Research Progress and Hotspot Analysis of Underground Comprehensive Pipeline Building Based on Knowledge Map

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Abstract. Using bibliometric analysis method and visualized knowledge mapping tool, this paper analyzes and reveals the status quo of research on underground comprehensive pipeline corridor construction in China. The study finds that research in this field started late, but the paper has grown very rapidly; there are extensive cooperation relationships among core authors, but the cooperation is dominated by the internal cooperation of the affiliated institutions; the periodical level of published papers is not high, and research focused on two disciplines of architecture and economics.

1. Introduction
The urban underground integrated pipe gallery has an intensive function in the construction of municipal pipelines, including the organic synthesis, centralized management and maintenance of water supply and drainage, power and telecommunications, and gas pipelines [1]. The earliest underground integrated pipe gallery construction in the world began in Paris in 1833. After that, this concept and technology was introduced into western countries such as Britain, France, Germany and Japan. Since the construction of the first comprehensive pipe corridor in Beijing in 1958, China has built comprehensive pipe gallery in cities such as Shanghai, Guangzhou and Shenzhen. In 2014, the State Council, the Ministry of Housing and Urban-Rural Development and the Ministry of Finance successively issued documents encouraging the development of underground integrated pipe gallery in urban cities. Under this background, the research on the construction of urban underground integrated pipe gallery has also shown a blowout growth in China in recent years. Therefore, this paper analyzes the current research status on the construction of underground integrated pipe gallery in academic circles, in order to understand the evolution and trends of research in this field in the past.

2. Data Sources and Research Methods

2.1. Data source
In order to obtain comprehensive and accurate research data on underground integrated pipe gallery construction, papers related to the research on the construction of underground integrated pipe gallery were searched in the database. A total of 1913 papers were retrieved and the relevant bibliographic data of these papers were obtained. The research on the construction of underground integrated pipe corridor in China can be traced back to 2004. Since 2015, the research papers in this field have grown rapidly. In 2016 and 2017, the number of research papers published has exceeded the total number of
papers in all previous years, which proves that academic circles have paid close attention to the study of underground integrated pipe gallery in recent years.

2.2. Research Methods
CiteSpace software is adopted in this paper to analyze the research status of China's underground integrated pipe gallery to reveal the trends of underground integrated pipe gallery research. The basic statistical analysis method is used in this study for descriptive statistics of the 1798 articles retrieved and the distribution results of authors, institutions, subject areas and journals so as to obtain the basic overview of underground comprehensive pipe gallery research. CiteSpace 5.1 is also used to draw knowledge maps of author cohesion, institutional cohesion and keyword co-occurrence, in order to reveal the research structure of underground integrated pipe gallery in a more in-depth way, fully present its current research status and analyze its research trend.

3. Research Findings

3.1. Distribution of research strength in underground integrated pipe gallery
The author cooperation network and institutional cooperation network of China's underground comprehensive pipe gallery research was obtained through the CiteSpace visualization software.

| No. | Author | Institution | No. of papers | 1st author | Cited | Average Cited |
|-----|--------|-------------|---------------|------------|-------|---------------|
| 1   | Hengdong Wang | Shanghai Municipal Engineering Design and Research Institute (Group) Co., Ltd. | 18 | 12 | 100 | 5.56 |
| 2   | Jie Li | Department of Architectural Engineering, Tongji University | 10 | 1 | 145 | 14.5 |
| 3   | Qian Li | University Of Architecture and Technology | 7 | 7 | 5 | 0.71 |
| 4   | Hailong Li Wang Shuhong | China Construction Second Engineering Bureau Co., Ltd. School of Resources and Civil Engineering, Northeastern University | 7 | 2 | 1 | 0.14 |
| 5   | Jun Chen Yingming Liu | Department of Architectural Engineering, Tongji University Shenzhen Urban Planning and Design Research Institute | 7 | 1 | 116 | 16.57 |
| 6   | Yingming Liu | Shenzhen Urban Planning and Design Research Institute | 7 | 1 | 2 | 0.29 |
| 7   | Bo Chen | China Construction Second Engineering Bureau Co., Ltd. Jiangxi General Provincial Architectural Design Research Institute | 6 | 1 | 2 | 0.33 |
| 8   | Qinghong Zeng Ying Wang | Architectural Design Research Institute Guangzhou International Engineering Consulting Company | 5 | 5 | 10 | 2 |
Table 1 reveals information on the affiliation of the high-yielding authors in this field, the amount of publications, and the number of publications in the name of the first author, the quotation and the frequency of citing. In general, the co-authoring relationship is quite common in the publication of the underground comprehensive pipe gallery research, thus a number of research teams of different sizes can be found. But the authors in cooperative relationship are basically from the same institution, which indicates that there’s little cross-institutional research on underground integrated pipe gallery is less, which needs to be further deepened.

3.2. Distribution of journals on underground integrated pipe gallery research

The top 10 journals in the field of underground comprehensive pipe gallery research are mainly from the sub-disciplines of architecture science and engineering, road and water transport, macroeconomic management and sustainable development, and trade economy. The total volume of papers on these 10 kinds of journals only accounted for 20.13% of the total number of papers in the field, indicating that the papers in this field are scattered on various different kinds of journals. Among the 10 kinds of journals, only Construction Technology, which ranks 5th in terms of publication volume, is a core journal with an impact factor of 0.913. Other journals are general journals with lower impact factors. It indicates that the research level of this field needs to be improved.

3.3. Disciplinary distribution of underground integrated pipe gallery research

It can be seen from the distribution of the papers in Table 2 that the research on underground integrated pipe gallery in China mainly involves the areas of construction science and engineering, macroeconomic management and sustainable development, industrial economy, computer software and computer applications, and road and water transport. It belongs to the intersection of architecture and economics. However, most of the papers still belong to the category of architecture, with a proportion of 74.14%. The subjects with relatively high proportion include automation technology, administration, geology, and financial investment and power, but the proportion of papers in these disciplines is very low, all remain below 1%.

Table 2. Disciplinary distribution of underground integrated pipe gallery research

| No. | Discipline                                      | No. of papers | Ratio   |
|-----|------------------------------------------------|--------------|---------|
| 1   | Architecture Science and Engineering           | 1333         | 74.14%  |
| 2   | Macroeconomic management and sustainable development | 391         | 21.75%  |
| 3   | Industrial economy                            | 69           | 3.84%   |
| 4   | Computer software and computer applications    | 45           | 2.50%   |
| 5   | Road and water transport                      | 26           | 1.45%   |
| 6   | Economic reform                               | 17           | 0.95%   |
| 7   | Automation technology                          | 17           | 0.95%   |
| 8   | Chinese politics and international politics    | 16           | 0.89%   |
| 9   | Administration and State Administration        | 14           | 0.78%   |
| 10  | Geology                                       | 14           | 0.78%   |
3.4. Highly Cited Research Papers on Underground Comprehensive Pipe Gallery

In general, the highly cited papers in this field have the following salient features: (1) The journals of highly cited papers are ordinary journals except for China Municipal Engineering, Modern Urban Studies, and Tunnel Construction which are the core journals. And the quality of these journals is not very good. (2) The research topics of the papers focus on the research on the status quo, existing problems and development trends of urban integrated pipe gallery. These research papers are generally published around 2011, which is in the initial stage of research in this field. Therefore, the research is mainly based on the introduction and summarization of experience, with relatively shallow research depth.

3.5. Key words distribution and trend of underground comprehensive pipe gallery research

The core keywords of the underground integrated pipe gallery research include underground pipe gallery, sponge city, underground space, integrated pipe gallery, underground integrated pipe gallery, urban underground integrated pipe gallery, etc. The specific frequency of these keywords can be seen in Table 3. From the frequency of occurrence of these keywords, integrated pipe gallery (823), underground integrated pipe gallery (515), urban underground integrated pipe gallery (238), sponge cities (116), underground pipe gallery (89), ppp (76), planning (67), pipeline (64), etc are the keywords with high occurrence frequency; and from the centrality ranking of keywords, the top keywords are integrated pipe gallery (0.55), underground integrated pipe gallery (0.42), Urban underground integrated pipe gallery (0.33), sponge city (0.13), planning (0.12), etc. From the previous frequency and center rankings of keywords, it can be seen that the researches in this field are mainly focusing on urban underground integrated pipe gallery and sponge city construction, including the planning, design, investment and construction of underground integrated pipe gallery and ppp projects.

Table 3. High-frequency keywords of research on the construction of underground integrated pipe gallery. (top 10 in frequency ranking)

| No | Keywords                           | First Appearance | Frequency | Centrality |
|----|------------------------------------|------------------|-----------|------------|
| 1  | Integrated pipe gallery            | 2011             | 823       | 0.55       |
| 2  | Underground integrated pipe gallery| 2010             | 515       | 0.42       |
| 3  | Urban underground integrated pipe gallery | 2013 | 238       | 0.33       |
| 4  | Spongy City                       | 2015             | 116       | 0.13       |
| 5  | Underground pipe gallery           | 2015             | 89        | 0.02       |
| 6  | PPP                               | 2014             | 76        | 0.04       |
| 7  | Planning                          | 2015             | 67        | 0.12       |
| 8  | Pipeline                          | 2013             | 64        | 0.06       |
| 9  | Ministry of construction           | 2014             | 61        | 0.06       |
| 10 | Housing                           | 2015             | 61        | 0.01       |

3.6. Theme distribution of underground integrated pipe gallery research

Using the clustering function of CiteSpace software, the theme distribution of underground integrated pipe gallery research can be obtained. The research in this field can be roughly divided into four themes:

(1) Research on the design and construction of urban underground integrated pipe gallery. As an artificial underground space of the city, the urban underground integrated pipe gallery project provides
a modern and intensive infrastructure for urban development through the centralized setting of various urban pipelines, which has become an inevitable trend of modern urban development[2]. There are many problems need to be solved in the design of urban underground integrated pipe gallery, including the structure of the pipe gallery, waterproof function, fire protection system, power system, intelligent system, etc., as well as the overall planning and resource allocation, investment system and financing incentive mechanisms, PPP projects and economic benefit assessment issues.

(2) Research on investment and management of underground integrated pipe gallery. In the construction process of underground integrated pipe gallery, it is common to face problems such as large investment amount, solidification of construction mode and difficulty in operation and management. Therefore, in the process of underground integrated pipe corridor construction, efforts should be made to expand investment channels, improve the charging mechanism and form a scientific and rational construction management concept and system [3].

(3) Research on planning and implementation of PPP project for underground integrated pipe gallery. PPP refers to the public investment operation model of government and social capital cooperation. This model encourages all kinds of enterprises and capital to cooperate with the government to jointly promote the construction of public infrastructure [4]. Many scholars have discussed the application, content and role of the PPP model in underground pipeline construction projects. Overall, the research on the application of PPP model in underground integrated pipe gallery focuses on project contract, operation management, project risk management, business model, quantitative evaluation and its role.

(4) Research on sponge City, underground pipeline and urban underground pipe gallery. The concept of sponge city was first put forward by General Secretary of Jinping in 2013, and then in 2016 the Ministry of Housing and Construction issued a comprehensive urban corridor and sponge city construction standard system [5]. Sponge city and underground pipeline corridor are considered as the key projects of urban infrastructure construction in China. The related problems of these projects are being actively considered in the process of urban planning. Sponge city has a good ability to absorb, store and utilize rainwater. The application of Sponge city to the construction of underground integrated pipe gallery can solve the drainage construction problem of underground integrated pipe gallery construction [6]. Some scholars have discussed how to apply the technical index of sponge city and comprehensive pipeline corridor to urban construction, and put forward a new type of urban system planning and construction party which combines the two [7].

4. Conclusion
Using bibliometric analysis method and visualized knowledge mapping tool, this paper analyzes and reveals the status quo of research on underground comprehensive pipeline corridor construction in China. The study finds that research in this field started late, but the paper has grown very rapidly; there are extensive cooperation relationships among core authors, but the cooperation is dominated by the internal cooperation of the affiliated institutions; the periodical level of published papers is not high, and research focused on two disciplines of architecture and economics. The core words in this area of the paper focus on the planning, design, investment and construction of the underground integrated pipe gallery, and the PPP project, and his area has formed research topics such as the design and construction of underground pipe gallery, investment and management research, PPP project planning and implementation research, and sponge city and underground pipelines.

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