure (per year) of urban fire stations;

BCR_i — the benefit-cost ratio in the specific year;

B_i — the benefit output of urban fire stations in the specific year;

C_i — the cost input of urban fire stations in the specific year.

Apparently, BCR value can be increased with maximized benefit output and minimized cost input. Cost input of fire stations is regarded as a long-term investment, which is closely related to economic situation, urban characteristics and construction features. So, the return of such investment seems to be not obvious. However, urban fire station investment has magnificent influences on our society and politics. In certain empirical study, some indexes are beyond measurement. In this case, benefit-cost ratio can be adjusted mathematically to be in line with general circumstance and standard.

This BCR model can not only be used for economic evaluation of single plan, but also be available to making choices between many alternative plans. When facing the investment decision-making of fire stations, the best plan must have the greatest value of BCR, which stands for highest efficiency and feasibility.

V. STRATEGIES OF OPTIMIZING URBAN FIRE STATIONS MANAGEMENT

Based on the cost-benefit analysis of urban fire stations, several key strategies on enhancing urban firefighting strength are unfolded as follow:

A. Reasonable Allocation on Cost Input of Urban Fire Stations

Human labor, material resource and financial capability are all integrated into the comprehensive proposal of urban

fire stations management primarily. By optimizing the density and distribution of urban fire stations, all the factors above need to be allocated reasonably. In order to enhance the benefit-cost ratio to a large extent, number of fire stations, scale of construction, level of apparatus should be taken into great consideration. Under the universal trend of energy saving and low carbon, overall benefits become to be the core of firefighting, so as to improve the efficiency of urban fire stations management.

B. Scientific Promotion on Benefit Output of Urban Fire Stations

Technology is the interior driving force to the modernization of urban firefighting. With the advanced technology, the level of cost input will be improved, in order to realize maximum benefit with minimum investment. In addition, the assessment of economic benefit of urban fire stations becomes more and more essential with a viewpoint of scientific management. Through quantifying the effects and quality of all kinds of firefighting activities, the efficiency of all regional fire stations can be evaluated with the rank of the benefit-cost ratio. In this sense, the firefighting staff will show great initiative in improving their working performance.

VI. CONCLUSION

In light of the developing background of urban fire stations in China, this paper aims to illustrate the cost input and benefit output systematically. In general, the costs consist of location requisition cost, building construction cost, apparatus installment cost and daily operation cost. No matter what benefits, the ultimate outcome rests with the rescued people's life value and the saved property value. The tradeoff is increased safety and security versus the higher cost of providing fire protection. By comparison between basic models applied in dynamic cost-benefit analysis, the benefit-cost ratio model has been chosen to evaluate the optimal plan of urban fire station management. With the quantified evaluation, some feasible measures are proposed to enhance efficiency of the urban fire stations management.

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