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Case Report
Research of City Metro Decision-making Method Based on Multi Hierarchy Fuzzy Comprehensive Evaluation

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Abstract

Background: Metro system is an important to resolve city traffic problem, imporve city environment and deal with energy cirisis, so its decision-making must be resonable. **Materials and Methods:** Decision principle and system framework of city metro evaluation index are introduced firstly. Corresponding fuzzy evaluation factor Set and comment set are then put forward. Lastly, multi grade weight and fuzzy evaluation process for metro decision-making is discussed by taking ShenSui metro for an instance. **Results:** ShenSui metro line project can reduce the space-time distance and boost Guangdong economy. It's important and significance for changes of regional economic structure, the formation of urban system and the adjustment of urban industrial structure. **Conclusion:** Case study of Guangzhou metro ShenSui project fuzzy decision-making provides scientific reference for government decision-making including subjective factors.

Key words: Metro project, evaluation index, fuzzy evaluation

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

As an investment activity, metro project is complicated system engineer which involves metro planning, bidding, design, construction and operation. Its influencing factors include construction period, regional stability, per capita GDP of city, influence on ambient environment, etc. As a result, it is very urgent and necessary to analyze, model and resolve metro project decision problem scientifically. Thomas L. Saaty, American operational research expert, puts forward analytic hierarchy process method, combined with qualitative and quantitative analysis[1]. Xueshen Qian, Chinese scientist, presents synthesized method for complicated system from qualification to quantification[2]. Multi-objective fuzzy optimization theory is applied by ShouYu Chen to hydraulic and hydroelectricity system, civil engineering system and environmental engineering system[3]. Gu[4] discusses decision problem of small hydropower construction projects. In all areas of evaluation and decision, Data Envelopment Analysis (DEA) method, Markoff Decision Process (MDP), analytic hierarchy process (APH), Fuzzy Mathematics Decision (FMD) method and Grey Correlation Analysis (GCA) method are applied widely.

EVALUATION INDEX SYSTEM OF CITY METRO DECISION-MAKING

By collecting relevant data about metro project[5,6] of China Xi'an, Guang Zhou and Wuhan, evaluation index system of city metro decision-making is constructed from economy, society and environment, as shown in Fig. 1.

ESTABLISHMENT OF EVALUATION FACTOR SET AND COMMENT SET

According to evaluation index system, evaluation factor set is $U = \{U_1, U_2, U_3\}$ = {economy index, environment index, social index}, where $U_1 = \{U_{11}, U_{12}, U_{13}\}$ = {per capita GDP, local finance income, Internal rate of economy return}, $U_2 = \{U_{21}, U_{22}, U_{23}\}$ = {nature environment, residential environment, geological environment}, $U_{21} = \{U_{211}, U_{212}\} = \{U_{211}, U_{212}\}$ = {improve atmospheric pollution degree, reduce noise pollution degree}, $U_{23} = \{U_{231}, U_{232}, U_{233}, U_{234}\}$ = {stratum situation along the MTR, crustal stability, groundwater and soil corrosion, bag geological phenomena}, $U_3 = \{U_{31}, U_{32}, U_{33}\}$ = {Urban population, employment improve degree, traffic

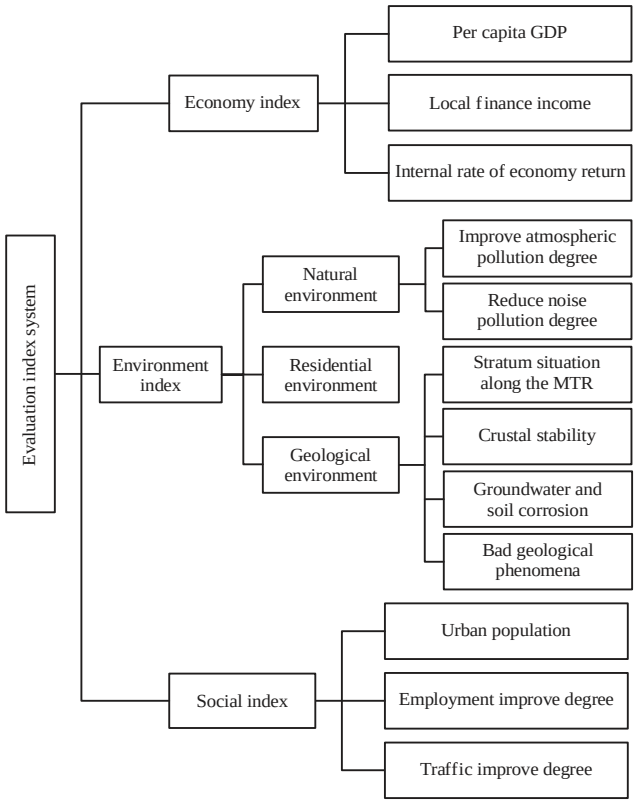

Fig. 1: Evaluation index system of city metro decision-making

Table 1: Local finance income evaluation rules

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{11} \leq 50$	✓				
$50 < U_{11} \leq 100$		✓			
$100 < U_{11} \leq 130$			✓		
$130 < U_{11} \leq 200$				✓	
$200 < U_{11}$					✓

*Unit of evaluation factor is billion

Table 2: Evaluation criterion of FIRR

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{12} \leq 1\%$	✓				
$1\% < U_{12} \leq 2\%$		✓			
$2\% < U_{12} \leq 3\%$			✓		
$3\% < U_{12} \leq 5\%$				✓	
$5\% < U_{12}$					✓

Table 3: Economic internal rate of return evaluation criteria

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{13} \leq 5\%$	✓				
$5\% < U_{13} \leq 8\%$		✓			
$8\% < U_{13} \leq 10\%$			✓		
$10\% < U_{13} \leq 12\%$				✓	
$12\% < U_{13}$					✓

Table 4: Per capita GDP evaluation criteria

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{14} \leq 300$	✓				
$300 < U_{14} \leq 500$		✓			
$500 < U_{14} \leq 1000$			✓		
$1000 < U_{14} \leq 2000$				✓	
$2000 < U_{14}$					✓

*Unit of evaluation factor is dollar

improve degree}. The evaluation set is defined as $V = \{V_1, V_2, V_3, V_4, V_5\}$ = {Very poor, Poor, General, Good, Very good}.

Economy index U_1: Local finance revenue (FIRR, U_{11}) is one of the three decisive factors of city metro decision-making. According to statistics, except for Hong Kong, all the city metro that had been built in china are at a loss and need the subsidies of government finance. Therefore, only when the local financial revenue get a certain level can the metro construction is taken in to account. The evaluation rules are shown in Table 1.

Financial internal rate of return (U_{12}) is not only one of the key evaluation criteria of the analysis of profitability, but also the financial analysis results that are based on project financial benefits and cost estimation. The project is financially acceptable when U_{12} is greater than or equal to the set identifying benchmark (IRR). On the basis of reference on the standard of city rapid rail transit project standard, the benchmark interest rate was cut down to 3% and allows the U_{12} was allowed to be less than it because of the obvious social benefits of metro project. In the early stage of project operation, operating losses may be lessen by the appropriate subsidies of regional governments, loans principal are paid by the distributed profits of annual project operation and the rest can be repaid by the earnings of along land development given by government. In this regard, Hong Kong has set a good example and is worth considering in the development of city metro decision-making. The evaluation criteria of internal rate of economy return as shown in Table 2.

Economic internal rate of return (U_{13}) is a kind of analysis indexes of the economic cost-benefit, which can be used to analyze the economic efficiency of the project investment and the contributions made to social welfare. When the economic internal rate of return is equal to or greater than the social discount rate, it means that the net contribution of this project has reach or exceeds the required level to the national economy. Namely, this project is acceptable. There are two methods to confirm social index; social opportunity cost method based on capital and the preference rate method based on social time. According to the statistical data of economic development since the founding, the social capital return rate will be 9~11% within the next 20 years. As is studied by related economists, social time preference rate in our nation is about 4.5~6%. Therefore, taking the two conditions into account, social discount rate is set to 7% in this study. Evaluation criteria of economic internal rate of return as shown in Table 3.

Per capita GDP (U_{14}), namely per capita gross domestic product, is a comprehensive indicator of the local economic development, which is able to reflect the comprehensive benefit and quality of economy. Through the analysis of the world metro development, it is not difficult to find that there is a demand for metro when the national per capita GDP is more than $500. The metro can be developed widely when per capita GDP reaches the stage of $500-$2000. The metro can be developed to high levels when the per capita GDP is more than $2000. Evaluation criteria of Per capita GDP are shown in Table 4.

Social index U_2

City population (U_{21}): City population (U_{21}) is one of the three indexes approved by the State Council to the metro construction. On the condition those urban forms into a certain scale, when city population reaches a certain level, there will be a demands for metro construction because of traffic congestion, the accelerated life pace and enlarged infrastructure density. Evaluation criteria of quantitative index are shown in Table 5.

Table 5: Evaluation criteria of urban population

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{21} \leq 100$	✓				
$100 < U_{21} \leq 300$		✓			
$300 < U_{21} \leq 500$			✓		
$500 < U_{21} \leq 1000$				✓	
$1000 < U_{21}$					✓

*Unit of evaluation factor is million

Table 6: Qualitative index of expert investigation consultation table

Parameters	V_1	V_2	V_3	V_4	V_5
Impact on road traffic level					
Improvement level of infrastructure					
Improvement level of air pollution					
Reduced level of noise pollution					
Influence on surrounding environment level					
Influence on the existing buildings level					
Formation conditions					
Crustal stability along the metro lines					
Causticity of underground water and soil					

Table 7: Evaluation criteria of employment benefit index

Parameters	V_1	V_2	V_3	V_4	V_5
$U_{24} \leq 500$	✓				
$500 < U_{24} \leq 800$		✓			
$800 < U_{24} \leq 2500$			✓		
$2500 < U_{24} \leq 3500$				✓	
$3500 < U_{24}$					✓

Influence on road traffic (U_{22}): With the unceasing development of our economic level, traffic congestion is becoming more and more serious even though the transportation infrastructure construction is strengthened continuously in most cities. According to statistics in Beijing, Shanghai and Guangzhou and other domestic first-tier cities, the average speed at the peak is only 20 km h^{-1}, which caused shocking casualties and property losses events. The characteristics of fast speed and large carrying capacity of metro makes it possible to remit the ground traffic pressure, thus becoming one of the primary factors in metro construction. As the degree which influence road traffic is qualitative, by sending Delphi questionnaires relative to evaluation factors to experts through network, telephone, mail and other forms, it's feasible to obtain the fuzzy judgment matrix element values with statistical methods to this kind of clear content and ambiguous epitaxial index. The research and consulting table conducted by qualitative indicators experts are shown in Table 6.

Improvement of infrastructure U_{23}: Urban infrastructure is the foundation of urban social economic development and operation, the more perfect the infrastructure is, the more excellent the city investment environment will be, the more coordinated the urban running and development will be. Urban metro can combine functional areas such as city office district, commercial district and residential district each other organically. Therefore, it will promote regional economic development as well as the standards of the people's material and cultural life at the same time. The improvement of infrastructure is set as indicators of metro decision-making in this study. For this qualitative index, the evaluation results can be obtained through expert questionnaire that are shown in Table 6.

Employment benefit index (U_{24}): Under the circumstance of economic crisis, the contradiction between supply and demand of labor market becomes more prominent. Whether the authors can develop harmoniously will highly depend on the ability to solve employment problems. Employment benefit index can be measured by the new employment figures ratio, unit investment ratio of employment and direct employment figures. In this paper, this study will regard direct employment figures as the employment benefit index of metro decision-making. Evaluation criteria of quantitative index are shown in Table 7.

Environmental index U_3

Natural environment index (U_{31})

Improvement on air pollution (U_{311}): In generally speaking, metro trains are EMUs, so there are no motorcycle exhaust emission. Moreover, the planned metro can replace buses and private cars partly, which can reduce the discharge of vehicle exhaust certainly. Along with the mitigation of ground traffic congestion, it will help to improve the speed of the cars, thereby reducing fuel consumption. According to the degrees of reducing air pollution, the qualitative evaluation index can be realized through some experts' scoring. The evaluation content are shown in Table 6.

Improvement on noise pollution (U_{312}): Noise pollution on the ground transportation is mainly attributed to cars, such as the sound of a car engine, emergency braking and the horn at congestion, which contribute almost 50% of traffic noise in the city. Study shows that road traffic noise may disturb the people's normal life and rest, even cause serious traffic accidents. Metro can replace part of the road vehicles, so it will surely reduce noise pollution of land traffic. However, the metro itself is also the source of noise, including all kinds of fan noise, air flow noise, cooling tower noise and trains running noise etc. Comparing with land traffic noise, metro noise is interrupted. The improvement on air pollution can be assessed by the experts and evaluation content as shown in Table 6.

Table 8: Evaluation criteria of formation

Parameters	V_1	V_2	V_3	V_4	V_5
Structural plane combines worse, structure type is granular	✓				
Structural plane combines worse, structure type is fractured blocky or cataclastic texture		✓			
Structural plane combines general, structure type is joint, fissure, level or small faults			✓		
Structural plane combines well, structure type is bulk or thick layered				✓	
Structural plane combines well, structure type is overall shape or thick layered					✓

Residential environmental index (U_{32})

Influence on surrounding environment (U_{321}): The metro is a complex municipal engineering with long distance. It will traverse different functional region in the city and have impact on the urban environment during construction. For metro construction will occupy some green land and even cause contemporary close especially in the prosperous downtown roads, thus resulting in bus route changes, traffic congestion and the deterioration of the urban humanities and ecological environment. In addition, in some historic cities such as Xi'an, Beijing, Nanjing etc., there may have a large number of cultural relics along the MTR lines, so they will inevitably be affected in metro construction. According to the damage to the environment in metro construction and the recovery of the environment after construction, the expert's had scored to determine the qualitative evaluation index and evaluation content as shown in Table 6.

Influence on existing buildings (U_{322}): During metro operation, the wheels and rails will make periodic impulse, which will form periodic vibration because the alternating load can be transferred to the buildings on the ground through the sleeper, tunnel and soil. As the long time effect of the alternating load on the soil structure, it will affect the fatigue damage and the safety performance of the existing buildings. The metro tunnel is near from the buildings as its shallow way. With the expansion of the metro scale, there will be more and more buildings along the MTR. The metro tunnel construction of soil stress and load will affect the safety of metro tunnel and the buildings, so it is necessary to carry out inspection, assessment and maintenance of buildings along the line. According to the influence on existing buildings and the input repairing costs during operation, the qualitative indexes can be evaluated by the experts, the evaluation content are shown in Table 6.

Geological environment index (U_{33}): Metro is built on the surface of the earth crust in definite geological environment. Therefore, what must be chiefly taken into consideration in metro decision-making is that how to avoid devastating damage caused by large-scale collapse, landslide and earthquake to ensure the construction and operation of metro safely and economically. As the long time of metro project construction and its usage and higher requirements on the structure and stability, so the authors will evaluate it in four aspects-the formation conditions, regional stability, groundwater corrosive and bad geological phenomenon according to some factors such as hydrological and geological conditions, rock and soil types in the comprehensive geological environment.

Stratum situation (U_{331}): As the metro construction should be excavated with underground holes with a certain cross sectional shape and size as well as great extended length, therefore, formation may have a great influence on metro project investment and operation safety. The underground engineering will always crush and collapse which will cause the ground subsidence after excavation because of the broken rock and soil. Serious stratigraphic fluctuates will also bring big trouble to design and construction of underground project. According to the fluctuation and rock breaking condition along the metro lines, the qualitative evaluation criteria are shown in Table 8, then the qualitative index can be determined through expert evaluation and evaluation content as shown in Table 6.

Crustal stability along the metro (U_{332}): Crustal stability along the metro is carried out with the metro construction and economic planning activities in China, which has become one of the important bases for decision making of site selection and prophase argumentation of national metro planning. The emphasis on structure activity and rock structure has become a dominant factor in controlling the stability along the metro lines with the fault activity, seismicity and fault block stability as the main analysis method. In China, for the metro project, the upper time limit of potential faults is 10000 years. According to the position relationship between metro lines and active faults and local earthquake frequency as shown in Table 9, evaluation of crust stability along the metro, the expert evaluation method as shown in Table 6.

Table 9: Evaluation criteria of crustal stability along the metro

Parameters	V_1	V_2	V_3	V_4	V_5
Active fault exists in metro lines and seismic activity is frequent	✓				
Active fault exists nearby metro lines and seismic activity is more		✓			
Active fault exists nearby metro lines and seismic activity occurs rarely			✓		
Active fault doesn't exists nearby metro lines and seismic activity occurs rarely				✓	
Active fault doesn't exists nearby metro lines and seismic activity almost never happens					✓

Table 10: Evaluation criteria of bad geologic phenomena

Parameters	V_1	V_2	V_3	V_4	V_5
Karsts, soil cave, landslide and special soil soft soil, expansive soil, etc., exist in metro lines	✓				
Karsts, the soil cave and landslide exist in metro lines		✓			
Special soil such as soft soil, expansive soil exist in metro lines			✓		
Karsts, soil cave, landslide and special soil exist not in metro lines				✓	
Metro lines are with good soil and uniform distribution					✓

Underground water and soil erosion (U_{333}): The metro tunnel is mainly the reinforced concrete structure, so underground water and soil erosion will have a great impact on the concrete structure and durability of steel members. Referring to the rock soil engineering reconnaissance specification about evaluation of corrosion on groundwater and soil, the experts will evaluate the underground water and soil corrosion according to PH values, sulfate content, magnesium salt content, ammonium salt content, caustic alkali content, total salinity and so on. The reference code for investigation of geotechnical engineering analysis and evaluation by experts according to the groundwater and soil corrosion of underground soil pH in size, content of sulfate, magnesium salt content, salt content, alkali content, total salinity, the content of the questionnaire is shown in Table 6. The corrosion grade is divided into strong, moderately strong, moderate, moderately weak, weak, which is corresponded to the evaluation grade of very poor, poor, general, good and very good.

Bad geologic phenomena (U_{334}): Bad geological phenomenon refers to the dynamic geological phenomenon of adverse metro construction or bad effects, mainly for the karsts, the soil cave and landslide phenomenon along metro. Comparing with general soil, different geologic conditions, environment and climate conditions in different regions results in the different engineering soil properties such as loess, a special soil in soft soil, expansive soil, frozen soil, red clay, saline soil with special engineering properties and rules. Whether the MTR along exist karsts, soil cave, landslide and special soil has formed a qualitative evaluation criteria as shown in Table 10, then the method for determining the qualitative index through expert evaluation, evaluation content as shown in Table 6.

For the qualitative index, membership degree of each evaluation factor belonging to evaluation comment set according to Delphi method. For the quantitative index, membership degree can be gotten by interval quantitative standard.

CASE STUDY

Determination of decision-making weight

Determination of first grade weight: According to this study, priority of natural environment constitute elements is $U_{212} \succ U_{211}$; priority of geological environment constitute elements is $U_{234} \succ U_{231} \succ U_{232} \succ U_{233}$. In terms of judgment matrix element scale method, natural environment judgment A_{21} and geological environment judgment A_{23} can be acquired:

$$A_{21} = \begin{bmatrix} 1 & 1/3 \\ 3 & 1 \end{bmatrix} \quad A_{23} = \begin{bmatrix} 1 & 3 & 5 & 1/3 \\ 1/3 & 1 & 3 & 1/5 \\ 1/5 & 1/3 & 1 & 1/7 \\ 3 & 5 & 7 & 1 \end{bmatrix}$$

Corresponding eigenvectors are gotten by data processing, normalization and sum\|product method:

$$W_{A21} = \{0.25, 0.75\}$$

$$W_{A23} = \{0.263, 0.122, 0.057, 0.558\}$$

According to equation $AW = \lambda_{max}W$, max eigenvalue $\lambda_{A23max} = 4.117$ and its consistency index $CR_{A23} = (4.117\text{-}4)/[(4\text{-}1)\times 0.9] = 0.0433<0.1$. Hence, its judgment matrix A_{23} passes through consistency check.

Second grade weight computation: Priority sequence of element in economy index is $U_{11} \succ U_{13} \succ U_{12}$; priority sequence of element in environment index is $U_{23} \succ U_{21} \succ U_{22}$; priority sequence of element in social index is $U_{32} \succ U_{31} \succ U_{33}$. Economy index judgment A_1 social index judgment A_2 and economy index judgment A_3 can be gotten.

$$A_1 = \begin{bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/3 \\ 1/3 & 3 & 1 \end{bmatrix} \quad A_2 = \begin{bmatrix} 1 & 3 & 1/3 \\ 1/3 & 1 & 1/5 \\ 3 & 5 & 1 \end{bmatrix} \quad A_3 = \begin{bmatrix} 1 & 1/3 & 3 \\ 3 & 1 & 5 \\ 1/3 & 1/5 & 1 \end{bmatrix}$$

Corresponding weight vectors is:

$$W_{A1} = \{0.5829, 0.1053, 0.3118\}$$

$$W_{A2} = \{0.3118, 0.1053, 0.5829\}$$

$$W_{A3} = \{0.3118, 0.5829, 0.1053\}$$

Max eigenvalue of judgment A_1, A_2 and A_3 is 3.0385 and its consistency index $CR_{A1} = CR_{A2} = CR_{A3} = (3.0385\text{-}3)/[(3\text{-}1) \times 0.58] = 0.0332 < 0.1$. Hence, its judgment matrix A_1, A2 and A_3 passes through consistency check.

Determination of third grade weight: By investigation and analysis, priority sequence of third grade index is $U_1 \succ U_2 \succ U_3$ and its judgment matrix and corresponding weight vector respectively are:

$$A = \begin{bmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix}, \quad W_A = \{0.633, 0.260, 0.106\}$$

Consistency index $CR_A = 3.0385$ and judgment matrix A passes through consistency check in terms of second grade weight solution process.

Fuzzy comprehensive evaluation of city metro decision-making: In 2010, the GDP of Pearl river delta economic zone will reach 2,800 billion with10.6% annual growth rate and 40000 per capita GDP[6]. After the continuously adjusting and optimizing course of industrial structure, the comprehensive agricultural production capacity is enhanced, the industrial structure is further optimized, the industrial international competitiveness is significantly enhanced, the service industry is all-round developed and the ratio of three major industrial structure is 5:35:60. Among them, in 2007, the GDP of Guangzhou, Dongguan, Huizhou were 692.4, 6315.1 and 110.5 billion[7]. The total GDP reached 1118 billion, among which the year-on-year growth were 18.1, 17.4 and 14.5%, per capita GDP were 7018.6, 4601.4 and 2894.5 billion[8], respectively, total industrial output value was 564.5, 348.6 and 137.4 billion, respectively, total exports were 37.9, 60.2 and 14.6 billion dollars, respectively, the actual utilization of foreign capital is 3.3, 2.1 and 1.2 billion dollars, investment in fixed assets were 186.3, 84.1 and 48.3 billion, respectively, local financial revenue were 52.4, 18.6 and 6.2 billion, respectively, total retail sales of social consumer goods are 259.5, 69.6 and 35.4 billion, respectively. For the project, the financial internal rate of return before financing and tax is 6.33%, large orbit traffic project benchmark rate of return before financing tax is 5%; investment financial net present value of 443749 million, greater than zero, the investment payback period is 18.18 years, which is less than the reference investment recovery period of 20 years, the economic internal rate of return is 18.55%, higher than the social discount rate 8%, economic net present value (I = 8%) is 2520950 million yuan, greater than zero[9]. Dongguan to Huizhou inter-city rail traffic project affected area is Dongguan, Huizhou and Guangzhou,the economic data of Guangdong (GD), Dongguan (DG), Huizhou (HZ) are taking into account according to the 4:3:3 importance of three cities, economic indicators of Dongguan Hui intercity project evaluation are as follows:

- $U_{11GD} = 524 > 200,130 < U_{11DG} = 186 < 200,50 < U_{11HZ} = 62 < 100$, the corresponding fuzzy membership degree vector can be concluded from Table 1 the local finance income evaluation rules:

$$\underset{\sim 11}{C} = \frac{0}{V_1} + \frac{0.3}{V_2} + \frac{0}{V_3} + \frac{0.3}{V_4} + \frac{0.4}{V_5}$$

- $U_{12} = 6.33 > 5\%$, the corresponding fuzzy membership degree vector can be concluded from Table 2 the financial internal rate of return evaluation rules:

$$\underset{\sim 12}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0}{V_3} + \frac{0}{V_4} + \frac{1}{V_5}$$

- $U_{13} = 18.55 > 12\%$, the corresponding fuzzy membership degree vector can be concluded from Table 3 the economic internal rate of return evaluation rules:

$$\underset{\sim 13}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0}{V_3} + \frac{0}{V_4} + \frac{1}{V_5}$$

- U_{14GD} = 10339.87>2000, U_{14DG} = 6764.38>2000, U_{14HZ} = 4255.11>2000, the corresponding fuzzy membership degree vector can be concluded from Table 4 the per capita GDP evaluation rules:

$$\underset{\sim 14}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0}{V_3} + \frac{0}{V_4} + \frac{1}{V_5}$$

Guanhui inter-city along the road owns location advantages, higher population density and better urbanization level, high strength of land development and utilization with the political, economic, financial and manufacturing center cities in the Pearl river delta economic zone included. The three total land area is 2.11 plus 104 km^2. In 2007, the total resident population is 22.6 million, of which the household registration population reached 12.52 million, temporary resident population is 10.08 million, the total population density is 1071 persons km^{-2}. The resident population of Guangzhou, Dongguan, Huizhou were respectively 10.05, 6.95 and 3.88 million. At present, the intercity passenger flow is mainly borne by road, as the road undertake too much intercity passenger flow, which resulting in traffic congestion, much environmental pressure, low service level of GuanHui channel road. As estimated in 2022, the intercity travelling passengers will reach 488,213 per day, which is beyond the capacity of current traffic structure. Huizhou inner-city project will create about 200000 job opportunities and expense 630000 t of steel, 3800000 t of cement. Evaluation of social index of Dongguan Hui intercity project is as follows:

- U_{21GD} = 1005>1000,500<U_{21DG} = 695<1000, 300<U_{21HZ} = 388<500, the corresponding fuzzy membership degree vector can be concluded from Table 4 the city population evaluation rules:

$$\underset{\sim 21}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0.3}{V_3} + \frac{0.3}{V_4} + \frac{0.4}{V_5}$$

Evaluation of road traffic impact is shown in the form of expert Del's questionnaire in Table 5, 10% of which believe that the general, 30% think good, 60% consider very good. So the corresponding fuzzy membership degree vector is:

$$\underset{\sim 22}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0.1}{V_3} + \frac{0.3}{V_4} + \frac{0.6}{V_5}$$

Improvement of infrastructure is shown in the form of expert Del's questionnaire in Table 6, 8% of which believe that the general, 25% think good, 67% consider very good. So, the corresponding fuzzy membership degree vector is:

$$\underset{\sim 23}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0.08}{V_3} + \frac{0.25}{V_4} + \frac{0.67}{V_5}$$

- U_{24} = 200000>3500, the corresponding fuzzy membership degree vector is be obtained from the evaluation rules of employment benefit:

$$\underset{\sim 24}{C} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0}{V_3} + \frac{0}{V_4} + \frac{1}{V_5}$$

The inter-city engineering route and station as well as parking location in Guanhui are generally coordinates with city planning, which can ensure the control ability of vibration noise, pollution. Although, the destruction to the ecological environment is inevitable, the impact on the environment may be minimized through taking feasible measures of environmental protection during construction and appropriate compensating after construction. In addition, the operation of inter-city rail traffic can disperse city highway volumes, alleviate road congestion, reduce vehicle emissions, with which all these are playing positive role of improving the city's ecological environment. Dust is the most important source of pollution during construction, so measures must be taken according to related specified requirements of Guangdong province to prevent and control the dust in construction, such as watering, covering, compacting and so on, in order to make good preparation for preventing and controlling dust in the aspects of excavation surface, construction site, construction office and living areas, waste storage and transportation construction.

The air environment along the line performs secondary standard[10] (GB3095-1996). According to the distribution characteristics of sensitive points and the city development planning, it should set up upright, inverted L-type sound barrier for the subgrade, elevated line focus in the vicinity of residential areas, schools, hospitals. It also set up full enclosed sound barrier and the semi enclosed compartment sound barrier for the very medium dense large community. At the same time, for those who haven't reached the standard, this study should set up subsidiary ventilation and sound insulation window for residents. For other scattered households, ventilation sound insulation window can be set up to ensure indoor noise is appropriate to the standard. In order to reduce the noise produced by the fan and cooling tower, the author selected noise fan and cooling tower in this study, meanwhile, this study set up a large type muffler in

the wind Pavilion air duct and the air outlet is located in the departure from the sensitive point of wind direction to make the outer row of noise meet local function zoning requirements.

Guangzhou (Dongguan) to Huizhou inter city rail transit project is located in the downstream of East river. The overall terrain is higher in North East and lower in southwest, the topography along the line is the Dongjiang river delta plain, denuded hills and river valley. Tectonic in the region is mainly northeast and northwest, including both East-West and North-South, which also develops a basement folded belt and continental marginal mobile belt folded belt. Bad geology along the line is mainly local slide collapse, landslide and earthquake zones, special rock is mainly artificial filled soil, soft soil. Geological environmental conditions of the project along the line is complex, the leading factor of geological environment is geotechnical engineering geological condition, motivating factor is human engineering activity and atmospheric rainfall and the rest is subordinate geological environmental factors. At the same time, the assessment grade of geological hazard is rated as first order, through field investigation of geological disasters; it has been found that the geological disasters sorts are landslide, collapse and soft land base surface subsidence. There is one landslides, one collapse, fifteen soft land base surface subsidence, of which the harm and danger is generally small.

According to the analysis conclusion of natural conditions and engineering geological exploration of the project, the fuzzy evaluation of indexes, which is composed of improvement on infrastructure, air pollution, noise pollution, surrounding environment and influence on the existing buildings, the formation conditions, crustal stability along the metro, the underground water and soil erosion, bad geological phenomena, can be obtained in the form of expert Del's questionnaire in Table 6. The corresponding fuzzy membership degree vectors are referred from the evaluation results:

$$\underset{\sim}{C}_{311} = \frac{0.05}{V_1} + \frac{0.12}{V_2} + \frac{0.25}{V_3} + \frac{0.37}{V_4} + \frac{0.21}{V_5}$$

$$\underset{\sim}{C}_{312} = \frac{0.14}{V_1} + \frac{0.166}{V_2} + \frac{0.32}{V_3} + \frac{0.25}{V_4} + \frac{0.13}{V_5}$$

$$\underset{\sim}{C}_{321} = \frac{0.1}{V_1} + \frac{0.13}{V_2} + \frac{0.32}{V_3} + \frac{0.29}{V_4} + \frac{0.16}{V_5}$$

$$\underset{\sim}{C}_{322} = \frac{0.03}{V_1} + \frac{0.09}{V_2} + \frac{0.39}{V_3} + \frac{0.38}{V_4} + \frac{0.11}{V_5}$$

$$\underset{\sim}{C}_{331} = \frac{0.03}{V_1} + \frac{0.08}{V_2} + \frac{0.72}{V_3} + \frac{0.17}{V_4} + \frac{0}{V_5}$$

$$\underset{\sim}{C}_{332} = \frac{0}{V_1} + \frac{0}{V_2} + \frac{0.47}{V_3} + \frac{0.53}{V_4} + \frac{0}{V_5}$$

$$\underset{\sim}{C}_{333} = \frac{0.1}{V_1} + \frac{0.27}{V_2} + \frac{0.46}{V_3} + \frac{0.17}{V_4} + \frac{0}{V_5}$$

$$\underset{\sim}{C}_{334} = \frac{0.09}{V_1} + \frac{0.37}{V_2} + \frac{0.47}{V_3} + \frac{0.07}{V_4} + \frac{0}{V_5}$$

Relation matrix of corresponding evaluation index fuzzy evaluation can be gotten by analysis of above membership degree vector:

$$R_1 = \left[\underset{\sim}{C}_{11}, \underset{\sim}{C}_{12}, \underset{\sim}{C}_{13}\right] = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_{21} = \left[\underset{\sim}{C}_{211}, \underset{\sim}{C}_{212}\right] = \begin{bmatrix} 0.05 & 0.12 & 0.25 & 0.37 & 0.21 \\ 0.14 & 0.16 & 0.32 & 0.25 & 0.13 \end{bmatrix}$$

$$R_{22} = \left[\underset{\sim}{C}_{22}\right] = \begin{bmatrix} 0.03 & 0.09 & 0.39 & 0.38 & 0.11 \end{bmatrix}$$

$$R_{23} = \left[\underset{\sim}{C}_{231}, \underset{\sim}{C}_{232}, \underset{\sim}{C}_{233}, \underset{\sim}{C}_{234}\right] = \begin{bmatrix} 0.10 & 0.13 & 0.32 & 0.29 & 0.16 \\ 0.03 & 0.08 & 0.72 & 0.17 & 0 \\ 0.02 & 0.07 & 0.40 & 0.51 & 0 \\ 0.10 & 0.27 & 0.46 & 0.17 & 0 \end{bmatrix}$$

$$R_3 = \left[\underset{\sim}{C}_{311}, \underset{\sim}{C}_{312}, \underset{\sim}{C}_{313}\right] = \begin{bmatrix} 0.08 & 0.32 & 0.25 & 0.35 & 0 \\ 0 & 0.31 & 0.37 & 0.32 & 0 \\ 0.13 & 0.19 & 0.34 & 0.36 & 0 \end{bmatrix}$$

First grade fuzzy evaluation: According to first grade evaluation equation $B^{(1)} = A^{(1)} \cdot R^{(1)}$, economy index fuzzy evaluation[11] is:

$$B_1^{(1)} = A_1^{(1)} \cdot R_1^{(1)} = W_{A1} \cdot R_1 = [0 \;\; 0 \;\; 0 \;\; 0.1053 \;\; 0.8947]$$

Nature index fuzzy evaluation is shown as follows:

$$B_{21}^{(1)} = A_{21}^{(1)} \cdot R_{21}^{(1)} = W_{A21} \cdot R_{21} = [0.1175 \;\; 0.1500 \;\; 0.3025 \;\; 0.2800 \;\; 0.1500]$$

Nature index fuzzy evaluation is shown as follows:

$$B_{23}^{(1)} = A_{23}^{(1)} \cdot R_{23}^{(1)} = W_{A23} \cdot R_{23} = [0.0478 \;\; 0.1067 \;\; 0.3390 \;\; 0.3632 \;\; 0.1433]$$

Social index fuzzy evaluation is shown as follows:

$$B_{3}^{(1)} = A_{3}^{(1)} \cdot R_{3}^{(1)} = W_{A3} \cdot R_{3} = [0.0386 \;\; 0.3005 \;\; 0.3294 \;\; 0.3336 \;\; 0]$$

Second grade fuzzy evaluation: In terms of second grade evaluation equation $B^{(2)} = A^{(2)} \cdot R^{(2)}$, environment index fuzzy evaluation is:

$$B_{2}^{(2)} = A_{2}^{(2)} \cdot R_{2}^{(2)} = W_{A2} \cdot [B_{21}^{(1)} \;\; B_{22}^{(1)} \;\; B_{23}^{(1)}]$$
$$= [0.0677 \;\; 0.1184 \;\; 0.3330 \;\; 0.3390 \;\; 0.1419]$$

Third grade fuzzy evaluation: By referring to third grade evaluation equation $B^{(3)} = A^{(3)} \cdot R^{(3)}$, Xi'an metro line fuzzy decision-making is:

$$B = B^{(3)} = A^{(3)} \cdot R_{3}^{(3)} = W_{A} \cdot [B_{1}^{(1)} \;\; B_{2}^{(2)} \;\; B_{3}^{(1)}]$$
$$= [0.0217 \;\; 0.0626 \;\; 0.1215 \;\; 0.1902 \;\; 0.6032]$$

RESULTS

In terms of Fig. 2, membership degree of v5 (very good) is maxim and ShenSui metro line project can reduce the space-time distance and boost Guangdong economy. It's important and significance for changes of regional economic structure, the formation of urban system and the adjustment of urban industrial structure. The project total length is 86.62 km and total investment is 196.9 billion Yuan. The project has been evaluated by environmental protection agency of Guangdong province and it is expected to be opened to traffic by the end of 2016.

DISCUSSION

In this case study, evaluation index system is crucial for city metro decision-making. Literature provide reference of evaluation index system for the paper and the valuation system is more complete and comprehensive, especially environment index and social index[5,6]. In addition to, the priority order of evaluation indicators affects the final evaluation of the project and current priority order is determined based on a large number of questionnaires and data analysis. By case study result analysis shown as Fig. 3, Improvement on air pollution evaluation is good, improvement on noise pollution, influence on existing buildings, bad geologic phenomena, underground water and soil erosion, stratum situation and influence on surrounding environment evaluation are general. Crustal stability along the metro evaluation is good and other indexes evaluation are all very good.

The project decision multistage fuzzy evaluation and project evaluation gray relation selection research are established on the basis of the evaluation indicators to quantify. However, the results are not accurate for the evaluation of subjectivity and uncertainty. If neural network theory is applied into evaluation, the project decision will be more accurate and appropriate.

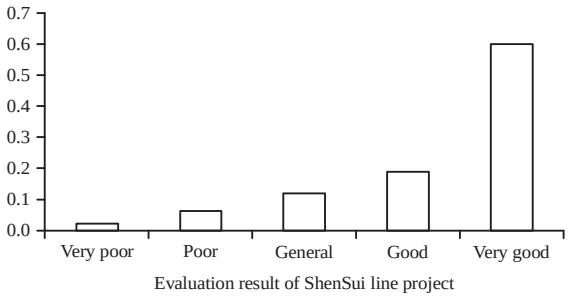

Fig. 2: Evaluation result of city metro decision-making

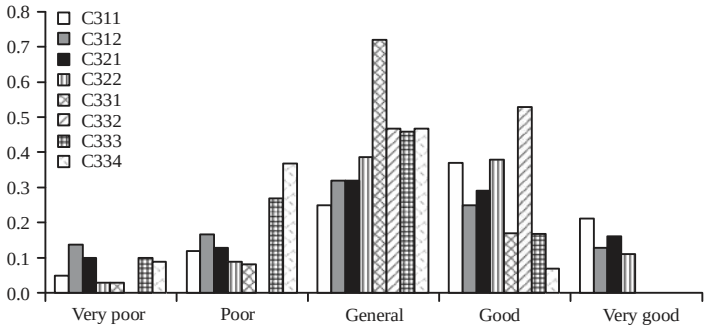

Fig. 3: Detail evaluation result of city metro decision-making

CONCLUSION

A number of quantitative and qualitative factors are considered in city metro decision-making and it's a multi-level and complex thought process. By utilizing AHP and fuzzy theory, Guangzhou metro ShenSui project decision-making is discussed at the respect of economy, environment and society and it provides scientific reference for government decision-making including subjective factors.

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