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Environmental Pollution Evaluation of Urban Rail Transit Construction Based on Entropy Weight Method

Yang Yin* and Yu Zhang**†

*School of Management, Wuhan University of Technology, Wuhan 430070, China
**School of Economics & Management, Hubei University of Arts and Science, Xiangyang 441000, China
†Corresponding author: Yu Zhang: hbuaszy@163.com

ABSTRACT

With the development of cities, urban rail transit has entered into a stage of rapid construction and development, but the environmental pollution caused by rail transit construction cannot be ignored. To evaluate the environmental pollution of urban rail transit construction, an evaluation system for the environmental pollution induced by urban rail transit construction was established by using the literature survey method and the entropy weight method. The evaluation index system involved three first-level indicators of the physical environment, natural environment and social environment, and 11 second-level indicators. The impact of XA-XDM project construction on urban environmental pollution in Wuhan, China was evaluated by using the evaluation system. Results show that the evaluation score of XA-XDM project is 76.5, which means that the XA-XDM project construction has a strong impact on environmental pollution. It should be paid to the prevention, control and monitoring of various pollution indicators, reducing environmental pollution, and realizing green construction.

INTRODUCTION

Urban rail transit is the main transportation mode currently promoted, and its construction will inevitably pass through transportation hubs such as urban arterial roads, prosperous business districts and densely populated areas. However, the construction of urban rail transit projects needs a long period and is on large scale. Construction in existing transportation hub areas unavoidably faces difficulties such as a harsh construction environment and narrow working space. Meanwhile, the construction process inevitably creates a great deal of pollution to the existing urban environment (Wang 2019). Relevant studies reveal that the environmental pollution caused by urban construction has become more and more serious (Wang et al. 2015, Wang et al. 2015). For example, the frequent urban smog pollution in recent years has mainly occurred in major cities. Contrarily, such pollution in small cities is relatively light. The main pollution source generates from the construction of urban buildings and the continuous expansion of the scale of municipal public construction. These constructions have caused dust, exhaust gas in the air, noise pollution and vegetation destruction, increasing pollution sources and exceeding the city's ecological self-purification ability (Xue et al. 2017). Data show that there were more than 500,000 complaints about environmental pollution in China in 2018, accounting for 35.3% of the total complaints, while the number of noise pollution cases caused by construction reached 46.1%, which is the largest proportion (Ministry of Environmental Protection of the People's Republic of China 2018).

Due to the complex construction environments, the environmental pollution caused by urban rail construction is difficult to be evaluated. Therefore, how to evaluate the pollution degree of construction to the environment is important to control the construction process, and then adopting targeted measures to reduce environmental pollution and improving the urban environment. It is of great significance to realize the green construction of urban rail transit and the sustainable development of urban construction.

EARLIER STUDIES

As the country attaches importance to environmental protection, people's awareness of urban environmental protection has been continuously improved. The pollution of the urban environment caused by construction has attracted widespread attention from all walks of life. Requirements and guidance on environmental aspects of rail transit construction have been made by "*Notice on Doing a Good Job in Environmental Impact Assessment of Urban Rail Transit Projects (2014)*" and "*Technical Specification for Environmental Vibration and Noise Control Engineering of Urban Rail Transit (HJ2055-2018)*" issued by the Ministry

of Environmental Protection and the Ministry of Ecology and Environment, respectively.

Concerning the research on air pollution caused by urban rail transit construction, Huang et al. (2007) compared and analyzed the environmental pollution caused by construction in different construction stages. The results showed that excavation and construction can cause more environmental pollution than other stages. Li et al. (2014) used point monitoring TSP to achieve the monitoring of work areas, construction sheds and roadsides, and found that the earth and stone cause the most serious dust pollution to the environment. Hala et al. (2015) applied the dust concentration prediction model (FDM) to monitor the fugitive dust and particulate matter on the construction site in Doha, Qatar, and the results showed that the FDM simulation can determine the characteristics of fugitive dust pollution.

Regarding the research on noise pollution caused by urban rail transit construction, Bowlby studied the construction noise of high-speed rail construction projects, abstracting the noise source into points, lines, and surfaces, and considering the attenuation and propagation of noise by sound insulation panels (Haron et al. 2009). Based on the above conditions, a noise simulation model was finally established. Wang et al. (2018) analyzed environmental noise monitoring and evaluation methods in China, Japan, the European Union and the United States. Liu (2005) monitored the noise at the boundary of the construction project, and the results showed that the noise pollution to the surrounding environment during the piling stage was serious, which even affects the health of surrounding residents. Zhang (2013) used noise simulation software to analyze the impact of loaders, rammers, and vibration-impact ramming on the noise pollution and pointed out the largest noise source.

Considering the land subsidence caused by urban rail transit construction, Yang et al. (2013) used the finite element software MIDAS to simulate the track excavation project in the Wuhan rail transit project. The influence of track excavation on the ground settlement was studied. Meng et al. (2016) used the finite element software ANSYS to analyze the effect of track excavation on the impact of ground subsidence in the Qingdao rail transit project. Zhang (2021) analyzed the construction of Hefei Rail Transit Line 6 and Line 8 and found that the installation of urban rail transit has a non-negligible impact on ground settlement and surrounding buildings.

Studies on the vibration pollution caused by urban rail transit construction indicate that noise and vibration are mainly caused by the driving process of rail vehicles such as trains, subways, and light rails. They result from the collision between the wheels and the track and the mutual transmission of the power unit of the locomotive. Long-term noise interference can cause headache, dizziness, tinnitus, irritability, irritability, insomnia, neurasthenia, etc. (Yang 2011). Continuous vibrations cause the human brain to reduce the level of arousal, distracted, and have difficulty in spatial orientation, damaging mental function. Hu (2020) took the construction of the Chongqing subway as the main research object and conducted effective investigations on the vibration pollution caused by it with different prevention methods to provide a reference for environmental governance.

The pollution of land subsidence, air pollution, vibration pollution and urban landscape caused by urban rail transit construction has become an urgent problem to be solved in the process of urban civilization construction. This is not only related to the daily life of citizens but also concerned the image of the city. This is the core issue of this study.

MATERIALS AND METHODS

Environmental Pollution Evaluation Index System

With the demand for transportation in urban development, more and more long-term requirements have been put forward for the planning and design of urban rail transit, such as long routes, multiple lines, and large intersections. The development of rails needs to not only meet the transportation requirement of the city centre, but also consider the development of the suburbs, and even take into account the development of surrounding satellite cities. The construction methods for urban rail transit are different in various construction sites. Underground construction is mostly used in urban centres, while ground construction is mainly employed in suburban areas. Different construction methods cause different pollution to the surrounding environment. Xue et al. (2018) analyzed the pollution to the ecological and natural environment caused by rail transit construction. It showed that construction and excavation damage surrounding vegetation, muck transfer generates dust, and foundation pit construction causes soil settlement and other pollution. Zhu (2018) pointed out that the negative environmental pollution caused by rail transit construction involves noise, water, atmosphere, vibration, and residents' health quality. Zhang et al. (2020) constructed environmental pollution indicators of hydropower projects from the natural, social and ecological environment. The weights of 14 pollution indicators were also analyzed based on probabilistic language close to entropy, and scientific suggestions for project selection was provided.

According to Guan (2018), the environmental pollution caused by urban rail transit construction involves water and soil pollution, vegetation destruction, agricultural ecology, land subsidence, water pollution, air pollution, solid waste,

Table 1: Environmental Impact Assessment Index system of urban rail transit construction.

Target layer	First-level index	Second-level index	Meaning
Environmental Pollution Assessment of Urban Rail Transit Construction A	Ecosystem B1	Water and soil pollution C1	Pollution of groundwater caused by cement and chemical grout during construction
		Vegetation destruction C2	Ground excavation and ground track erection damage surrounding vegetation
		Agricultural ecology C3	Damage to farmland caused by rail transit route planning
	Natural environment B2	Ground subsidence C4	Excavation of underground rail transit lines and excavation of station foundation pits cause deformation and settlement of roads and surrounding buildings
		Water pollution C5	Engineering wastewater from construction operations, cleaning wastewater from construction machinery, domestic wastewater from construction workers, etc.
		Air pollution C6	During the construction process, the dust generated by vehicles entering and exiting, earth excavation and backfilling, and the fuel exhaust gas generated by mechanical equipment and vehicles
		Solid Waste C7	Waste soil, waste rock and construction waste generated during construction
	Social environmental pollution B3	Sound pollution C8	The sound produced by the mechanical equipment and construction process during the construction, which has an interference effect on the surrounding residents
		Vibration pollution C9	Vibration generated during the construction of large engineering equipment, shock vibration generated by blasting
		City view C10	The impact of construction on the scale, vision and aesthetics of the original urban space occupation, construction enclosure, and exposed buildings
		Population health C11	The impact of urban rail transit construction on the work, travel, daily life and rest of the surrounding residents

noise pollution, vibration pollution, urban landscape and population health, etc. Moreover, further categorization of the various pollution indicators can result in environmental pollution involving the ecological, natural and social environment. This paper summarizes and sorts out the environmental impact evaluation index system of urban rail transit construction, as given in Table 1.

Evaluation Model

Entropy is originally a thermodynamic concept. In 1948, Shannon introduced information theory based on the principle of entropy, which was used to describe and measure the degree of disorder in a system. The description of the degree of system order is information. So, the increase or decrease of information is inversely proportional to entropy. Richer information means less entropy. The entropy weight method is a method of calculating indicator weights by objectively assigning weights. According to the degree of variation of selected indicators, a matrix is established, and the threshold method is used to non-dimensionalize the matrix to calculate the information entropy, and then obtain the entropy weight through the difference coefficient (Lu & Liu 2021). The detailed steps are as follows:

Firstly, the evaluation index and evaluation object are digitized, and the original matrix X is established. The evaluation target M_i (I = 1, 2, 3, ⋯, m) is the row of the matrix, the evaluation index N_j (j = 1, 2, 3, ⋯, n) is the column of the matrix, and X_{ij} is the M_i evaluation The value of the N_j index of the object.

$$X = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1n} \\ x_{21} & x_{22} & ... & x_{2n} \\ ... & ... & ... & ... \\ x_{m1} & x_{m2} & ... & x_{mn} \end{bmatrix}$$

Secondly, it should be considered that there are differences in dimensions of different orders of magnitude in the original matrix. When this situation occurs, matrix X should be non-dimensionalized so that the value of X_{ij} is in the range of 0~1.

Positive dimensionless:

$$X_{ij} = \frac{x_{ij} - \min(x_j)}{\max(r_j) - \min(r_j)} \qquad …(1)$$

Negative dimensionless:

$$X_{ij} = \frac{\min(x_j) - x_{ij}}{\max(r_j) - \min(r_j)} \qquad \ldots(2)$$

Calculate the weight of each index X_{ij}:

$$P_{ij} = X_{ij} / \sum_{i=1}^{m} X_{ij} \qquad \ldots(3)$$

Get the entropy value of each index X_{ij}

$$e_{ij} = -1/\ln(m) \sum_{i=1}^{m} P_{ij} \ln P_{ij} \qquad \ldots(4)$$

Finally, calculate the entropy weight W_j
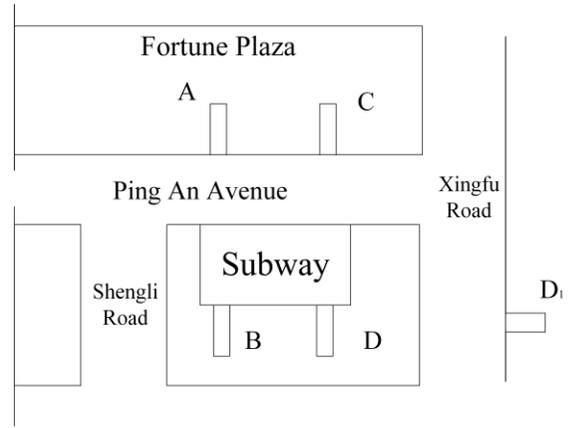
$$W_j = (1 - e_{ij}) / \sum_{j=1}^{n} d_j \qquad \ldots(5)$$

RESULTS ANALYSIS AND DISCUSSION

Project Background

The XA-XDM project belongs to a bid section of XA Rail Transit Line 10 in Wuhan, China. The XDM station of the project is located at Fortune Plaza in the city centre of Wuhan, surrounded by facilities such as Fortune Plaza, parks, office buildings and residential areas, as shown in Fig. 1.

Taking into account the particularity of the project location, it is necessary to evaluate the environmental pollution during the construction period before the project construction, analyze the weight of each index, and help the project make the best construction plan. To ensure the scientific and fair evaluation, many experts and citizen representatives were invited to make an evaluation team to score 11 evaluation indicators. The evaluation involves the magnitude of the impact on each indicator, and the impact is "Very big", "Larger", "General", "Smaller" and

Fig. 1: Schematic diagram of XDM station.

"Very small". By recovering the evaluation data to form the original matrix X and using formulas (1)-(3) to non-dimensionalize and normalize the collected data, we obtain the environmental pollution of each indicator. The evaluation results are shown in Table 2.

Analysis of the Weight of Environmental Pollution Index

Based on the evaluation results of environmental pollution by various indicators, the entropy weight method is used to calculate the entropy value and entropy weight of the standardized matrix. Formulas (4) and (5) are used to obtain the entropy weight of environmental pollution indicators, as shown in Table 3.

The entropy weight results show that the environmental pollution indicators of the project's XDM station construction are ranked as land subsidence, air pollution, vibration

Table 2: Evaluation results of the project's environmental impact assessment indicators.

Target layer	First-level index	Second-level index	Environmental pollution assessment				
			Very big	Larger	General	Smaller	Very small
Environmental Pollution Assessment of Urban Rail Transit Construction A	Ecosystem B1	Water and soil pollution C1	0.06	0.06	0.19	0.30	0.40
		Vegetation destruction C2	0.15	0.20	0.10	0.30	0.25
		Agricultural ecology C3	0.03	0.20	0.40	0.25	0.12
	Natural environment B2	Ground subsidence C4	0.70	0.20	0.05	0.03	0.02
		Water pollution C5	0.45	0.30	0.15	0.08	0.02
		Air pollution C6	0.45	0.40	0.09	0.05	0.02
		Solid waste C7	0.20	0.40	0.30	0.06	0.04
	Social environmental pollution B3	Sound pollution C8	0.25	0.48	0.10	0.13	0.05
		Vibration pollution C9	0.35	0.45	0.10	0.05	0.05
		City view C10	0.35	0.40	0.15	0.05	0.05
		Population health C11	0.25	0.25	0.40	0.05	0.05

Table 3: Entropy weight of environmental pollution indicators.

Target layer	First-level index	Weights	Second-level index	Weights
Environmental Pollution Assessment of Urban Rail Transit Construction A	Ecosystem B1	0.1533	Water and soil pollution C1	0.0719
			Vegetation destruction C2	0.0189
			Agricultural ecology C3	0.0625
	Natural environment B2	0.5083	Ground subsidence C4	0.2050
			Water pollution C5	0.0943
			Air pollution C6	0.1327
			Solid waste C7	0.0763
	Social environmental pollution B3	0.3385	Sound pollution C8	0.0783
			Vibration pollution C9	0.1026
			City view C10	0.0847
			Population health C11	0.0728

pollution, water pollution, urban landscape pollution, noise pollution, solid waste, population health, and water and soil pollution. It indicates that the most serious environmental pollution caused by rail transit construction in the city centre is ground subsidence (0.2050). The reason is that since the urban centre construction has been completed, the newly constructed rail transit inevitably damages and affects the original urban structure. The project needs to focus on construction to protect the surrounding structure, reduce the impact on ground settlement, and restore the damaged environment after the construction is completed. Among the environmental pollution indicators, the urban landscape (0.0847) is ranked in the top five, indicating that in the current urban development, urban landscapes also attract a lot of attention. The construction of urban rail transit in the city centre should pay full attention to match the original urban landscape. The impact of enclosure and work area on the urban environment during the construction should also take into account. The image of the city should not be ignored during rapid construction. Moreover, air pollution (0.1327), vibration pollution (0.1026), water pollution (0.0943), as well as the results of previous studies on environmental pollution, indicate that the application of the entropy method to evaluation of environmental pollution caused by urban rail transit construction is scientific. The results also show that air pollution causes greater environmental pollution than vibration pollution.

Based on the entropy weight data of the Second-level index, the First-level index weights are obtained. The data shows that the natural environmental pollution caused by the construction of rail transit in the city centre (0.5083) exceeds the sum of other indicators, i.e., the social environment, and the ecological environment. Natural environmental pollution, as a direct pollution object of track construction, has been relatively concerned by all parties. Its higher weight is in line with the actual situation. However, the social environmental pollution is also relatively high, indicating that with social development, people are increasingly paying attention to the urban environment. The requirements for the social environment are getting higher and higher. The construction of rail projects should pay attention to the social environmental pollution, reducing noise and vibration pollution. It also should consider urban landscaping, which effectively avoids unnecessary impacts on the project due to pollution to the social environment. The low weight of the ecological environment means that the construction of rail transit in the city centre relatively weakens the ecological damage, and the energy of the project in this regard may be weak.

Environmental Pollution Assessment of XA-XDM Project by Combining Weight Method

The combination weight method to determine the emergency capability index score is similar to the entropy weight method. The row vector for all indicators of the XA-XDM project is calculated by $W \times R = R_{row}$, and the specific scores of each index are $R_{final} = R_{row} \times [100,80,60,40,20]^T$, among which the environmental impact is 100 to 80 points, the stronger is 80 to 60 points, the general is 60 to 40 points, the weaker is 40 to 20 points, and the weak is 20 to 0 points. Combining the right of environmental pollution indicators, the specific score of each indicator is [41.6, 54.0, 55.4, 90.6, 81.6, 84.3, 73.2, 75.0, 80.0, 79.0, 72.0], and further calculations based on the weight of the indicators were made to investigate the environmental pollution impact of the XA-XDM project. The evaluation score is 76.5. The evaluation results show that the XA-XDM project has a strong impact on environmental pollution. During the construction process, attention should be paid to the prevention, control and monitoring of various pollution indicators to reduce environmental pollution and achieve green construction.

CONCLUSION

Aiming at evaluation of the environmental pollution caused by urban rail transit construction, an environmental impact assessment index system for urban rail transit construction was constructed by using the literature research method, and the entropy method was used to evaluate the pollution of the XA-XDM project construction on the urban environmental pollution, and the following conclusions are obtained:

1. An environmental impact assessment index system for urban rail transit construction is established, which fully summarizes the environmental pollution caused by rail construction, and provides a certain reference for subsequent research on environmental pollution caused by urban construction.

2. The entropy weight method is used to evaluate the environmental pollution caused by urban rail transit construction, and the weight of each pollution indicator is determined based on the results of quantitative analysis. The weighted result is in accordance with the law of previous research results, indicating that the entropy weight method is feasible to evaluate the environmental pollution of urban rail transit construction by law.

3. The environmental pollution impact assessment score of the XA-XDM project is 76.5. This result indicates that the XA-XDM project has a strong impact on environmental pollution. The construction of rail transit in the centre of the city should focus on indicators such as land subsidence, air pollution, and vibration pollution. Meanwhile, the protection of the urban landscape should not be neglected during track construction.

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