Financing Risks Models of Bus Rapid Transit Projects Based on Hall Three Dimensions Structure

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***Abstract*—Due to substantial investment, long duration, complex interest relationship, and etc., there exist many financing risk factors for BRT projects, and risk disposal without prior meticulous analyses on those factors may possibly lead to project failure. In this study, Hall three dimensions structure model, i.e., a system engineering theory, is applied in risk analysis in combination with Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) methods, which is beneficial to conduct comprehensive identification, cluster analysis and quantitative study on financing risks of BRT projects, aiming to provide a basis for financing risk management of BRT projects.**

Keywords—BRT; financing risks; Hall three dimensions structure; AHP; FEC

I. Introduction

Bus Rapid Transit (BRT) is dedicated to provide operation service similar to the rail transit on bus lanes and at specified bus stations, characterized by large traffic volume and prompt service of rail transit system as well as convenience and flexibility of regular buses [1]. At present, with the development of BRT in total 39 cities in America, Europe and Asia, it has become one of the strategic measures to improve traffic conditions in modern cities.

As the construction of BRT requires large capital input, many countries adopt financing methods to attract investment due to the limitation of government finance. For BRT projects, however, there exist many financing risk factors resulting from substantial investment, long duration, multiple participants and complex interest relationship. Therefore, the risk disposal without prior meticulous analyses on those factors may possibly lead to project failure. Under such circumstance, it is of great significance to study the financing risks of BRT projects.

The financing risks of BRT projects involve many factors, and form the complex system engineering, and consequently theories and approaches of modern system science shall be introduced when studying on financing risks of BRT projects. This paper firstly applies the system engineering theories of Hall three dimensions structure model to classify the financing content of BRT projects at home and abroad in accordance with time dimension, spatial dimension and logical dimension, and then applies ZOPP [2] approach to make analyses on the problems concerning the financing of BRT projects to cluster and convert these problems into risk factors. Finally, AHP-FCE model is applied to make quantitative analyses on all risk factors and propose countermeasures so as to provide guiding suggestions on the financing risk management of BRT projects.

II. Financing Risk Identification of BRT Projects

A. Hall Three dimensions Structure Model of Risk Management

Hall three dimensions structure is a system engineering methodology proposed in 1969 by A. D. Hall, an American expert on system engineering, for the purpose of providing systematic methods of thinking for planning, organization and management of large-scale complex system. Hall three dimensions structure divides the whole activity of system engineering into seven phases and steps respectively, which are closely linked in sequence, and also takes into consideration the diversified expertise required for completing such phases and steps [3]. The three dimensions for BRT financing risk management system refer to time dimension, logical dimension and knowledge dimension, based on which the elemental composition of BRT financing risk management system is classified.

1) Time dimension: Each project has a life cycle: commencement, growth, development, maturity, recession and termination, which is a basic description of the project in terms of time dimension. For risk management, it is essential to identify all the risk factors existing in each phase of project life cycle based on time dimension, and conduct quantitative disposal on risk factors using qualitative and quantitative approaches, and further comprehensively manage the risk factors existing in each phase within time dimension. This paper mainly adopts ZOPP qualitative approach and AHP-FCE quantitative approach to conduct analyses on financing risks of BRT projects.

2) Logical dimension: Logical dimension, aiming to solve problems in the logical process of project risk management, refers to the work to be done as well as the thinking procedures to be obeyed in each phase within time dimension. The logical process of project risk management plays an important role in all phases of the whole project, and such logical process is repeatedly applied in each phase, proposing the risk planning and countermeasures in earlier phase, focusing on the implementation of corresponding plans and monitoring measures in middle phase and attaching importance to summarizing experience and drawing lessons from risk disposal in later phase.

3) Knowledge dimension: Knowledge dimension refers to the comprehensive knowledge required for solving all the problems relating to project risks. Systematology, information theory and integrated thoughts of viewpoints are all required for risk identification.

B. ZOPP risk factor identification

ZOPP (Ziel Orientierte Projekt Planung in German), i.e., "Objectives-Oriented Project Planning" in English, refers to a set of theoretical systems, operating tools and working techniques proposed for regional economic development projects in respect of survey, analysis, diagnosis, project design, project plan, project implementation, project monitoring and evaluation, project management, etc [2]. By applying ZOPP approach, problem analysis is carried out on the financing cases of BRT projects in Curitiba of Brazil as well as Changzhou, Guangzhou, Xiamen, Zhengzhou, etc. in China according to the dividing principle of Hall three dimensions structure, and then cluster these problems so as to finally transform them into financing risk factors of BRT projects.

For risk factors of BRT projects, refer to the table below:

TABLE I. FIANCING RISK FACTORS OF BRT PROJECTS

BRT Risk Factors	**Indicator Mark**		
	Rx First-level Indicator	***Rxx Second-level Indicator***	***Rxxx Third-level Indicator***
Financing Risk Factors of BRT Projects	R1-Low governmental management level	R11-Governmental inexperience	R111, Insufficiency of professional financing staff in government departments; R112, poor support with relevant BRT cases to the government; R113, deficiency of relevant government systems; R114, weak cooperation consciousness of the government; R115, poor governmental capability to undertake risks.
		R12-Weak governmental management function	R121, insufficient exercise of governmental authority and responsibility; R122, insufficient macroscopic organization and coordination by the government; R123, competent authorities' failure to act in accordance with objective technical and economic laws; R124, governmental failure to strengthen the management on project planning, design and construction; R125, competent authorities' vague attitude on specific strategies and management objectives; R126, redundant control on project financing process.
		R13-Insufficient attention paid by the government	R131, little importance attached to the facility construction of BRT; R132, inadequate publicity on BRT projects; R133, insufficient support to project loans.
	R2-Imperfection policies and regulations	R21-Great policy changes	R211, price adjustment by government; R212, changes of governmental financial assistance; R213, unspecified governmental policies on BRT projects; R214, unstable tax polices relating to imported materials and equipments; R215, poor persistence of policies.
		R22-imperfection of policies and regulations relating to BRT projects	R221, inconsequence between governmental policies and operating enterprises of BRT project construction in practice; R222, imperfection of laws and regulations relating to franchise operation.
	R3-Issues on macroeconomic environment	R31-Low economic development level	R311, backward economy within the whole region; R312, backward BRT project development.
		R32-Instability of financial and economic factors	R321, interest rate swap; R322, fluctuation in interest rate; R323, market instability (changes in demands and supplies of raw materials); R324, fluctuation in exchange rate; R325, inflation.
	R4- Socio-cultural issues	R41-Large information gap and great conflicts among participants	R411, information asymmetry between central and local governments; R412, information asymmetry between local governments and BRT project companies.
		R42-Issues of environmental protection	R421, influence of BRT projects on surrounding environment; R422, great social concern attached to environmental protection.
	R5-Problems relating to contracts	R51-Insufficient fairness of agreements on franchise operation	R511, inaccurate franchise term of BRT; R512, unreasonable benefit allocation.
		R52-Existence of certain problems relating to contracts	R521, imperfection of BRT contracts; R522, problems relating to performance of BRT contracts, including ambiguity of power and duties, unequal risk assumption, etc.
		R53-Problems	R531, insufficient estimation of BRT sales volume; R532, low

BRT Risk Factors	Indicator Mark		
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		relating to product pricing	charging standards of BRT ticket prices.
		R54-Insufficient estimation of construction cost	R541, high construction cost; R542, complex BRT construction technique; R543, great difficulty in BRT construction safety management; R544, insufficient estimation of BRT construction cost.
	R6-Problems relating to project companies' managing capabilities	R61-Insufficient information on project benefit	R611, Limited project operation capability; R612, imperfection of project functions; R613, imperfection of service system of BRT supporting facilities; R614, long cost recovery cycles; R615, failure in expected BRT functions; R616, influence of uncertain factors.
		R62-Insufficient information obtained relating to the project	R621, failing to obtain authoritative data through the government; R622, insufficient sincerity of the government to cooperate with enterprises; R623, low cooperation level between the government and enterprises.
		R63-Irrational economic control	R631, deficiency of technical support for operation management; R632, irrational benefit allocation; R633, difficulties in achieving the targeted passenger capacity; R634, difficulties in capital turnover; R635, inflexibility to know charging standards of ticket prices (slack season and peak season).
	R7-Problems relating to project companies' investing capabilities	R71-Irrational financial management by investors	R711, irrational financing plans; R712, increase in financing cost; R713, low financing speed.
		R72-Higher difficulties in investment recovery	R721, irrational plans to use project funds; R722, high cost of project fund loans; R723, excessive funds in each phase; R724, difficulties in accurate calculation of project value; R725, higher difficulties in application and repayment of the loans.

III. Financing Risk Evaluating Model of BRT Projects

AHP-FCE is a forecasting and evaluating approach based on fuzzy mathematical theory as well as a basic approach to establish evaluating indicator system, determine factor weight and introduce Fuzzy Comprehensive Evaluation (FCE) by applying Analytic Hierarchy Process (AHP). It describes fuzzy boundaries of all factors and determinants in terms of membership grade based on fuzz set transformation principle, and then establish fuzzy evaluation matrix. Finally, the grade of evaluation targets is determined through multilevel compound operation. By adopting this approach, mathematicization of human beings' thinking process towards complex systems can be realized, as well as quantification of qualitative analysis mainly based on subjective judgment and quantization of difference among judgment factors. Therefore, it is particularly suitable to solve those fuzzy, non-quantitative and undefinable practical problems, such as financing risk evaluation of the projects [4]. The evaluation process will be described in combination with analysis on financing risks of BRT projects as follows.

A. Fuzzy set setting

Firstly, set the evaluation indicators of criteria level: Rx=(R1,R2,…,R7), and the corresponding weight set is: A=(a1,a2,…,a7); secondly, set the indicators of sub-criteria level: Rxx=(Rx1,Rx2,…,Rxn), where "n" refers to the number of second-level indicators, and the corresponding weight set is: Ax=(a1,a2,…,an); thirdly, the weight set of indicator level is expressed as Rxxx=(Rxx1,Rxx2,…,Rxxm), where "n" refers to the number of third-level indicators, and the corresponding weight set is: Axx=(ax1,ax2,…,axm); Finally, determine the risk level evaluating indicator set: V=(V1,V2,…,V5)=(peak risk, higher risk, average risk, low risk and valley risk)=(0.8< V1≤ 1.0, 0.6<V2 ≤0.8, 0.4<V3≤0.6, 0.2<V4 ≤0.4, 0.0<V5 ≤0.2).

B. Determination of weight of evaluation indicators

This paper adopts AHP method proposed by A. L. Satty, an American operations research expert, to determine the indicator weight, construct judgment, matrix by means of pairwise comparison in indicator importance and solve the characteristic value of the matrix, which has been proved by consistency check [5].

The results are shown as below:

Weight of criteria level:

A=(0.0794,0.1622,0.1057,0.1669,0.1669,0.1151,0.2038)

Weight of sub-criteria level:

A1=(0.1821,0.3547,0.4631);

A2=(0.6900,0.3100);

A3=(0.4013,0.5987);

A4=(0.5987,0.4013);

A5=(0.3517,0.2880,0.2243,0.1360);

A6=(0.1299,0.3774,0.4927);

A7=(0.4013,0.5927);

Weight of indicator level:

A11=(0.1627,0.3212,0.1443,0.1564,0.2153;

A12=(0.2488,0.1118,0.2106,0.1724,0.0593,0.1970);

A13=(0.4483,0.3213,0.2302);

A21=(0.2740,0.2243,0.0793,0.2529,0.1695);

A22=(0.4502,0.5498);

A31=(0.4502,0.5498);

A32=(0.0985,0.1795,0.1795,0.2282,0.3143);

A41=(0.5987,0.4013);

A42=(0.4013,0.5987);

A51=(0.6900,0.3100);

A52=(0.1978,0.8022);

A53=(0.3100,0.6900);

A54=(0.4020,0.2695,0.1806,0.1479);

A61=(0.1783,0.0946,0.1118,0.3472,0.0775,0.1906);

A62=(0.3774,0.1299,0.4927);

A63=(0.3356,0.2342,0.1842,0.1449,0.1011);

A71=(0.1721,0.5713,0.2567);

A72=(0.2668,0.1788,0.2777,0.1861,0.0906);

C. Fuzzy evaluation of single factor and establishment of single factor fuzzy evaluation matrix

After determining the weights of all evaluation indicators and evaluation values of risk levels, 10 experts assess the indicator (Rxxx) of indictor level with scores according to evaluation values of risk levels. For example, there are totally 10 experts invited to assess R111, of which 3 make assessment with "higher risk", 4 make assessment with "average risk", 2 make assessment with "lower risk" and 1 makes assessment with "low risk", and then the membership grade of R111 risk evaluation can be calculated as follows:

Evaluation set R'111={Level 0.0/1, Level 0.3/2, Level 0.4/3, Level 0.2/4, Level 0.1/5}. Similarly, the evaluations for R'112, R'113, etc., can be made to achieve the following fuzzy matrix:

$$R'11 = \begin{bmatrix} 0.0 & 0.3 & 0.4 & 0.2 & 0.1 \\ 0.2 & 0.1 & 0.5 & 0.0 & 0.2 \\ 0.3 & 0.7 & 0.0 & 0.0 & 0.0 \\ 0.1 & 0.0 & 0.3 & 0.0 & 0.7 \\ 0.1 & 0.2 & 0.0 & 0.7 & 0.0 \end{bmatrix}$$

The construction methods of other fuzzy indicator matrixes are the same as above. Illustration in detail is not available due to the limited length of this paper.

D. Fuzzy hierarchy comprehensive evaluation

Evaluation principle: the evaluation shall be conducted from the lowest level, and the evaluation results of each level will be deemed as the single factor evaluation set of the former. Then single factor evaluation matrix of the high level shall be constructed prior to its comprehensive evaluation until the end of evaluation on the highest level. Fuzzy comprehensive evaluation model is:

$$B = A \bullet R \tag{1}$$

Note: this paper adopts general matrix multiplication for all the operators " • ". After multi-level fuzzy operation, the final fuzzy set is obtained as below: B=(b1,b2,…,bn). The results obtained after normalization is:

$$\widetilde{B} = (\widetilde{b}1, \widetilde{b}2, \cdots, \widetilde{b}m) \tag{2}$$

where :

$$\widetilde{b}j = bj /(\sum_{i=1}^{n} bi) \tag{3}$$

The results obtained after normalization of the lowest level are shown as follows:

B11=[0.1 0.2 0.3 0.2 0.2]	B12=[0.3 0.3 0.3 0.1 0.0]
B13=[0.6 0.1 0.3 0.0 0.0]	B21=[0.3 0.2 0.2 0.2 0.2]
B22=[0.3 0.3 0.3 0.0 0.2]	B31=[0.3 0.1 0.4 0.2 0.0]
B32=[0.2 0.1 0.3 0.3 0.0]	B41=[0.2 0.4 0.3 0.0 0.2]
B42=[0.4 0.1 0.1 0.3 0.1]	B51=[0.1 0.2 0.2 0.1 0.4]
B52=[0.3 0.3 0.3 0.0 0.3]	B53=[0.3 0.2 0.5 0.0 0.0]
B54=[0.2 0.2 0.3 0.2 0.2]	B61=[0.2 0.4 0.2 0.1 0.1]
B62=[0.2 0.0 0.4 0.3 0.0]	B63=[0.2 0.3 0.2 0.2 0.1]
B71=[0.1 0.1 0.7 0.0 0.0]	B72=[0.2 0.1 0.2 0.3 0.1]

The results obtained after normalization of the second level are shown as follows:

B1=[0.2 0.2 0.4 0.2 0.0]	B2=[0.3 0.2 0.2 0.2 0.2]
B3=[0.3 0.1 0.3 0.3 0.0]	B4=[0.3 0.3 0.2 0.2 0.1]
B5=[0.2 0.2 0.3 0.1 0.3]	B6=[0.2 0.2 0.4 0.2 0.0]
B7=[0.0 0.0 1 0.0 0.0]	

The results obtained after normalization of the third level are shown as follows:

B=[0.2 0.2 0.2 0.2 0.1]

The final evaluation conclusion is determined in accordance with the overall evaluation B and proper evaluation principle, and in this study, it is determined by adopting the grade principle. The evaluation results are quantized, and then make V=(V1,V2,…,V5)= (1, 0.8 ,0.6, 0.4, 0.2). The judgment principle is as follows:

$$P \in \begin{cases} [0.8,1] & \text{Project with peak risk} \\ [0.6,0.8] & \text{Project with higher risk} \\ [0.4,0.6] & \text{Project with average} \\ [0.2,0.4] & \text{Project with lower risk} \\ [0,0.2] & \text{Project with low risk} \end{cases} \tag{4}$$

$$P = \sum_{j=1}^{5} \widetilde{b}j * Vj \tag{5}$$

The final result is: P=0.58∈[0.4,0.6].

It can be seen from the final data that this project is of average risk. Attention shall be paid to avoid high risk factors as implementing the project and propose countermeasures so as to ensure its successful development. Moreover, the indicator weights of all levels indicate that the key first-level indicators for risks are socio-cultural issues and problems concerning contracts; the key second-level indicators for risks are great policy changes, instability of economic factors, large information gap and great conflicts among participants, and higher difficulties in investment recovery; the key third-level indicators for risks are information asymmetry between central and local governments as well as increasing financing cost.

IV. Studies on Countermeasures against Financing Risks of BRT Projects

According to the definition and application of Hall three dimensions structure model, this paper proposes countermeasures based on the important risk factors in risk statistics of BRT projects.

A. To improve risk sharing systems and clarify responsibilities of the government and enterprises

Although the construction of BRT is beneficial to solve many urban problems, including insufficient space, traffic jam, etc., risks exist in the whole construction and operation process of BRT projects. In order to eliminate the private enterprises' worries towards large project investment and reduce risks, it is necessary to establish impartial risk sharing systems and clarify responsibilities of the government and enterprises respectively. Firstly, for the political risk, we shall mainly adopt the measures of risk aversion, and take into consideration the political stand of the host country in advance as well as its attitude towards the construction of BRT. Meanwhile, we shall seek the written assurance of the host country and refer to international commercial arbitral institutions to reduce government intervention of the host country. Secondly, for the financial risk, exchange rate options and engineering swap transaction can be adopted to hedge the currency exchange risk. Elimination of interest rate risk can be realized by adopting the measures of interest rate futures, options, swaps, forward rate agreements, and etc. Moreover, as to the risk of inflation, we can mainly adopt the measures of risk transfer or acceptance to minimize loses incurred as much as possible. Finally, for the environmental risk, it mainly results from the construction and should be inevitable. Therefore, the measures of risk aversion or transfer shall be adopted to minimize risks.

B. To enlarge financing targets and adopt adequate financing modes

Considering the property, large scale, substantial fund demand of the public infrastructure construction of BRT projects, large-scale and extensive financing measures shall be adopted to solve the fund problems for the whole BRT projects. It is unrealistic and infeasible to develop cities only relying on urban investment. At present, there are sufficient foreign investments and idle funds in the capital market, and efficient utilization of those foreign and private capitals will play an active role in the development of urban road construction. In order to encourage the investors, reduce investment risk and improve social and economic environment, the government must play its due role in BRT projects, take full advantages of financing modes on the basis of perfect legal systems and the characteristics of BOT and TOT projects, and even adopt integrated financing modes to expand financing channels to a significant extent and reduce financing difficulties and complexity so as to ensure the normal constructional and operational procedures of BRT projects and further achieve the ultimate objectives of project construction.

V. Conclusions

This paper applies Hall three dimensions structure in the risk management of BRT projects, comprehensively takes into consideration influence of multiple risk factors on the projects and makes quantitative evaluation on risk factors by means of AHP-FCE methods. Furthermore, the author figures out the influence weights of all risk factors by calculation and analysis, and proposes relevant countermeasures, which provides a basis for the financing risk management of BRT projects.

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