PAPER • OPEN ACCESS

Analysis of Adding Elevator to Multi-storey Residential Buildings in Xining Based on Cost Benefit Analysis

View the article online for updates and enhancements.

Analysis of Adding Elevator to Multi-storey Residential Buildings in Xining Based on Cost Benefit Analysis

Chunyan Chen[1], Zhiqi Gong[1*], Hui Yang[1] and Taimin Zhao[1]

[1]College of Civil Engineering, Qinghai University, Xining, Qinghai, 810016, China

442953016@qq.com

Abstract: Adding elevators to multi-story houses can improve the social problems brought about by the aging of the population and enhance the use of old buildings. At present, the provinces have actively promoted the "people's livelihood project" of installing elevators in multi-story houses, issued *Guiding Opinions* and determined the cost sharing factor, and established a complete system of installing elevators. This article uses cost-benefit analysis to determine the cost items and revenue items in the retrofit elevator project, determines the direct costs, and calculates the apportionment factor and apportionment costs. Taking a residential area in Xining as an example, the number of effective floors is set to calculate the allocation coefficient. The allocation cost increases as the floor rises. Through this calculation, data can be provided for Xining to determine the cost-sharing coefficient for installing elevators.Further promote the project of installing elevators in old residences can greatly improve the quality of life and happiness of the elderly.

1. Introduction

Cost-benefit analysis is generally considered to be the first formal proposal by French civil construction engineer and economist Jule Dupi, who used mathematical methods to analyze consumer supply and demand in 1844 [1]. Dupi established the basis of "marginal analysis" and defined how to measure benefits and costs [2]. This concept was later redefined by Italian economist Pareto.By 1940, American economists Nicholas Calder and John Hicks refined the theory of their predecessors, forming the theoretical basis of the "cost-benefit" analysis, namely the Calder-Hicks rule, which is here In one period, "cost-benefit" analysis began to permeate government activities, such as the US Flood Control Act of 1939 and the budget of the Tyreke Dam in Tennessee.Cost-benefit analysis is a method of assessing the value of a project by comparing all the costs and benefits of the project. This is an economic decision-making method. The cost-benefit analysis method is used in the planning decisions of government departments to seek How to get the maximum benefit with the least cost in investment decisions. It is often used to evaluate the value of public utility projects that need to quantify social benefits. Non-public industry managers can also use this method to analyze the intangible benefits of a large project.In this approach, all costs and benefits of a project or decision are listed and quantified. One problem with the cost-benefit analysis is that the cost terms are always real, large, and easy to calculate, while the benefit terms may be "soft" items that are not measurable.

According to the data from the 2018 National Economic and Social Development Statistical Bulletin of Xining City (Qinghai Province), among the permanent population at the end of 2018, there were 409,800 people aged 60 and over, a proportion of 17.3%;the population aged 65 and over is 292,500, a proportion of 12.3%. The degree of population aging in Xining is higher than the national

population aging level.Huang Mingan and Chen Yu mentioned in the article that there are three major problems with the elderly population. Due to the gradual increase in age, the elderly population will face heavy physical and psychological burdens and economic pressure. The heavy burden on the body is closely related to age, and chronic diseases such as heart disease, cancer, arthritis and dementia [3].At the National Two Conferences in 2018, "the orderly advancement of the transformation of 'villages in the city' and old communities, improvement of supporting facilities, and encouragement of conditional installation of elevators" were written into the government work report.

The state has included the installation of elevators in old homes into people's livelihood projects. Most old homes have been built for decades. Most of the residents are now elderly people. Up and down stairs have become a heavy burden that they have to face in their daily lives. Especially for the elderly, the difficulty of going up and down the stairs makes them reluctant to go downstairs, which seriously affects the quality of life and health and safety of the elderly [4].However, the promotion of installing an elevator is not smooth. One side is the response and advancement of high-rise residents, and the other side is the different opinions and objections of low-rise residents. The low-rise owners require the high-rise owners to compensate them. Difficult to advance [5].

According to the data provided in Xining newly-built inert construction waste generation, it can be concluded that Xining newly built five to seven-story residential buildings between 1995 and 2017 reached 4,298, with a serious aging population and a large number of multi-storey residential buildings. The advancement of the elevator project is slightly behind that of other provinces and cities, and there is no complete set of standards for sharing the cost of retrofitting elevators. A cost-benefit analysis of the retrofitting elevator projects is performed to determine the costs and benefits to be obtained by all parties. The implementation of retrofitting elevators can be promoted to improve the social problems brought about by an aging society, and to prevent the elderly from giving up going out due to inconvenience of legs and feet, and the impact on quality of life and health brought about by this.

2. Materials and methods

2.1. Basis for building alteration regulations
In accordance with Chapter VI of *the Property Rights Law of the People's Republic of China*, the owners of the buildings have separate ownership. Article 76 provides that the owners shall jointly decide on the following matters: raising and using funds for the maintenance of buildings and their auxiliary facilities; its ancillary facilities.The above matters shall be decided with the consent of the owners who own more than two thirds of the total area of the building and the owners who account for more than two thirds of the total number of people. Article 80 stipulates that, if there is an agreement on the cost allocation, income distribution and other matters of the building and its ancillary facilities, the agreement shall be followed; if there is no agreement or the agreement is not clear, it shall be determined according to the proportion of the owner's exclusive portion to the total area of the building.

2.2. Charges for installing elevators by province
Li Li [6] established a cooperative countermeasure model for sharing the cost of installing elevators in old houses through the theory of cooperative countermeasures. Liu Xiaojun [7] proposed that to solve the fair and reasonable allocation ratio of elevators in old residential houses, a critical floor should be determined, that is, the floor with the smallest revenue after the elevator is installed. The residents above the critical floor share the cost of installing the elevator. Do not participate in cost sharing and get a certain percentage of compensation. Guangzhou has issued the *Reference Standard for Urgently Needing Compensation for Installing Elevators in Old Buildings* and *Measures for Adding Elevators to Existing Residential Buildings in Guangzhou* to determine the cost sharing parameters for each floor. Taking eight-story buildings as an example, the first, second, and third floors respectively is 0, 0.5, 1, and the fourth to eighth layers are 1.1-1.5.There are two iron rules for installing elevators. One is that the cost is increased one by one, and the other is that the residents on the same floor have a smaller

share of expenses than a large area.Weifang adopts the "4321" model for the cost of installing elevators. The so-called "4321" model is 40% of the total costs on the 6th floor, 30% on the 5th floor, 20% on the 4th floor, and 10% on the 3rd floor. The floor and the second floor do not bear any costs.The People's Government of Zhengzhou issued the *Implementation Opinions of the People's Government of Zhengzhou on the Installation of Elevators in Existing Residential Buildings*. Older residential houses will be equipped with elevators. The eligible finances will bear 1/4 of the cost and the subsidy amount shall not exceed 150,000. Table 1 summarizes the existing cost allocation coefficients for retrofitting elevators, and Table 2 summarizes the local government subsidies.

Table 1. Principles for sharing the cost

	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
Guangzhou	0.0	0.5	1.0	1.1	1.2	1.3	1.4	1.5
Kunming	0.0	0.0	1.0	1.1	1.2	1.3	1.4	1.5
Weifang	0.0	0.0	10%	20%	30%	40%	—	—
Zhengzhou	0.0	0.5	1.0	1.2	1.4	1.6	1.8	2.0
	0.0	0.0	1.0	1.2	1.4	1.6	1.8	2.0
Tianjin	0.0	0.0	1.0	1.2	1.4	1.6	—	—

Table 2. Subsidy policies

Region	Subsidy Policy
Haidian	The maximum subsidy of 700,000 (equipment purchase: 50% of municipal and district financial subsidies, up to 300,000 yuan; reconstruction costs: municipal finance subsidies based on actual costs, up to 400,000 yuan)
Shanghai	Government subsidies account for 40% of the total project price, up to 240,000 yuan
Ningbo, Hangzhou	Maximum subsidy of 200,000
Nanjing	Maximum subsidy of 200,000
Shenzhen	Property special maintenance funds, housing provident fund
Guangzhou	Maximum subsidy of 100,000 yuan (50,000 yuan for needy families)
Chongqing	Maximum subsidy of 100,000 yuan (50,000 yuan for needy families)
Chengdu	Maximum subsidy of 200,000
Weihai	Maximum subsidy of 200,000
Xi'an	Maximum subsidy of 150,000
Hefei	250,000 yuan subsidy (including 10-year maintenance fee and electricity subsidy of 3,000 yuan)
Xiamen	Maximum subsidy of 220,000

On July 4, 2019, the Qinghai Provincial Department of Finance and the Provincial Department of Housing, Urban and Rural Construction issued the *Administrative Measures for Provincial Awards and Replenishment Funds for Installing Elevators in Existing Multistory Residential Buildings in*

Qinghai Province, clearly stating that from 2019 to 2023, compliance with the principle of "build first, supplement later, and substitute awards" is provided by the provincial finance according to the standard of 150,000 yuan for each unit to provide appropriate subsidies for the existing multi-storey residential buildings in cities and towns.The subsidy funds are mainly used for subsidies for the purchase of elevator equipment, elevator installation and construction of elevator rooms. The operation, post-maintenance, and annual inspection of the elevator after installation are borne by the owner of the elevator. The finance at all levels does not arrange subsidy funds.Applicants can apply for the use of special housing repair funds, or use the housing provident fund in the name of the owner and spouse of the house.The implementation process of installing an elevator includes: 1) the applicant and the application conditions, 2) signing an agreement, 3) written application, 4) special design, 5) fund raising, 6) joint review, 7) construction permit, 8) completion acceptance, 9) Use registration.In order to accelerate the implementation of the project, in 2019, Xining, through public bidding, evaluated 10 elevator brands, 3 design units, 3 supervision units, and 5 general contracting units. List of residential elevator installation design, supervision, elevator brands and general contractors.

3. Comparison and selection of retrofit elevator solutions

Based on the understanding of the existing elevator installation schemes in other provinces and cities, Table 3 mainly summarizes the following five elevator installation schemes, and introduces their advantages and disadvantages.

Table 3. Elevator installation plan

Program	Pros and cons
Wall-mounted	It is necessary to take advantage of the building's own advantages and install it in the depression of the outer wall of the corridor. It adopts an integrated fully transparent shaft structure design, which has little effect on the lighting and ventilation of the residents on the ground floor, but the elevator load and the shaft design size will be small.
Covered bridge	The distance between the elevator and the corridor needs to be considered. Sightseeing elevators should be used on the first and second floors to minimize the impact on the lighting of low-rise residents. In order to avoid reflections on the third floor and above, aluminum plates are used on both sides instead of glass.
Penetrating	A fully transparent sightseeing elevator can be used. The elevator car adopts two doors. The residents take the elevator at the north entrance of the elevator. After arriving at the floor, they enter the corridor from the south side of the car. The through elevator is very convenient for residents who use wheelchairs.
Flat floor home	If the residential building is designed with a convex balcony, after the elevator arrives, residents can directly enter the house through the balcony instead of walking down the half-story stairs. To ensure security, the balcony needs to be equipped with anti-theft doors. This solution affects the use of the room's functions.
Implantable	The shape of the building needs to be "concave". The specially customized elevator is perfectly embedded in this "concave". It does not occupy the public space outside the unit building, and it also makes reasonable use of the previously wasted idle space.

According to the construction case, it can be found that the corridor bridge elevator has more cost of the bridge than the wall-mounted elevator. The two programs have little difference in the preliminary preparation costs. The cost differences are mainly in the implementation cost of the renovation, maintenance and operation costs, and compensation for low-rise residents. Both schemes have little effect on the lighting and ventilation of the ground floor residents.Installing a wall-mounted

elevator takes 74 days and a bridge-mounted elevator takes 67 days. In terms of construction time, the bridge-type elevator has a short construction period and less noise, gas, and construction waste due to construction.In addition, the elevator load and hoistway size design are more flexible than the wall type. The disadvantage is that the poor selection of the bridge length will affect the passage of vehicles and pedestrians in the hospital. As for the two retrofitting schemes, the corridor bridge is more economical.

4. Cost-sharing plan

4.1. Determination of apportionment coefficient
Residents on the first and second floors will not share any expenses, and residents on the remaining floors will be allocated proportionally. The calculation of the allocation coefficient introduces the concept of the number of effective floors. The number of effective floors: Let the third floor be the reference floor, the number of effective floors in this floor is 1, the number of effective floors in the second floor is 2.By analogy, the sum of the number of effective floors is calculated. Residents on the first and second floors are not responsible for the cost of installing elevators, elevator use and maintenance costs; residents on the third floor and above share the cost of installing elevators according to the above calculation formula, and evenly share the elevator usage and maintenance costs.The calculation of the allocation factor is shown in Equation 1, and the calculation of the allocation cost is shown in Equation 2. Table 4 shows the cost-effectiveness of retrofitting elevators.

$$\alpha = 2\beta_i / \sum_{i=1}^{n} 2\beta_i \left(1 \le n \le 5\right) \tag{1}$$

Where α is apportionment factor,β is number of effective floors,i is the number of floors based on the third floor,n is the value range.The number 2 in the formula can be changed according to two households on one elevator and three households on one elevator.

$$A = C \times \alpha \tag{2}$$

Where A is the total cost to be shared by the households on each floor, and the average household cost is calculated based on the number of households on each floor,C is the installation cost of retrofitting the elevator,α is apportionment factor.

Table 4. Cost-benefit composition

Direct cost	Indirect cost	Direct benefit	Indirect benefit
Design fees	Lighting and ventilation		
Approval fee	Noise	Include in pooled area	Improve the living standards of the elderly
Civil costs	Internal use function		
Equipment cost	Building structure	House appreciation	
Maintenance costs	Fire Safety		Convenient travel
Electricity cost	Depreciation		

4.2. Case study
Take a seven-story old house in a community in Zhonghua Lane, Chengxi District, Xining as an example.As shown in Table 5. There are two households with one elevator and 14 households, and an elevator is installed for 500,000 yuan.After the elevator is put into operation, the residents must pay a minimum maintenance fee of 300 yuan per month (if advertising is allowed in the elevator, the advertising company can bear it),The electricity fee generated during the use of the elevator is priced according to Xining's charging standard (electricity 1-150 kWh, electricity price 0.3771 yuan per kilowatt-hour), the elevator runs at 3 kWh per hour, and the monthly electricity cost is 610 yuan.

Table 5. Cost sharing plan for installing elevators on 2 units in a community in Zhonghua Lane

Residential building	A total of seven floors,two households on one ladder		
Installation cost	Adding an elevator costs 500,000		
Average cost	The average cost is 16.667 million (50/30 = 1.6667)		
Effective layers	Effective number of layers 30 ((1 + 2 + 3 + 4 + 5) * 2 = 30)		
Floor	Apportionment factor	Share the expense	Per household
First	0	0	0
Second	0	0	0
Third	2/30	3.3333	1.6667
Fourth	4/30	6.6667	3.3334
Fifth	6/30	10.0000	5.0000
Sixth	8/30	13.3333	6.6667
Seventh	10/30	16.6667	8.3334

Remarks:(Unit:Ten thousand yuan)

1. During the use of the elevator, the residents will share 300 yuan in maintenance cost and 61 yuan in usage fee.

2. The government subsidized 150,000 yuan, and the expenses incurred during the use of the elevator were borne by the owner.

5. Conclusion

With the in-depth publicity and promotion of retrofitting elevators in old homes, Xining has completed the installation of elevators in 4 communities and 15 units. So far, a total of 42 communities in Xining have applied to install elevators. In the process of elevator installation, the interests of low-rise and high-rise residents should be considered. The total cost of installing the elevator includes the directly allocated capital contribution and the cost of negative impact (landscape, noise, internal use functions, building structure, fire safety, and depreciation of the house). The total benefits include the benefits of travel convenience, house appreciation, etc., as well as the cost benefits of elevator operation and maintenance.

At present, the installation of elevators in Xining is mainly led by neighborhood committees, and the head of the building is responsible for related matters. The specific cost sharing is determined by consultation among the residents in the unit. There is no uniform cost sharing principle. The method of introducing effective floors to determine the allocation coefficient has universal significance, and the incremental cost of each floor is a definite value, and the households have high acceptance. The unified cost allocation coefficient can better resolve the contradictions among households and speed up the installation of elevators. To improve the living standards of the elderly.

Acknowledgment

References

[1]   Stephen Breyer.1995 *Harvard University Press*
[2]   David Pearce.*Oxford Review of Economic Policy*,Vol.14,No
[3]   Mingan Huang,Yu Chen.2018 *Economic Research Guide* 10-0054-05
[4]   Canhuang Huang.2016 .*Huaqiao University*
[5]   Zhan Chen.2019 *Well-off*
[6]   Li Li,Changle Xu.2014 *Economic Mathematics* 31(03):26-29
[7]   Xiaojun Liu,Yongkai Sun.2019 *Practice and Understanding of Mathematics* 49(10):114-121