Research on the Social Benefits of Urban Rail Transit Operation: A Measurement Scale

Quanhong Liu[1*], Yu Nie[2]
Corresponding author: qhliu@163.com, Email: 1697010415@qq.com

[1]Manufacturing Industry Development Research Center on Wuhan City Circle, Jianghan University, China,

[2]School of Business, Jianghan University, China

Abstract—Rail transit has increasingly played an important role in urban transportation system due to its high capacity and low energy consumption. Since the existing literature on rail transit's operation benefits mainly focus on its economic benefits, this paper pays attention to its social benefits using a combination of qualitative and quantitative research methods. Through expert and group interviews, combined with literature combing, the conceptual connotation of social benefits of rail transportation is refined and structural dimensions are constructed. Data were obtained by distributing questionnaires, applying exploratory factor analysis and confirmatory factor analysis, in addition to empirically testing the validity of the developed scale, and finally developing a set of measurement scales for the social benefits of rail transit operations. The scale contains 5 dimensions of residents' travel benefits, cultural and livelihood benefits, urban layout benefits, comprehensive urban benefits, and ecological and environmental benefits, with a total of 17 entries. Based on the results of the empirical analysis, the study proposes policy recommendations for rail transit construction and operation.

Keywords-rail transit; social benefit; evaluation index

1 INTRODUCTION

With the rapid development of China's economy, the demand for urban transportation is growing rapidly, the traffic structure is becoming more and more complex, the problems of traffic congestion and serious pollution are becoming more and more prominent, and the traditional transportation methods can no longer meet the daily needs of residents. With its high capacity and low energy consumption, the urban public transportation system, especially rail transportation, has the advantages of safety, high speed and low pollution as the primary choice for every city innovation. By the end of 2020, there are 45 cities in China (excluding Hong Kong, Macao and Taiwan) with 237 urban rail lines in operation, with a total mileage of about 7,546.9km, which helps to relieve urban traffic pressure, enrich urban transportation structure and improve residents' travel efficiency to a certain extent.

Rail transportation is an important infrastructure for the normal operation and steady development of society. Systematization of rail transit requires steady planning by integrating the traffic pressure of the city, the demand of the residents and the layout of the city structure. Since the construction of rail transit requires a high technical level and operational capability of the city,

ICICA 2022, December 02-04, Chongqing, People's Republic of China

DOI 10.4108/eai.2-12-2022.2328039

the process of rail transit construction must undergo scientific benefit assessment to guarantee the sustainable development of the city.

Most of the current studies on rail transit benefits have focused on economic benefits. Du & Mulley (2012) used a geographically weighted regression (GWR) method to study the factors influencing housing prices in the Tyne and Wear area; Cervero (1994) studied the market conditions of office buildings near stations in the Washington and Atlanta areas. Rail transit operators, real estate along the line, and businesses along the line are the primary beneficiaries of the economic benefits of rail transport. The process of rail transit operation brings ticket revenue and advertising income to the operators, but at the same time, the operators also have to bear huge construction and maintenance costs, so their economic benefits often need to bear the corresponding risks. Rail transit's economic benefits are more directly evident in the influence on the economy along the route. Studies have confirmed that urban rail transit can significantly increase the value of real estate along the line. Commercial and service enterprises along the rail transit lines will also see significant improvements in their business environment. As transportation convenience is greatly improved, bringing more people flow and business resources, the business environment for commercial and service enterprises along the rail transit lines will also be greatly improved, and the business efficiency of commercial enterprises will be continuously enhanced.

It is difficult to measure the benefits directly using quantitative analysis because the public benefits of rail transportation are rather indirect. The social benefits of rail transit benefit a wide range of subjects, including urban residents, urban transportation, urban economy, urban culture and urban ecology. That the urban rail system provides residents with a higher speed and more convenient means of travel, and a comfortable and safe service experience for passengers.; the operation of urban rail transit enriches urban transportation, thus improving the traffic structure of cities, relieving the pressure of ground traffic, reducing the chance of traffic accidents, and balancing the supply and demand of the public transportation system; the operation of urban rail transit provides diversified jobs for more types of talents, and cultural propaganda through rail transit can achieve a subtle and meticulous effect; the operation of urban rail transit provides more types of talents with diversified jobs, and cultural propaganda through rail transit can achieve a subtle and meticulous effect; the operation of urban rail transit provides great convenience to the life of the surrounding residents and also promotes the economic take-off of the surrounding area, rationalizes the industrial layout of the city, promotes the economic and industrial development of the suburbs, and at the same time forms a city circle with the surrounding cities for intermingling and synergistic development; compared with traditional buses and cars, urban rail transit systems consume relatively less energy and pollute the surrounding environment less, with lower pollution emissions and exhaust emissions, maintaining the green development of urban ecology.

However, existing studies have not paid enough attention to the social benefits of rail transportation, and there has not been a clear dimensional definition and assessment system. Therefore, this paper seeks to define the concept of social benefits of rail transportation and construct its structural dimensions through theoretical extrapolation and qualitative research based on a large number of theories provided by previous studies, and explore the construction of a relatively comprehensive, reliable and valid tool for measuring social benefits of rail transportation.

2 THEORETICAL FOUNDATION

Social benefit refers to the social effect resulting from a social action or social activity, which can affect many aspects such as politics, national defense, society, livelihood, culture, spirituality and ecology. As a process of measuring social benefits, social benefit evaluation is a project analysis tool that effectively integrates the public into social activities. Through systematic investigation and analysis, social benefit evaluation involves project stakeholders in the design of the project, examines the social factors affected by the project, and proposes measures to increase the positive effects and reduce the negative ones. The purpose of social benefit evaluation is to analyze the degree of adaptation of the social system in the target project site by investigating, analyzing and predicting the impact of the construction and operation of the target project on society. The main difference between social benefit evaluation and economic benefit evaluation is the quantifiability of indicators. One of the major differences between social benefit evaluation and economic benefit evaluation is the quantifiability of indicators. The social benefit evaluation is based on the social policies formulated by the state and assesses the impact of the project on social development and the mutual adaptability of the project to social development goals.

From the perspective of social development, the assessment of social benefits of rail transit should include the analysis of many different fields such as society, economy, people's livelihood, culture and ecology. Through the reference of domestic and foreign studies, this paper defines the concept of social benefits of rail transit as the role of rail transit operation in improving people's quality of life, promoting regional economic development, promoting the construction of spiritual civilization and improving natural ecological environment.

The earliest way to evaluate social benefits was social cost analysis, and based on such thinking after economists included distributive justice in national development goals, traditional cost-benefit analysis included income distribution, employment, and other social development goals as new evaluation items, thus giving rise to social cost analysis. However, Horn (1981) argues that the cost-efficiency approach cannot fairly evaluate urban rail transit projects for the U.S. When he applied the cost-efficiency approach to measure urban rail transit indicators, he found that there were significant geographical differences. In the analysis of social costs, only the principle of equity is considered, ignoring other social benefits that exist, such as environment, transportation, etc. Fielding (1978) proposed four effectiveness indicators, three efficiency indicators and two comprehensive indicators about public transportation operation performance for a total of nine indicators to evaluate public transportation projects. Lin & Chen (2005) divides the social benefits of urban rail transit into tangible benefits and intangible benefits and reasonably quantify the social benefits of urban rail transit through the conditional value assessment method.

3 DIMENSION CONSTRUCTION

Through expert and group interviews, combined with existing literature, the social benefits of rail transit operation are summarized in the following five areas (Fig.1).

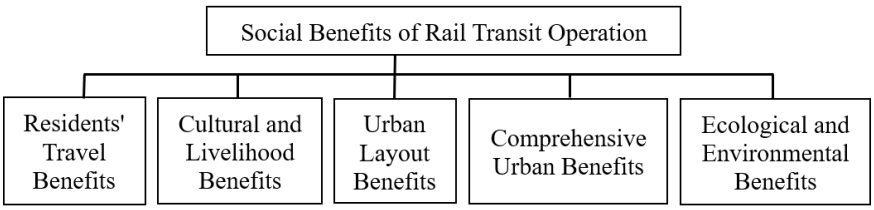

Figure1. The structure of social benefits of rail transit operation

3.1 Residents' Travel Benefits

Most urban rail transit projects choose to be built underground and laid with specific driving tracks, which can effectively alleviate the congestion of surface traffic, avoid delays caused by traffic congestion and maintain high-speed operation of vehicles. Urban rail transit can operate at speeds up to 80 km/h, which greatly improves the efficiency of residents' travel and saves travel time. Mackie[2]et al. (2003) in their study pointed out that the time-saving benefit is the main benefit of transportation project investment, which accounts for more than 80% of the total benefits of transportation projects in developed countries. At the same time, the rail transit line stations are dense, the service radiation radius is about 800m, the line interchange is more convenient, the running time is accurate, and the overall operation level has reached systematization and standardization. In addition, the operation of rail transit has significantly improved the accessibility of the city, which will induce an increase in the passenger volume of the city and improve the travel demand of the residents.

3.2 Cultural and Livelihood Benefits

The construction and operation of rail transit can effectively improve the living quality of residents. Rail transit creates a large number of jobs, and its construction requires long-term investment and therefore a large demand for labor, and also requires a large number of employees to be involved in operation and maintenance after its completion. The completion of the rail line has boosted the local economy and business growth and brought more job demand to the area. A study by Hensher, Ellison & Mulley (2014) on employment density in Australia found that accessibility due to public transport construction increases regional employment agglomeration rates. Urban rail transit operates on established tracks, sharing the pressure of surface traffic, reducing traffic safety accidents, and improving the quality of transportation for residents traveling. Bhattacharjee & Goetz (2012)[4] found that since the completion of Denver's light rail system, local highway traffic volumes have decreased significantly and traffic congestion has been effectively reduced.

There are numerous cultural benefits brought by rail transit, which are reflected in the construction of rail transit stations. By citing the subway design of London, Tokyo and Hong Kong, Lou (2012)[5] points out that the subway can achieve "integrated communication design" of the brand and show the accumulation of humanistic values of the city.

3.3 Urban Layout Benefits

Rail transit has an intuitive impact on the economy along its route, Hess & Almeida (2007) studied land prices in New York City and found that the closer a light rail station is to a residential

property, the higher the appraised value and that homes near a light rail station can command a 2-5% premium to the city's median home value. Due to the operation of rail transit, the city's economic industry gradually spreads out from the center to the surrounding area, driving the suburban economy to improve. By controlling the direction of urban construction using rail transit, it changes the way cities expand, directs urban industries to divert and evolves from a monocentric to a polycentric structure. The architecture of intercity rail transit radiates the economic advantages of cities to neighboring cities and regions, realizing synergistic development and reaching the joint effect of city circle.

3.4 Comprehensive Urban Benefits

As a high-efficiency public transportation facility, rail transit is a symbol of the high-tech development level. The operation of rail transit improves the overall competitiveness and comprehensive strength of the city and presents a more modern image of the city. Rail transit provides a higher level of service to the residents and visitors in the city, showing the strong capacity of urban public transportation. At the same time, the improvement of the city's overall strength also increases the city's visibility and achieves a higher investment attractiveness due to the accessibility of the city brought by rail transit.

3.5 Ecological and Environmental Benefits

Rail transit is a highly environmentally friendly green transportation, and its improvement of the natural environment and optimization of the urban environment cannot be ignored. The carbon emissions of rail transit are low, and Zheng & Kahn (2013) studied the causes of urban pollution in China and found that the CO_2 emission per passenger per km of rail transit is only 1/25 of that of small cars. Chester, Horvath & Madanat (2010) compared greenhouse gas emissions in different cities and found that cities with higher public transportation ridership had the lowest greenhouse gas emissions. Through years of optimization and improvement, the noise pollution caused by rail transit has also reached a low level, much lower than the sum of noise from cars and other means of transportation with the same passenger capacity.

4 SCALE DEVELOPMENT

In this study, the development of a scale for measuring the social benefits of rail transportation was carried out according to the standardized scale development procedure, and the above qualitative research findings were revised and tested.

4.1 Initial Questionaire

We develop initial questionnaire through in-depth interviews, combined with the existing literature on the social benefits of rail transit operation.

First, we collected information on the social benefits of Rail transit operations, and then refined its conceptual content and dimensional composition. Afterward, the respondents were asked to add their own perceived social benefits of rail transit based on the conceptual connotation of social benefits of rail transit operation defined in this study. The items collected were integrated with the dimensions obtained in the qualitative research phase, and by removing the items that

did not meet the social benefits of rail transit operations, 24 scale items were finally collected that met the criteria (Table I).

TABLE I. INITIAL QUESTIONAIRE

Number	Items
X1	Traveling by rail can shorten travel time
X2	Traveling by rail can reduce the level of fatigue
X3	Traveling by rail is more convenient than using other modes of travel
X4	Traveling by rail is more comfortable than using other modes of travel
X5	Traveling by rail is more punctual than using other modes of travel
X6	Traveling by rail saves more money than using other modes of travel
X7	The operation of rail transit helps provide more jobs
X8	The operation of the railroad helps to expand the window of cultural promotion
X9	The operation of railways can reduce traffic accidents
X10	Rail operations can reduce energy losses
X11	The operation of railways can share the pressure of surface traffic
X12	The operation of rail transit helps to adjust the industrial structure layout of the city
X13	The operation of rail transit helps drive economic development around rail transit
X14	The operation of rail transit helps drive suburban economic development
X15	The operation of rail transit helps to link the city circle and co-locate with the surrounding towns
X16	The operation of rail transit helps save surface land
X17	The operation of rail transit helps to improve the level of urban services
X18	The operation of rail transit helps to improve the overall image of the city
X19	The operation of rail transit helps create a better investment environment
X20	The operation of rail transit helps to improve the technology of the city
X21	Rail operations help develop new areas of research
X22	The operation of rail transit helps reduce urban emissions
X23	The operation of rail transit helps reduce urban carbon emissions
X24	The operation of rail transit helps reduce urban noise

4.2 Data Collection

The Likert 5 scale was used to compile the initial questions on the 24 social benefits of rail transit, with 1-5 indicating from "disagree" to "agree". According to the initial scale design, the questionnaire was distributed mainly by electronic questionnaires, and the target population was the residents who had used rail transportation in Hubei. A total of 337 questionnaires were distributed, 270 were collected, 61 that did not meet the requirements and did not answer seriously were excluded, and 209 valid questionnaires were finally obtained. The sample consisted of 90 males, accounting for 43.1%, and 119 females, accounting for 56.9%; the age was mostly 35-55 years old, with 137 people, accounting for 56.6%; the education level was mostly undergraduate, with 92 people, accounting for 44%.

4.3 Scale Purification and Testing

4.3.1 Initial scale purification

Reliability tests were conducted using Cronbach's alpha coefficient to evaluate the internal consistency of the multidimensional scales and combined with the single-item-integral correlation coefficient (CITC) to purify the measured question items. Question items with internal consistency of alpha coefficients of factors less than 0.6 and CITC index less than 0.45 were removed. Using SPSS22.0, taking the intersection of Cronbach's α coefficient and the basic requirement of the CITC index, it is found that the CITC indices of X1 (travel time benefit), X6 (money-saving benefit) and X11 (traffic pressure relief benefit) are 0.405, 0.177 and 0.447, which were lower than 0.45, so they are deleted.

TABLE II. CONFIRMATORY FACTOR ANALYSIS

Models	Contained factors	x^2	df	x^2/df	RMSEA	CFI	NNFI
Five-factor model	A, B, C, D, E	214.429	94	2.281	0.078	0.966	0.951
Four-factor model	A+B, C, D, E	276.967	95	2.915	0.096	0.949	0.927
Three-factor model	A+B+C, D, E	316.969	97	3.268	0.104	0.938	0.913
Two-factor model	A+B+C+D, E	521.847	100	5.218	0.142	0.881	0.838
One-factor model	A+B+C+D+E	592.263	104	5.695	0.150	0.863	0.820

4.3.2 Exploratory factor analysis

Before the exploratory factor analysis, KMO and Bartlett's sphericity tests were performed on the samples, and the results showed that the KMO value was 0.861, higher than the standard 0.70 value, indicating more common factors among the variables. The value of Bartlett's sphericity test x^2 value was 3573.113, which reached the significance level ($p<0.001$), representing the presence of common factors between the correlation matrices of the parent groups and suitable for factor analysis.

Using principal component analysis, the maximum variance method was adopted to select the 5 factors with characteristic roots greater than 1. In order to obtain a theoretically meaningful factor structure, the items that met one of the following criteria were deleted: first, the factor loadings of the items were lower than 0.5; second, the cross-loadings with other items were higher than 0.4; and third, they deviated from their expected dimensionality. In this way, X10 (energy benefits), X16 (land saving benefits), X20 (technology benefits), and X21 (research benefits) were deleted.

Five factors were finally extracted, with factor loadings ranging from 0.688-0.913 for all question items and a cumulative contribution of 84.525% of the total variance.

4.3.3 Confirmatory factor analysis

To test the stability of the scale's structure, a validation factor analysis was conducted in this study, and the results of the analysis are shown in table II, with factor loadings for each question item greater than 0.6, x^2/df=2.281, RMSEA=0.078, CFI=0.966, and NNFI=0.951.

4.3.4 Reliability test

The reliability of the scale was tested using Cronbach's alpha coefficient to evaluate the internal consistency of the scale, and the acceptable value of 0.70 of Cronbach's alpha was that the reliability coefficient of the total scale of high quality was 0.80above. The reliability coefficients of the subscales of the social5 benefits of rail transit operation factors found in this study are 0.871, 0.880, 0.955, 0.939, 0.894 and the reliability coefficients of the total scale are 0.917 greater than 0.80, which prove that the social benefits of rail transit operation scale designed in this study have high reliability.

4.3.5 Validity test

The validity level of this scale was determined by examining the structural validity. Structural validity consists of convergent validity and discriminant validity. Standardized factor loadings greater than 0.5, combined reliability greater than 0.7, and average variance extracted (AVE) greater than 0.5 indicate that the scale has good convergent validity. If the square root of AVE of each dimension is greater than the correlation coefficient among the dimensions, it indicates good discriminant validity among the dimensions.

The results of the analysis show the combined validity CR is greater than 0.8, and the AVE value of each dimension is exceeded 0.6, which proves that the scale has good convergent validity. Meanwhile, the square root of AVE of each dimension is greater than the correlation coefficient between dimensions, which indicates that the scale has good discriminant validity.

4.4 Formal Scale Formation

This study strictly follows the standardized scale development procedure, and through qualitative analysis of literature research and in-depth interviews and quantitative analysis of criteria to remove unreasonable items, we finally obtained a formal scale of social benefits of rail transit operation with good reliability and validity containing 17 items (Table III).

TABLE III. FORMAL MEASUREMENT SCALE

Dimensions	Items
Residents' travel benefits	Traveling by rail can reduce the level of fatigue
	Traveling by rail is more convenient than using other modes of travel
	Traveling by rail is more comfortable than using other modes of travel
	Traveling by rail is more punctual than using other modes of travel
Cultural and livelihood benefits	The operation of rail transit helps provide more jobs
	The operation of the railroad helps to expand the window of cultural promotion
	The operation of railways can reduce traffic accidents

Urban layout benefits	The operation of rail transit helps to adjust the industrial structure layout of the city
	The operation of rail transit helps drive economic development around rail transit
	The operation of rail transit helps drive suburban economic development
	The operation of rail transit helps to link the city circle and co-locate with the surrounding towns
Comprehensive Urban benefits	The operation of rail transit helps to improve the level of urban services
	The operation of rail transit helps to improve the overall image of the city
	The operation of rail transit helps create a better investment environment
Ecological and environmental benefits	The operation of rail transit helps reduce urban emissions
	The operation of rail transit helps reduce carbon emissions
	The operation of rail transit helps reduce urban noise

5 CONCLUSION AND DISCUSSION

In this paper, the social benefits of rail transit are divided into five dimensions from the perspective of empirical evidence, namely, residents' travel benefits, cultural and livelihood benefits, urban layout benefits, comprehensive urban benefits, and ecological and environmental benefits, to construct a set of relatively comprehensive, reliable, and effective tools for measuring the social benefits of rail transit.

This study provides the following contributions: (1) Effective scales provided in this study can be used to determine the magnitude of the social benefits provided by rail transit in a given location; (2) An effective diagnostic tool for identifying deficient aspects of rail operations in a given location and thus targeting improvements; (3) As a reference for cities' rail transit construction planning, this paper can scientific the process of rail transit construction, quantify the degree of social benefits measurably, and improve the evaluation system of rail transit benefits.

Based on the above research results, the following relevant countermeasures are proposed to further promote the development of rail transportation in China.

First, establish the backbone of rail transit. Rail transit has the irreplaceable advantages of high speed, large passenger capacity and high safety, which makes it the core of solving urban transportation problems. The scientific and reasonable promotion of the construction of the rail transit system can improve the urban transportation structure, solve the problem of residents' travel, and make the urban transportation system develop towards standardization and systematization.

Second, with the rail transit culture propaganda. The construction style of rail transit station interior is largely influenced by the local culture, and the image of rail transit station often represents the local cultural image, while containing its spiritual civilization and historical heritage. The construction of the rail transit station shows the overall image of the city, and the station with great characteristics can often make the public remember its culture. At the same

time the posters, slogans and mobile libraries designed inside the rail transit are also a subtle way to promote spiritual civilization to passengers.

Third, pay attention to rail transit line planning. The construction and operation of rail transit can provide cities with more choices of travel means, thus relieving the traffic pressure in the central city or densely populated areas and solving the travel problems of residents. At the same time, rail transit is a public transportation product, and its construction should still focus on public welfare while taking into account profitability, so the construction of rail transit must abide by the principle of fairness, balancing the developed areas of the city with the less developed areas to achieve the harmonious development of the city as a whole. In the construction of rail transit, the layout of lines should also be considered to avoid isolation and fragmentation of lines as much as possible, so as to realize the scale effect of rail transit line network and achieve regional synergistic development.

Fourth, guide the outward development of rail transit. Development of the rail transit system can bring huge foot traffic, thus gathering important economic factors such as capital, business district and people flow in the vicinity of the rail transit. With the construction of rail transit, it promotes the development of commercial economy along the line, realizes the value-added of real estate along the line, extends the city's business circle, guides the development of new areas and regulates the flow of the city's economy. Using rail transit to promote the development of new areas helps cities to build new industrial parks, decentralize different industries, and guarantee the convenience of transportation at the same time.

Last, take advantage of the environmental effects of rail transit. Rail transit has unique environmental benefits, with lower pollutant emissions and noise volume than most other modes of transportation. By promoting the construction and operation of rail transit, rail transit can gradually replace traditional transportation modes, thus promoting the formation of a low-carbon urban transportation structure.

ACKNOWLEDGMENT. This paper is supported by the Open Fund Project of Manufacturing Industry Development Research Center on Wuhan City Circle of Jianghan University under grant WZ2016Z01.

REFERENCES

[1] H. Du and C. Mulley. “Understanding spatial variations in the impact of accessibility on land value using geographically weighted regression”, Journal of Transport and Land Use, vol. 5, pp. 46-59, Octobe 2012.

[2] P. J. Mackie, M. Wardman, A. S. Fowkes, et al. “Values of Travel Time Savings UK”, Institute of Transport Studies, University of Leeds , Leeds, UK, 2003.

[3] D. A. Hensher, R. B. Ellison and C. Mulley, “Assessing the employment agglomeration and social accessibility impacts of high speed rail in Eastern Australia”, Transportation, vol. 41, pp. 463-493, May 2014.

[4] S. Bhattacharjee and A. R. Goetz, “Impact of light rail on traffic congestion in Denver”, Journal of Transport Geography, vol. 22, pp. 262-270, May 2012.

[5] W. Lou, “Integrated communication design and humanistic value accumulation of urban subway brand identity-from London to Tokyo and Hong Kong”, Decoration, vol. 11, pp. 81-82, November 2012.
[6] S. Zheng and M. E. Kahn, “Understanding China's urban pollution dynamics”, Journal of Economic Literature, vol. 51, pp. 731-772, September 2013.
[7] M. V. Chester, A. Horvath and S. Madanat, “Comparison of life-cycle energy and emissions footprints of passenger transportation in metropolitan regions”, Atmospheric Environment, vol. 48, pp. 1071-1079, March 2010.