



# Article Data-Driven Evolution Analysis and Trend Prediction of Hotspots in Global PPP Research

Likun Zhao<sup>1</sup>, Shaotang Yang<sup>1,\*</sup> and Shouqing Wang<sup>2,3</sup>

- <sup>1</sup> School of Civil Engineering, North China University of Technology, Beijing 100144, China
- <sup>2</sup> Department of Construction Management, Tsinghua University, Beijing 100084, China
- <sup>3</sup> Center for Public-Private Partnership, Tsinghua University, Beijing 100084, China

Correspondence: lavineleo@mail.ncut.edu.cn

Abstract: Over the past three decades, there have been many comprehensive studies related to public-private partnerships (PPP), but the analysis at the macro level still lacks comprehensiveness and interpretability. Through the application of bibliometric analysis, 2-mode network, and strategic coordinate analysis, we systematically analyzed the derivative characteristics of the literature data and the coupling characteristics of countries and keywords. Moreover, through the frequency and betweenness centrality, etc., this paper determines the evolution path of keywords and the evolution direction of theme words and realizes the prediction of theme words and keywords in the future. The results show that: (1) Through the three-stage biclustering analysis, we determined the hot theme words and hot keywords for each stage and focused the theme direction and main research content of the evolution, which led to great interpretability of the data analysis in the literature characteristics; (2) Through the distribution characteristics of time and space, the USA, China, the UK and other mainstream publishing countries and their main research hotspots were determined. Among them, developing countries have strong willingness in academic cooperation and great potential for academic development; (3) According to the derivative characteristics of the literature data, it is predicted that the future research hotspots are: the integration of business economy and sustainability, the integration of policy support and innovative technology application, and the urbanization promotion of developing countries. Based on the findings, this study makes concrete and targeted research methods and provides reference value and application value for the future research and analysis of PPP.

**Keywords:** public–private partnerships; strategic coordinate; evolutionary trend; bibliometric analysis; 2-mode network

# 1. Introduction

As an important way to develop infrastructure and public services, a public–private partnership (PPP) is widely used in transportation, energy, environmental protection, medical care, education, etc. It is a project financing model that encourages the private sector to cooperate with the government and allows them to participate in public infrastructure construction. It plays an important role in revitalizing social capital and reducing financial burden [1].

In 2020, the Global Infrastructure Hub (GIH) stated in Infra Compass 2020 [2]: the gap in global infrastructure investment is approximately USD 15 trillion in the next 20 years. In 2021, the World Bank noted in the PPI Database Global Report, 2021 [3]: compared to 251 projects in 2020, 240 projects in 2021 have a larger scale, with private participation in infrastructure (PPI) investments totaling USD 76.2 billion, increasing 49% from last year. In addition, the level of capital investment in the water supply and sewage treatment sector is usually lower, but it reached a ten-year high in 2021, with a total investment of USD 9.9 billion (13% of the total PPI investment). Furthermore, in the energy sector, 95% are



Citation: Zhao, L.; Yang, S.; Wang, S. Data-Driven Evolution Analysis and Trend Prediction of Hotspots in Global PPP Research. *Buildings* **2023**, *13*, 206. https://doi.org/10.3390/ buildings13010206

Academic Editors: Gobinath Ravindran, Vutukuru Mahesh and Ahmed Senouci

Received: 28 November 2022 Revised: 26 December 2022 Accepted: 4 January 2023 Published: 12 January 2023



**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). renewable energy projects. Additionally, Sub-Saharan Africa has the highest proportion of PPI projects in all regions, approximately 38%. These show that the PPP market shows some signs of recovery in infrastructure investment, and sustainable development has become a direction of more concern for the private sector.

In the past 30 years, a large number of scholars around the world have conducted in-depth research on PPP from multiple dimensions. Al-sharif et al. [4] selected the relevant literature from four authoritative academic journals from 1998 to 2003 and conducted a quantitative study on PPP research trends.

Ke et al. [5] selected the Web of Science (WoS) database from 1998 to 2008 and studied the development process and evolution path of PPP from three dimensions: the earliest appearance of PPP literature in each country, the association between the authors of the literature, and the citation of the literature. They also assessed the academic level of authors and journal contributions. Song et al. [6] conducted a multidisciplinary quantitative visualization analysis of the areas, model evolution, and development paths involved in PPP. Zhang et al. [7] selected 12 engineering journals from the WoS database from 2009 to 2019 and systematically analyzed the characteristics of institutions, keywords, and scholars, etc. Sun et al. [8] compared the research in China with that in other countries by reviewing the PPP literature published in Chinese and English journals from 2008 to 2018. Shi et al. [9] used the H index to measure academic influence and used the Bibliometrix R-package tool to conduct a bibliometric analysis of PPP from both static and dynamic perspectives, broadening the depth of research. From the perspective of risk management of PPP, Robert et al. [10] applied VOSviewer software for quantitative analysis. Nevertheless, the feature extraction of many literature studies still relies on subjective literature survey and qualitative analysis. These studies still contain less research on the global PPP research hotspots, and the interpretability analysis of the characteristics of the literature data is still far from enough [11].

However, there is still no article that can scientifically and objectively predict trends in the field of global PPP research. Moreover, aiming at the problems of weak interpretability, insignificant quantitative analysis, and unscientific trend prediction in current research, we provide a new approach and perspective in the field of global PPP research. This study is of great significance for clarifying the research context and development characteristics of global PPP and accurately grasping the evolution trend of global PPP development.

This article selected the literature data from the WoS database from 1989 to 2022 as the research object for systematic analysis. First, we divided the stages by the natural breakpoint method and applied the 2-mode network clustering algorithm to determine the literature derivative characteristics in each stage, focusing on the research issues in mainstream countries. Second, through the analysis of the attention evolution and strategic position of the subject words, we determined the evolution path and direction of future research. Finally, based on the above results, we calculated the novelty index and realized the diversion prediction of keywords, and obtained the conclusion.

#### 2. Research Design

#### 2.1. Data Processing and Research Methods

## 2.1.1. Data Processing

This paper collected data from the WoS core database. The search formula is as follows: TS = ("public private partnership" OR "build operate transfer" OR "build-operate-transfer" OR "build/operate/transfer" OR "private finance initiative" OR "transfer operate transfer" OR "build own operate" OR "build own operate transfer" OR "build transfer operate" OR "rehabilitate operate transfer" OR "renovate operate transfer")

The starting time of WoS core database is defaulted to 1985, and the database first included PPP-related literature in 1989. Therefore, this paper selected 4134 related pieces of the literature from January 1989 to November 2022. Through screening and deduplicating the data, we finally selected 4060 valid articles as research samples. According to the data

characteristics, the year of publication, keywords, authors, countries, and subject words were divided, and 26,192 valid data were accumulated.

#### 2.1.2. Research Method

By examining the following characteristics of keywords: frequency, time distribution, and coupling relationship, this paper used visual forms such as co-occurrence maps and biclustering maps, etc., to show the evolution of research in the PPP field in the past and the current research frontiers. In addition, through the analysis of the attention and strategic trend of the keywords, we calculated the novelty index of the keywords. Eventually, based on the above analysis, we predicted the direction of potential research and future research trends.

In order to present the analysis results more intuitively and comprehensively, this paper intends to use the following methods:

- (1) Natural breakpoint method. Based on the distribution of numerical statistics and the number of pieces of the literature in different periods, this method can set class boundaries on the data values with large differences. K-means, mean shift, KNN, and other clustering methods mainly explore the center of the class. In contrast, the natural breakpoint method mainly explores the class boundary. Therefore, this method is suitable for solving the turning point of the cumulative difference data, especially the value of the cumulative number of pieces of the literature, so as to realize the phase division of the PPP literature from 1989 to 2022 [12–14].
- (2) Co-word analysis. This method can reflect the cascading relationships between objects. Among them, betweenness centrality is the key indicator to measure the importance of nodes in the network [15]. It is generally believed that keywords with betweenness centrality greater than 0.1 occupy a core position in the network [16,17]. This paper used CiteSpace 6.1 R3 to analyze the academic cooperation between countries and determine the intensity of cooperation between countries and the mainstream research countries. Moreover, we also used strategic coordinate analysis to mine the centrality and density of theme words, determining the position of each theme word in the strategic coordinate graph and analyzing the evolution trends [18].
- (3) The 2-mode network clustering algorithm. Through selecting two research objects, this method applied the unweighted pair group method with arithmetic mean (UPGMA) to determine the correlation coefficient between objects [19], and the 2-mode matrix was calculated [20,21]. Furthermore, we applied the R studio to the coupled biclustering graph between two objects. Among them, the connection between objects can determine the strength of correlation. The color depth represents the frequency, showing the heat degree of any keyword [22]. In summary, it identifies research hotspots in different phases and provides the data basis for the evolution and prediction of theme words.

#### 2.2. Evolution Mechanism and Prediction Model Construction

This paper is mainly divided into three parts: the trend analysis of the literature characteristics, the derivative analysis of the data characteristics, and the evolution prediction and analysis of theme words. The evolution mechanism and prediction model are shown in Figure 1.

First, this paper analyzed the temporal characteristics of literature to verify the rationality of natural breakpoint method. Additionally, we also analyzed the publication trend for each country and initially determined the mainstream countries for PPP research; Second, through the derivative analysis of data features, we mined the keyword co-occurrence features for each period and analyzed the coupling characteristics of keywords. Simultaneously, we also analyzed the research and collaboration trends in individual countries and identified the research hotspots in these countries; Third, according to the evolution prediction of theme words and keywords, we calculated the attention of theme words and



the strategic trend, so as to determine the core evolution direction. Finally, based on the above basis, we predicted the PPP research hotspots in the future.

Figure 1. Evolution Mechanism and Prediction Model.

#### 2.3. Trend Analysis of Literature Characteristics

# 2.3.1. Division of Literature Phases

The natural breakpoint method uses the idea of clustering to divide the data into different groups. Furthermore, the data similarity within the same group is maximized, and the difference between the external groups is maximized. The specific steps are as follows:

Primarily, this paper determines the classification number of arrays. Additionally, we calculate the sum of squared deviations from the array mean (SDAM) and the sum of squared deviations about class mean (SDCM). Then, we discover the minimal SDCM. Ultimately, we calculate the goodness of variance fit (GVF) so as to aggregate measurements of the classification effects [23]. The formula (1) is as follows:

$$SDAM = \frac{1}{N} \sum_{i=1}^{N} (X_{ji} - X_j)^2$$
  

$$SDCM = \sum_{i=1}^{N_1} (X_{1i} - \overline{X_1})^2 + \dots + \sum_{i=1}^{N_j} (X_{ji} - \overline{X_j})^2$$
  

$$GVF = 1 - \frac{SDCM_{min}}{SDAM}$$
(1)

Among them, *N* represents the number of groups.  $X_{ji}$  represents the amount of literature in year *j*. *SDAM* represents the variance of the data. *SDCM* represents the sum of all the variances. *GVF* represents the variance goodness of fit.

#### 2.3.2. Analysis of Time Series Characteristics of Literature Quantity

Based on Python, this chapter uses Jenks to traverse the possible classification number of arrays and calculate GVF values under different classification numbers. Simultaneously, we draw the GVF curve fitting chart and the global literature time series characteristic analysis chart under each classification number. The details are as shown in Figure 2.

As shown in Figure 2a, when N= 3, the GVF curve begins to fit. Consequently, the set of data is most appropriate when divided into three categories, and the four breakpoints are 0, 112, 288, and 400.



**Figure 2.** Global Bibliometric Comparison and GVF Test (**a**) GVF Curve of Global Countries; (**b**) Time Series Characteristics Analysis of Global Literature Quantity.

Among them, (0, 112) represents the exploration period (1989–2008), (112, 288) represents the rapid development period (2008–2017), and (288, 400) represents the steady development period (2017–2022). The color change from cold to warm corresponds with the above three phases. Additionally,  $R^2 = 0.8562$ , which indicates that the fitting effect is good, and there is a certain correlation between the number of publications and the year of publication. As shown in Figure 2b, according to the timing characteristics of the global literature volume, it can be observed that:

- (1) Exploration period (1989–2008): the attention concerning PPP was lower before 2008, and the amount of PPP literature increased year by year.
- (2) Rapid development period (2008–2017): with the increasing demand for investment in infrastructure construction, the PPP model has received extensive attention. However, this is due to the influence of the global economic environment, risk, benefit sharing, etc. With 2010 and 2014 as the time nodes, the fluctuation in the PPP literature volume is quite obvious. Moreover, the Global Infrastructure Hub (GIH), Office of Public–Private Partnership (OPPP), and the Global Infrastructure Facility (GIF) were established from 2014 to 2015. These not only promoted the development of global infrastructure [24] but also promoted the academic follow-up. Hence, the global PPP literature volume has rebounded rapidly after 2015 and has continued growing in a straight upward trend.
- (3) Steady development period (2017–2022): The growth of the PPP literature volume tends to be stable. Furthermore, the annual publication volume is approximately 360. Isaac et al. [25] believes that with the impact of the COVID-19 era on the global economy, the entire PPP market and construction industry are in deficit, and the economic growth fell by 2.3% last year. Simultaneously, due to the policy uncertainty, it is not difficult to see that the PPP research progress remains stagnant in this period [26].

#### 2.3.3. Attention Analysis of Literature Quantity

Due to the large difference in the earliest appearance of the PPP literature in different countries around the world, in order to facilitate horizontal comparison, this paper selected the year (2002) when PPP-related literature appeared in each country as the starting point so as to analyze the literature attention. The number of pieces of literature can be used as an indicator to measure the level of national academic research output [27]. On the one hand, this chapter selects the PPP literature in the WoS core database from 2002 to 2022 and conducts a comparative study according to the top 10 countries in PPP literature. On



the contrary, we calculate the GVF values of these countries under different classification numbers, and analyze the goodness of fit curve, as shown in Figure 3.

**Figure 3.** National literature comparison and GVF test (**a**) GVF Curve of Top 10 Countries; (**b**) Time Series Characteristics of Literature Quantity in Top 10 Countries.

As shown in Figure 3a, when N = 3, the top 10 countries initially achieved the fitting in the GVF curve. This indicates that the top 10 countries are in accord with the classification rule of the natural breakpoint method in 70% of the literature. Furthermore, the rationality is verified when N is 3.

Analysis in Figure 3b reveals:

- (1) The graph shows an overall growth state. Since 2006, the volume growth trend in global PPP literature is obvious. Conversely, the USA and the UK perform the most prominently. After 2014, the global PPP literature growth gains momentum, and simultaneously, China and Australia show the greatest increases. Since 2007, the growth of global PPP literature tends to flatten out. However, China still maintains rapid growth and is significantly ahead of other countries. After 2019, except for China, the USA, and the UK, other countries all show slow growth or even a downward trend.
- (2) On the contrary, the total number of pieces of literature between China and the USA is similar. PPP literature in the USA has always been significantly ahead of China, and shows a steady growth trend from 2002 to 2017. However, the strong development period of PPP research in China is mainly concentrated in the second half of this period (2017–2022). It can be shown as: the China Public Private Partnerships Center (CPPPC) was officially approved in 2017, and the number of PPP-related policies promulgated also exploded in China. Until 2016, the number of joint policy enactments accounted for 35.6% of the total number of policy enactments [28]. Therefore, under the effective promotion of national policies, Chinese PPP practice and academic research received unprecedented attention [29]. Moreover, the number of PPP publications in China began to surpass that of the USA in 2017 and maintained a relatively stable growth rate.

#### 3. Derivative Analysis of Data Characteristics

Data characteristics of keywords determine the generation path and shape of the tree, and keywords with high data similarity are preferentially clustered until the only cluster with the highest discrimination is formed. UPGMA is a clustering method to calculate the distance between two clusters that can identify the relationship between objects and the



degree of clustering [30]. Eventually, we determine the degree of co-occurrence between keywords. The principle is shown in Figure 4.

Figure 4. The Principle of Tree Generation.

The branches of the tree represent the classification of keywords. Class 1 represents the maximum similarity between keywords. As the level of classification increases, the degree of clustering also increases.

The branches of the tree represent the classification of keywords. The following characteristics are: the earlier the branch appears, the higher the similarity between the keywords; the higher the number of branches, the more types are divided; as the level of classification increases, the degree of clustering also increases.

The formula is as follows [31]:

$$d(x,y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} D_{UPGMA}(C_i, C_j) = \frac{1}{|C_i||C_j|} \sum_{x \in C_i, y \in C_i} d(x, y)$$
(2)

Among them, d(x, y) represents the true distance between any two keywords (Euclidean distance),  $D_{UPGMA}(C_i, C_j)$  represents the center-spot (The average of all sample points within each cluster) of square Euclidean distance between  $C_i$  and  $C_j$ . Furthermore, the main research contents of this phase can be determined by the outermost clustering connection.

These three phases: the exploration period, the rapid development period, and the steady development period have different research priorities. Consequently, through the above methods, we will explore the main research directions and the main coupling keywords so as to divide the traditional research and emerging research. In this chapter, we will use the UPGMA clustering algorithm to couple time and keywords, use Python to calculate the 2-mode matrix, and pass it to R Studio to draw the biclustering graph in three phases, respectively [32], as shown in Figures 5–7.



Figure 5. Time Zone Biclustering Analysis in Exploration Period.



Figure 6. Time Zone Biclustering Analysis in Rapid Development Period.





#### 3.1. Feature Derivative Analysis of Keywords

#### 3.1.1. Exploration Period (1989–2008)

As shown in Figure 5, the exploration period is the embryonic stage of PPP research. The main research content concerns infrastructure and is followed by public procurement and project management. Moreover, the keywords outbreak stage of this period is concentrated in 2002–2008.

Through further observation, we find that there are three parts of key phrases with higher similarity degree. Part 1: China, risk management, and sustainability; Part 2: globalization, waste management, and developing countries; Part 3: critical success factors, value for money, and investments.

In this period, China was actively carrying out the plan of infrastructure investment. In the 6 years from 2003 to 2008, the total investment in infrastructure construction reached CNY 246,770 billion, with an average annual growth rate of 24.5% [33]. In addition, Chinese macroeconomic policy support has also driven the vigorous development of PPP projects. However, in order to ensure the sustainability of the project, a large quantity of governments have adopted debt guarantees, which have also led to an increase in the risk of debt default [34]. Additionally, increasing numbers of developing countries regard waste management as a great challenge. The reason is that backward economic conditions are obstacles to the development of PPP projects has also moved from extensive to high quality and refinement, achieving the value for money in PPP.

#### 3.1.2. Rapid Development Period (2008–2017)

As shown in Figure 6, the rapid development period is the outbreak stage of PPP research. The main research content is around sustainability, project management, risk allocation, and infrastructure. In addition, public health and innovation are sprouting. Moreover, the number of clustering lines increase significantly, indicating that the subdivision of PPP research also begins to increase.

An analysis of Figure 5 reveals three salient features in this period:

First, sustainability and risk allocation are the main research topics of this period. Despite the rapid growth in the frequency of innovation, the private sector remains concerned about the risks of emerging PPP projects. The risks and uncertainties of policy also limit the investment growth in sustainable projects [36]. Especially in the areas of renewable energy and public health.

Second, from a combination of financing model, real options, value for money, and evaluation, the financial attribute of PPP received unprecedented attention in this period. It is noteworthy that the PPP mode requires flexible and scientific investment decisions. An accurate PPP project valuation can effectively reduce the investment risk, so as to quantitatively solve the problem of project value definition and reasonably assess the value of the project [37].

Finally, from a combination of developing countries, China, India, case studies, and collaboration mechanisms, the case study of the PPP model in developing countries has also attracted more and more attention from academia. Hence, in addition to the research content of developed countries, we still need to pay extra attention to the research progress of developing countries.

#### 3.1.3. Steady Development Period (2017–2022)

As shown in Figure 7, compared with the exploration period and rapid development period, the research topic of the steady development period is more mature and stable. The main research content concerns innovation, sustainability, project management, and infrastructure. In contrast, the period show the most and densest clustering connections. This shows that there are many subdivision fields in this period, and the emerging research content are more likely to appear in this period. Therefore, this period is also the most important data source of the keyword split prediction.

By comparing with the steady development period, we find that the theme of this period is more novel, and innovation has become the main research content. The novelty of the specific theme is reflected in the following:

Originally, from a combination of financing model, risk management, concession period, transport project, and risk allocation, and considering the characteristics of the three phases, we find that: PPP financing model and risks remain the research objects of continuous attention in the future. Additionally, with the shift from real options to the Monte Carlo simulation, we found that the real value of the project requires more accurate evaluation methods, which seems to be a potential research hotspot.

Additionally, from the combination of developing countries, redevelopment, and climate change, the sustainability of PPP projects is receiving increasing attention from academia. With the pressure of environmental pollution on climate change, the redevelopment of heavy pollution projects has become a severe problem for many countries [38].

Ultimately, from the combination of health economics, big data, and public health, the demand for diversified health services on a global scale is continuously growing. It can be predicted that medical and health services will become part of the important areas of PPP application, and PPP projects are also expected to extend more from construction and environmental protection to the medical field in the future. Furthermore, the destruction of the global economy by COVID-19 accelerates this trend even more dramatically. Angela et al. [39] considers that the cooperation between the public sector and the private sector in biomedical big data has great commercial development potential.

#### 3.2. Coupling Analysis of Countries and Keywords

This chapter takes countries and keywords as coupling objects, conducting the following analysis: geographic heat analysis, academic cooperation analysis, betweenness centrality comparison, and correlation analysis of coupled clustering. Furthermore, we determine the mainstream countries in PPP research and focus on their research directions, providing a data basis for the evolution and prediction of theme words and keywords. Due to the academic funds of each country, the research cases are different. As a result, the number of pieces of literature in developed countries is usually higher than that in developing and backward economic countries [40]. Consequently, this chapter classifies the spatial characteristics of global PPP literature. On the basis of considering the imbalance of literature distribution, we apply Origin 2021 and CiteSpace 6.1 R3 to draw a comparative analysis of global PPP heat maps [41] and national cooperation network analysis maps [42], as shown in Figure 8.



**Figure 8.** Geographic Heat And Academic Cooperation Analysis (**a**) Comparative Analysis of Global PPP Heat Maps; (**b**) National Cooperation Network Analysis Maps.

As shown in Figure 8a:

- 1. On the whole, the distribution of global PPP literature is uneven. The top 5 continents in the global PPP literature are the Americas, Europe, Asia, Oceania, and Africa. From a partial perspective, the total number of pieces of literature in the Americas is close to that in Europe, and the total number of publications accounts for approximately 66% of the total global literature. Moreover, the distribution of literature in European countries is also more balanced, and the intensity of academic cooperation is higher. In contrast, the number of pieces of African literature is less than 3%, significantly lower than the average of other continents.
- 2. Country collaboration network analysis can measure the scientific research strength of the country in this field. Among them, the connection color indicates the time of national cooperation, and the node size indicates the number of pieces of literature in each country, as shown in Figure 8b.

On the one hand, the USA has the largest node size and color span as the most important country for academic influence. Furthermore the country is followed by China, the UK, Australia, and India. On the one hand, some developing countries are actively participating in cross-border academic cooperation, such as: "South Africa, Brazil and Spain", "China, Australia and the USA", "India, Kenya, South Africa and the UK". Additionally, South Africa has the largest number of cooperation links and is the most academically connected country from 2017 to 2022. It is undeniable that South Africa has research development potential and may be the focus of research in the future.

For countries with large demand in infrastructure, especially low and middle-income countries, the PPP mode has made great contribution to the economic growth of construction industry in these countries [43]. Thus, PPP application cases in these countries should also attract academic attention.

Therefore, we have reason to believe that in addition to the mainstream publishing countries such as China, the USA, and the UK, etc., the academic research in these economi-

cally backward countries should also be of concern, such as South Africa, Kenya, Indonesia, Malaysia, and Ghana etc.

3.2.2. Comparison of Betweenness Centrality

Betweenness centrality is an important indicator to measure academic influence. It is generally believed that nodes with betweenness centrality greater than 0.1 have important influence. This chapter takes the author's signature unit in the WoS core database as the standard and determines the top 10 countries as the mainstream countries of PPP research. The following two aspects are compared and analyzed: literature quantity and betweenness centrality, as shown in Table 1.

	Comp	Comparison of Betweenness Centrality					
Rank	Numbers	Centrality	Year	Country	Centrality	Country	
1	902	0.55	1989	The USA	0.55	The USA	
2	815	0.05	2000	China	0.36	The UK	
3	630	0.36	1992	The UK	0.13	Italy	
4	355	0.11	1998	Australia	0.12	The Netherlands	
5	270	0.02	2003	India	0.12	Canada	
6	265	0.12	1999	The Netherlands	0.11	Australia	
7	256	0.06	2002	Russia	0.10	Germany	
8	194	0.12	2003	Canada	0.06	Russia	
9	191	0.13	1996	Italy	0.05	China	
10	144	0.10	1998	Germany	0.02	India	

 Table 1. Comparison of Literature Quantity and Betweenness Centrality in Top 10 Countries.

Table 1 shows the analysis:

- 1. These are the countries where PPP literature first appeared: the USA (1989) and the UK (1992). On the one hand, the Top 5 countries in the total number of pieces of literature are the USA, China, the UK, Australia, and India; On the other hand, the Top 5 countries in terms of betweenness centrality are the USA, the UK, Italy, the Netherlands, and Canada. Additionally, through comparison, it was found that although China and India rank the second and fifth in the world in terms of the number of publications, their betweenness centrality is lower than 0.1. The reason is that China has a unique political background and economic characteristics that restrict the interaction and cooperation with other countries [44]. Overall, there is a large gap between developing and developed countries in academic influence.
- 2. Through the comparative analysis of literature quantity and betweenness centrality, it can be determined that developed countries: the USA and the UK, have a higher academic discourse power in the field of PPP research, and the research direction of these countries is an important evolutionary reference target. In addition, China and India are the most important evolutionary reference targets for the keywords of developing countries. Furthermore, we find that the modernization process of some developing countries (China, India, etc.) are also an important research reference for economically backward countries. In particular, related research in these areas: hydro economy and sustainability [45].

#### 3.2.3. Cluster Analysis of National Coupling

National academic influence is an important factor in determining the future research direction of PPP. The keyword developing countries appears repeatedly in the exploration period, rapid development period, and steady development period, and this is an evolutionary direction that cannot be ignored. Based on the above, we selected the Top 10 countries and some economically backward countries (South Africa, Indonesia, Kenya, Malaysia and



Malaysia) as the objects of country coupling clustering analysis and applied R Studio to draw the country and keyword coupling bi-clustering matrix, as shown in Figure 9.

Figure 9. Coupled Biclustering Graph of Country and Keyword.

Through analysis, we found that: project management, infrastructure, risk management, sustainability, public health, China, risk allocation, and concession period are the most concerned research directions in Top 10 countries. Among them, China, the USA, and the UK are the most important countries in PPP research, and the research scope basically covers all aspects.

Through the further analysis:

Originally, countries with the highest academic relevance were two groups: the USA and China, the UK, Russia, India, Australia, and Italy. The common research direction of these countries is an important evolutionary reference goal, such as project management, infrastructure, risk management, sustainability, public health and concession period. Additionally, the USA is the country with the most research on developing countries and China and has higher relative attention in the areas of financing model, value for money, and innovation. In contrast, China pays more attention to developing countries, game theory, regulation, critical success factors, sustainability, and collaboration mechanism.

Moreover, economically backward countries tend to focus on traditional research areas such as project management, infrastructure, and risk management. Conversely, South Africa has more research on sustainability and innovation [46]. This also means that the country may have a greater possibility to expand emerging research content.

# 4. Evolution Prediction of Theme Word and Keyword

Keywords can directly, simply, and comprehensively summarize the core content of the literature. In contrast, theme words can easily distinguish and conceptualize the types of article affiliation and summarize the research direction [47,48]. Based on the previous hypothesis and the data derived from the literature, through the attention analysis and strategic coordinate analysis of theme words, this chapter will predict and focus on the main evolution direction of PPP research in the future.

# 4.1. Attention Evolution of Theme Word

In this chapter, we applied Python to calculate the betweenness centrality of theme words, analyze the centrality change and frequency change of theme words, then draw the attention evolution analysis diagram of theme words by Origin 2021 [49], as shown in Figure 10.



Evolution Analysis of Theme Word Attention

Figure 10. Evolution Analysis of Theme Word Attention.

It can be seen from Figure 9:

1. Standardization and intelligence may become the innovation in future research. The betweenness centrality of government and law, as well as computer science, is greater than 0.1 until the steady development period. In addition, their frequency also increases significantly. It shows that the government will pay increasing amounts of attention to policy formulation and intelligent application of PPP modes in the future. Cheng [50] pointed out that the combination of PPP mode with network and intelligence has application value, which is conducive to improving the efficiency of resource allocation and the management level for government function management. Moreover, the global cloud computing market is also critical to driving the development of digital infrastructure. Simultaneously, the digital economy is expected to grow from approximately USD 500 billion in 2021 to nearly USD 1 trillion in 2026 [51]. Additionally, the emerging infrastructure, such as blockchain applica-

tions [52], smart city [53], and data center [54], etc., will increase the willingness to invest in the private sector.

- 2. Compared with business and economics, the frequency of environmental studies is close behind. In contrast, the centrality trend of environmental studies falls sharply after a slight rise. This suggests that there may be a large divergence in environment-related research. This research content (sustainability and renewable energy source) may distract the academic attention from environmental studies [55].
- 3. The literature on business economics is steadily increasing, but it is not innovative enough. Although the frequency of business and economics increases from 186 to 632, the betweenness centrality gradually decreases. This shows that the academic linkage effect of PPP biased towards the financial economy is weakening. However, these research directions (asset securitization, debt-to-equity swap, etc.) still have a good research heat [56].
- 4. Digital informatization, policy support, and health care jointly drive the development of PPP research. On the one hand, health care sciences and services, computer science, and government and law are the most significant keywords in the growth of betweenness centrality, which have attracted more and more attention from the global academia. On the contrary, technological innovation and application is the research focus needing extra attention, especially in this cross-disciplinary integration of research: information digitization [57], national policy support, and health care services [58,59], etc. Despite the frequency in the literature, these keywords are not among the top, but their academic attention is annually increasing, which will promote the progress of relevant research and has considerable potential for development.

# 4.2. Strategic Trend Evolution of Theme Word

Strategic coordinate analysis can identify the core theme word so as to reveal the intrinsic relationship between the theme words and the relative trend of innovation. Through calculating the density and centrality of each topic cluster, this chapter constructs a 2-dimensional rectangular coordinate system and distributes the scatters in four quadrants [60], as shown in Figure 11.



Figure 11. Principle of Strategic Coordinates.

Each quadrant represents different meanings, as follows:

- I quadrant: this quadrant has a high degree of academic influence, indicating that the theme word has close academic links with other theme words. Simultaneously, it has close internal links. To a certain extent, this shows that such theme words are at the core of the research field. Therefore, this quadrant is the highest influence and the most mature research field.
- II quadrant: the centrality of this quadrant is low, and the density is high. Moreover, it
  is at the edge of the research field. Although its academic development is relatively
  mature, the research content in this field does not match the current research hotspots.
- III quadrant: the theme of this quadrant has low centrality and low density. Additionally, the development of this theme is not mature. Although there is a potential development trend, the development is not systematic, and the connection with other themes is relatively loose.
- IV quadrant: the centrality of this quadrant is high and the density is low, indicating that this theme is at the center of the research. Although the research in this quadrant is immature, however, there is a high possibility of emerging topics in this field, with higher novelty index and academic development potential.

Density is an index to measure the internal strength of clusters in theme words.

It is usually expressed by calculating the average co-word frequency between internal words, as shown in Formula (3).

$$T_D = \frac{1}{n(n-1)} \times \sum_{i=1}^n \sum_{j=1}^{n \neq i} F_{ij}$$
(3)

Among them,  $T_D$  represents the cluster density; *n* represents the number of words in class group;  $F_{ij}$  is the frequency of co-words between keyword *i* and keyword *j*.

Concentricity is an indicator to measure the degree of connection between a cluster theme and other cluster themes. The larger the index, the more central the strategic position of the theme is in the overall discipline. Additionally, concentricity is mainly expressed by the co-word strength between keywords in different theme words, as shown in Formula (4).

$$T_{C} = f\left(\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{x=1}^{x} F_{ij}^{x}\right)$$
(4)

Among them,  $T_C$  is the centripetal degree of cluster;  $F_{ij}^x$  is the co-word frequency between the keyword *i* of target cluster and the keyword *x* of cluster *j*. Furthermore, this paper uses the average co-word frequency as the concentricity of this cluster.

## 4.2.1. Clustering Division of Theme Words

By extracting the keywords, volume, time, and other information from each piece of the literature in the dataset, this paper imports them into Vosviewer software for clustering. When the minimum number for keyword co-occurrence is set to 5, the distance between classes is the farthest, and the clustering effect is reasonable. Eventually, eight clustered theme words were obtained. Simultaneously, we count the frequency of these words in the steady development period and summarize each theme word with the top 5 co-occurrence-strength keywords, as shown in Table 2.

Obviously, the total amount of literature in the eight Clusters reaches 2922 from 2017 to 2022. Among them, C2 business and economics ranks first, C0 environmental studies ranks second, and C1 public administration ranks third. Moreover, the top three clusters account for 58.6%, and more than half of the total number of pieces of literature. This shows that these three theme words are the main research topics in the steady development period.

Total Count (2017–2022) = 2922										
Cluster	Theme Words	Keywords (Top 5)	Frequency	Rate	Rank					
C0	Environmental studies	Sustainability, Climate Change, Waste Management, Public Sector Comparator, Green Retrofits	616	0.211	2					
C1	Public administration	Project Management, Concession Period, Public Procurement, Private Sector, Project Procurement	434	0.149	3					
C2	Business and economics	Financing Model, Risk Allocation, Value For Money, Trust, Real Options	659	0.226	1					
C3	Computer science	Innovation, Monte Carlo Simulation, System Dynamics, Big Data, Evaluation	288	0.099	5					
C4	Government and law	China, Privatization, Developing Countries, India, Policy	185	0.063	7					
C5	Health care sciences	Case Study, Public Health, Telemedicine, COVID-19, Health Economics	273	0.093	6					
C6	Management	Game Theory, Efficiency, Risk Management, Renegotiation, Cooperation	304	0.104	4					
C7	Urban studies	Infrastructure, Investment, Toll Road, Transport Project, Redevelopment	163	0.056	8					

Table 2. Thematic Clustering Division.

#### 4.2.2. Core Identification of Theme Words

Based on the clustering of 8 theme words, this chapter conducts the macro evolution analysis of the core theme. Furthermore, we decompose the clustering and analyze the micro-evolution of the core theme [61], as shown in Figure 12.

On the whole, as Figure 12a shows: eight theme words are distributed in all quadrants. Among them, the most nodes in quadrant I are C0 (environmental studies), C1 (public administration) and C2 (business and economics). It shows that academic research on environmental and sustainability, project management, and PPP financing models is well developed. Moreover, the three clusters have the largest literature distribution and earlier research time, and simultaneously, the related theories and techniques are also mature. Hence, these theme words are always the core topic in PPP research.

From a partial perspective, as Figure 12b shows: initially, C0(environment studies), C2 (business and economics), C5 (health care sciences) are the clusters with the most nodes in quadrant IV. This suggests a higher contingency in the emerging research; Furthermore, the nodes of C5 (health care sciences) are both less in the II quadrant and III quadrant, but more in I quadrant. This indicates that the novelty in health care research is higher, and it has become a hotspot for research in recent years. Even these areas have more mature research accumulation: healthcare and health policy, etc.

It is worth noting that C3 has a large size node in the I quadrant, indicating that the research in a certain field is also more mature, such as in the Monte Carlo simulation. In addition, there are also a considerable number of C3 (computer science) nodes, focusing on the edge of quadrant III and quadrant IV. This shows that the research into computer interdisciplinary application also has great potential for academic development.

Therefore, combined with the actual research progress, we believe that: traditional research areas such as environmental studies, public administration, business and economics will remain the hotspots in the future. Without question, these are the key research areas that determine the main direction of PPP evolution and are also the important theme for cross-disciplinary research. However, health care sciences and computer science are also hot research topics. Consequently, these research fields: interdisciplinary applications of



computer science, telemedicine, health care economics, etc., will have explosive academic development potential.

**Figure 12.** Strategic Coordinate Evolution of Theme Word (**a**) Macro Evolution of Core Themes; (**b**) Microscopic Evolution of Core Themes.

## 4.3. Keyword Diversion Prediction

# 4.3.1. Calculation of Novelty Index

Novelty index (NI) can measure the innovation of keywords and mine the latest research. It is generally believed that the first occurrence time is the most novel time for keywords, and the NI of keywords requires a time decrease. Based on the traditional novelty calculation formula, this chapter introduces theme strength  $T_{C_n}$  and frequency of keyword  $K_i$  so as to more reasonably show the innovation degree of emerging keywords. The specific calculation formula (5) is as follows [62]:

$$NI_i = \frac{K_i}{(i - FI + 1)} T_{C_n} \tag{5}$$

Among them, *i* represents the target year and takes the value of 2022; *FI* represents the earliest occurrence year of keyword;  $K_i$  represents the frequency of keyword in the steady development period;  $T_{C_n}$  represents the intensity index of theme word.

# 4.3.2. Keyword Prediction

First, according to the attention evolution of theme words, the mainstream evolution directions are determined as: environmental studies, public administration, business and economics, computer science, government and law, health care sciences, management, and urban studies. In addition, we count the frequency of keywords for related theme words in the steady development period. Eventually, we calculate the most novel keywords and classify them reasonably, applying R Studio to draw a diversion prediction diagram for keywords [63], as shown in Figure 13.



Figure 13. Keyword diversion prediction.

From left to right are as follows: the theme words of the cluster evolution prediction, the uppermost and high-frequency keywords in theme clustering, and the prediction results of emerging keywords. The specific analysis is as follows:

- 1. Integration of business economy and sustainability. A combination of computer science, government and law, and health care sciences. Among them, health economics, transition economy, waste management, and clean energy economy, etc., are the most novel keywords, which indicates the economic sustainability and effective value of the PPP model, and they receive increasing amounts of academic attention from countries and scholars.
- 2. Integration of policy support and innovative technology applications. It is a combination of computer science, government and law, and health care sciences.
  - On the one hand, with the progress of the times, scholars' demand for innovative research is increasing, and the application of advanced technology is more reflected in these aspects: big data, data envelopment analysis, machine learning and blockchain application. Second, the emergence of emerging concepts such as: smart city, data center, etc., also promoted interest in private capital for emerging PPP projects financing. However, policy uncertainty risk is a key influencing factor for many PPP projects. Additionally, the lack of available data analysis will lead to the risk of uncertainty in PPP project evaluation, leading to a reduction in the investment enthusiasm for PPI. Therefore, scientific data analysis and machine learning applications can provide an effective policy guidance for government, so as to realize the intelligent decision-making applications [64].
  - On the other hand, the NI of public health also reaches 0.13. The COVID-19 recovery plan has received urgent global attention in recent years [65]. Furthermore, this research also receives extensive academic attention: medical facilities construction, medical service policy, data analysis in medical health, public health management, etc.
- 3. Urbanization in developing countries is a combination of public administration, business and economics, government and law, management, and urban studies. Among them, mainstream PPP research will continue to focus on traditional areas of application in developing countries/regions (Sub-Saharan Africa, China, and India), such as: transport project, urban renewal model, and cooperation mechanism, etc. Moreover, infrastructure will always be the research focus in the field of urban studies. Furthermore, it is still the basic research direction for developing countries and even developed countries in the long-term.

# 5. Conclusions and Future Work

# 5.1. Conclusions

This paper divides the keywords and theme words of each period by the natural breakpoint method, combs the overall context and development trend of PPP research by 2-mode matrix clustering analysis, and focuses on the research hotspots of mainstream countries. Based on the analysis results of attention and strategic trend on theme words, we predict the future research directions. The specific conclusions are as follows:

- 1. The derivative characteristics of the literature data are explained descriptively. First, we divided global PPP research into three phases: the exploration period, the rapid development, and the steady development period, and verified the rationality. Based on this, more findings were as follows: we identified the main keywords of each period, the mainstream countries for PPP research and research trends, the attention evolution and strategic position of theme words. These provide an important data basis and evolution basis for the prediction of future keywords.
- 2. The evolutionary direction of PPP research can be summarized as economic sustainability, diversity of financing mechanisms, innovation in the application of technology, and the applicability in developing countries. The specific manifestations are, pri-

marily, the integration of business economy and sustainability, as well as transition economy, new energy economy, clean energy economy, and debt-to-equity swap, etc.; and additionally, the integration of policy support and innovative technology applications, such as government intelligent decision-making, big data analysis, smart city, etc.; and ultimately, urbanization in developing countries, such as transportation facilities construction, urban renewal strategy, public sector comparison, etc.

3. Moreover, global academic attention to developing countries will become increasingly high, especially in China, India, and Sub-Saharan Africa. In academic cooperation, the willingness of developing countries to cooperate is enhancing. The research direction is more manifested in urban infrastructure construction, cooperation mechanism research, public sector comparison, etc.

#### 5.2. Future Work

The shortcomings to be noted are: first, the limitations of the data, such as: the WoS core database of theme classification is unreasonable. Second, this article needs to track the future updates to the WoS database. Therefore, in the future work, we will apply NLP technology to classify the theme words reasonably and conduct empirical analysis to verify the accuracy of the prediction.

Author Contributions: L.Z.: Methodology, validation, formal analysis, writing—original draft preparation, project administration, writing—review and editing, supervision and funding acquisition.; S.Y.: writing—original draft preparation, data curation, formal analysis visualization, code writing, model building, writing-original draft preparation, and writing—review and editing; S.W.: project administration, writing—review and editing, supervision, investigation, and funding acquisition. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by the Beijing Municipal Natural Science Foundation (No. 9202006) and the Excellent Talent Project of North China University of Technology in 2019 (No. 216051360020XN225/004). The authors gratefully acknowledge this funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

**Data Availability Statement:** The data that support the findings of this study are available on request from the corresponding author. Data can be made available upon request for collaboration.

Conflicts of Interest: The authors declare no conflict of interest.

## References

- 1. Hernandez-Aguado, I.; Zaragoza, G.A. Support of public–private partnerships in health promotion and conflicts of interest. *BMJ Open* **2016**, *6*, e9342. [CrossRef] [PubMed]
- 2. Global Infrastructure Hub. InfraCompass 2020. Available online: https://www2.deloitte.com/global/en/pages/public-sector/ articles/infracompass-2020.html (accessed on 21 July 2022).
- 3. The World Bank. PPI Database Global Report 2021. Available online: https://ppi.worldbank.org/en/ppi (accessed on 15 August 2022).
- Al-Sharif, F.; Kaka, A. PFI/PPP topic coverage in construction journals. In Proceedings of the 20th Annual ARCOM Conference, Edinburgh, UK, 1–3 September 2004; pp. 711–719.
- Ke, Y.; Wang, S.; Chan, A.P.; Cheung, E. Research trend of public-private partnership in construction journals. *J. Constr. Eng. Manag.* 2009, 135, 1076–1086. [CrossRef]
- 6. Song, J.; Zhang, H.; Dong, W. A review of emerging trends in global PPP research: Analysis and visualization. *Scientometrics* **2016**, 107, 1111–1147. [CrossRef]
- Zhang, Y.; Luo, W.; Shan, M.; Pan, D.; Mu, W. Systematic analysis of PPP research in construction journals: From 2009 to 2019. Eng. Constr. Archit. Manag. 2020, 27, 3309–3339. [CrossRef]
- Sun, Q.; Zhang, S.; Ke, Y.; Ma, X.; Galvin, S. Comparative analysis on the PPP research in Chinese and international journals: A bibliometric perspective. Int. J. Constr. Manag. 2021, 1–21. [CrossRef]
- 9. Shi, J.; Duan, K.; Wu, G.; Zhang, R.; Feng, X. Comprehensive metrological and content analysis of the public–private partnerships (PPPs) research field: A new bibliometric journey. *Scientometrics* **2020**, *124*, 2145–2184. [CrossRef]
- 10. Osei-Kyei, R.; Jin, X.; Nnaji, C.; Akomea-Frimpong, I.; Wuni, I.Y. Review of risk management studies in public-private partnerships: A scientometric analysis. *Int. J. Constr. Manag.* **2022**, 1–12. [CrossRef]

- 11. Abdel Aziz, A.M. Successful delivery of public-private partnerships for infrastructure development. J. Constr. Eng. Manag. 2007, 133, 918–931. [CrossRef]
- Zhao, L.; Liu, Y.; Chen, L.; Tian, J. Evaluation of Coordination and Coupling Degree of Cross-Regional Influence of the Construction Industry Based on Regional Economic Factors: A Case Study of Beijing, Capital of China. *Discret. Dyn. Nat. Soc.* 2021, 2021, 6650493. [CrossRef]
- 13. Zhao, L.; Liu, Y.; Tian, J. Spatiotemporal evolution law and output prediction of construction waste in the People's Republic of China. *Waste Manag. Res.* **2021**, *40*, 174–184. [CrossRef]
- 14. Chen, J.; Yang, S.; Li, H.; Zhang, B.; Lv, J. Research on geographical environment unit division based on the method of natural breaks (Jenks). *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2013**, *3*, 47–50. [CrossRef]
- 15. Agryzkov, T.; Oliver, J.L.; Tortosa, L.; Vicent, J. A new betweenness centrality measure based on an algorithm for ranking the nodes of a network. *Appl. Math. Comput.* **2014**, 244, 467–478. [CrossRef]
- 16. Li, J.; Goerlandt, F.; Reniers, G. An overview of scientometric mapping for the safety science community: Methods, tools, and framework. *Saf. Sci.* **2021**, *134*, 105093. [CrossRef]
- 17. Abbas, N.N.; Ahmed, T.; Shah, S.H.U.; Omar, M.; Park, H.W. Investigating the applications of artificial intelligence in cyber security. *Scientometrics* **2019**, *121*, 1189–1211. [CrossRef]
- 18. Bai, X.; Zhang, X.; Li, K.X.; Zhou, Y.; Yuen, K.F. Research topics and trends in the maritime transport: A structural topic model. *Transp. Policy* **2021**, *102*, 11–24. [CrossRef]
- 19. Guseva, A.; Muraseva, D.; Cheryomushkina, V. Morphological and Genetic Diversity of Scutellaria tuvensis Juz., an Endemic of Desert Steppes. *Int. J. Plant Biol.* **2022**, *13*, 473–484. [CrossRef]
- 20. Miño, P.; Saffer, A.J. Networks of international public relations production: The case of Latin American organizations' connections to US agents. *Public Relat. Rev.* 2021, 47, 102054. [CrossRef]
- 21. Broccatelli, C.; Everett, M.; Koskinen, J. Temporal dynamics in covert networks. Methodol. Innov. Online 2016, 9, 1–14. [CrossRef]
- Nicholls, K.; Wallace, C. Comparison of sparse biclustering algorithms for gene expression datasets. *Brief. Bioinform.* 2021, 22, bbab140. [CrossRef]
- Pitera, M.; Chechkin, A.; Wyłomańska, A. Goodness-of-fit test for \$\$\alpha \\$ α-stable distribution based on the quantile conditional variance statistics. *Stat. Methods Appl.* 2022, 31, 387–424. [CrossRef]
- 24. Bayliss, K.; Van Waeyenberge, E. Unpacking the public private partnership revival. J. Dev. Stud. 2018, 54, 577–593. [CrossRef]
- 25. Akomea-Frimpong, I.; Jin, X.; Osei-Kyei, R.; Tumpa, R.J. A critical review of public–private partnerships in the COVID-19 pandemic: Key themes and future research agenda. *Smart Sustain. Built Environ.* **2022**. *ahead-of-print*. [CrossRef]
- Opara, M.; Rouse, P. The perceived efficacy of public-private partnerships: A study from Canada. Crit. Perspect. Account. 2019, 58, 77–99. [CrossRef]
- 27. Wang, Z.; Wang, K.; Liu, J.; Huang, J.; Chen, H. Measuring the innovation of method knowledge elements in scientific literature. *Scientometrics* **2022**, 127, 2803–2827. [CrossRef]
- 28. Likun, Z.; Jia, W.; Zhuo, W. Analysis on the Synergy Effectiveness of PPP Policy in China. Proj. Manag. Rev. 2019, 4, 48–53.
- 29. Biygautane, M. The institutional context of PPPs: The roles of institutions, organizations, and individual actors. In *The Institutional Context of Public–Private Partnerships*; Edward Elgar Publishing: Cheltenham, UK, 2022; pp. 21–57. ISBN 1802200142.
- Jaslam, P.M.; Bhardwaj, N.; Devi, M.; Singh, V.K.; Anu. Diversity structure analysis based on hierarchical clustering method. In AIP Conference Proceedings; AIP Publishing LLC: Melville, NY, USA, 2022; p. 80003.
- Segura-Alabart, N.; Serratosa, F.; Gómez, S.; Fernández, A. Nonunique UPGMA clusterings of microsatellite markers. *Brief. Bioinform.* 2022, 23, c312. [CrossRef]
- 32. Wang, B.; Liang, X.; Gleason, M.L.; Zhang, R.; Sun, G. Genome sequence of the ectophytic fungus Ramichloridium luteum reveals unique evolutionary adaptations to plant surface niche. *BMC Genom.* **2017**, *18*, 729. [CrossRef]
- Zhang, S.; Gao, Y.; Feng, Z.; Sun, W. PPP application in infrastructure development in China: Institutional analysis and implications. *Int. J. Proj. Manag.* 2015, 33, 497–509. [CrossRef]
- 34. Yurdakul, H.; Kamaşak, R.; öztürk, T.Y. Macroeconomic drivers of Public Private Partnership (PPP) projects in low income and developing countries: A panel data analysis. *Borsa Istanb. Rev.* 2022, 22, 37–46. [CrossRef]
- Henry, R.K.; Yongsheng, Z.; Jun, D. Municipal solid waste management challenges in developing countries–Kenyan case study. Waste Manag. 2006, 26, 92–100. [CrossRef]
- 36. Xie, F. Research on Sustainability of Financing Mode and Demand of PPP Project—Based on Chinese PPP and Local Financing Platform Alternative Perspective. *Sustainability* **2022**, *14*, 14591. [CrossRef]
- 37. Bagui, S.K.; Das, A.; Pandey, Y. Modification of NPV Value Based on Real Option Study. In Proceedings of the Fifth International Conference of Transportation Research Group of India; Springer: Singapore, 2022; pp. 411–420.
- 38. Hou, D.; Song, Y.; Zhang, J.; Hou, M.; O'Connor, D.; Harclerode, M. Climate change mitigation potential of contaminated land redevelopment: A city-level assessment method. *J. Clean. Prod.* **2018**, *171*, 1396–1406. [CrossRef]
- 39. Ballantyne, A.; Stewart, C. Big data and public-private partnerships in healthcare and research. *Asian Bioeth. Rev.* **2019**, *11*, 315–326. [CrossRef]
- 40. Lund, B.D. Is academic research and publishing still leaving developing countries behind? *Account. Res.* **2022**, *29*, 224–231. [CrossRef]

- Islam, T.; Kim, K.; Choi, J. Wheat Blast in Bangladesh: The Current Situation and Future Impacts. *Plant Pathol. J.* 2019, 35, 1–10. [CrossRef]
- 42. Wang, M.; Liu, P.; Zhang, R.; Li, Z.; Li, X. A scientometric analysis of global health research. J. Environ. Res. Public Health 2020, 17, 2963. [CrossRef]
- 43. Makarenko, I.; Serpeninova, Y.; Pogorila, K. Institutional support for sustainable development financing in the light of the multistakeholder approach. *Agric. Resour. Econ. Int. Sci. E-J.* **2018**, *4*, 85–96.
- 44. Majeed, M.A.; Yan, C.; Zhong, H. Do firms manipulate earnings after winning public-private partnership bids? Evidence from China. *Emerg. Mark. Rev.* 2022, *51*, 100880. [CrossRef]
- Kar, S.; Samal, K. Hydro Economy: Environmental Sustainability of Water and Wastewater Resources and Infrastructure. In Recent Developments in Sustainable Infrastructure (ICRDSI-2020)—GEO-TRA-ENV-WRM; Springer: Berlin/Heidelberg, Germany, 2022; pp. 181–197.
- 46. Okoro, C.S.; Musonda, I.; Agumba, J.N. Exploring the underlying structures of sustainability performance measures: A study of transportation projects in South Africa. *Int. J. Constr. Manag.* **2022**, *22*, 1550–1558. [CrossRef]
- Li, J.; Sun, X.; Dai, X.; Zhang, J.; Liu, B. Knowledge Map Analysis of Industry–University Research Cooperation Policy Research Based on CNKI and WOS Visualization in China. *Sustainability* 2022, 14, 7862. [CrossRef]
- Corell-Almuzara, A.; López-Belmonte, J.; Marín-Marín, J.; Moreno-Guerrero, A. COVID-19 in the Field of Education: State of the Art. Sustainability 2021, 13, 5452. [CrossRef]
- Singh, S.K.; Pandey, A.; Bahuguna, A.; Mohapatra, K.K.; Patra, A.; Sathyanarayana, E.; Jatav, H.S.; Jatav, S.S.; Rajput, V.D. Current State of Knowledge in Diagnosis and Mitigation of Micronutrients Deficiency in Crop Production in Indian Prospective; Nova Science Publishers: Hauppauge, NY, USA, 2022; pp. 383–415, ISBN 9781685076146.
- 50. Cheng, L. Discussion on the application of PPP model in new infrastructure construction. Open J. Soc. Sci. 2019, 7, 283. [CrossRef]
- 51. The Global Infrastructure Hub. In a Post-COVID World, the Future is Digital. Available online: https://www.gihub.org/articles/ in-a-post-covid-world-the-future-is-digital (accessed on 21 September 2022).
- Tian, Y.; Minchin, R.E.; Petersen, C.; Moayed, E.; Adriaens, P. Financing Public-Private Partnership Infrastructure Projects through Tokenization-enabled Project Finance on Blockchain. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2022; p. 12027.
- Liu, T.; Mostafa, S.; Mohamed, S.; Nguyen, T.S. Emerging themes of public-private partnership application in developing smart city projects: A conceptual framework. *Built Environ. Proj. Asset Manag.* 2020, 11, 138–156. [CrossRef]
- 54. Saunavaara, J.; Laine, A.; Salo, M. The Nordic societies and the development of the data centre industry: Digital transformation meets infrastructural and industrial inheritance. *Technol. Soc.* **2022**, *69*, 101931. [CrossRef]
- 55. Wang, Y. Credit Risk Evaluation of Asset Securitization of PPP Project of Sports Public Service Venues Based on Random Forest Algorithm. *Comput. Intell. Neurosci.* 2022, 2022, 5177015. [CrossRef]
- 56. Xu, N.; Kasimov, I.; Wang, Y. Unlocking private investment as a new determinants of green finance for renewable development in China. *Renew. Energy* **2022**, *198*, 1121–1130. [CrossRef]
- 57. Wang, Y.; Xiao, Z.; Tiong, R.L.; Zhang, L. Data-driven quantification of public–private partnership experience levels under uncertainty with Bayesian hierarchical model. *Appl. Soft Comput.* **2021**, *103*, 107176. [CrossRef]
- 58. Ho, M.K. Total joint replacement surgeries: Making the case for a public–private partnership in Hong Kong. *World Med. Health Policy* **2022**, *14*, 600–608. [CrossRef]
- 59. Ganapathy, K.; Das, S.; Reddy, S.; Thaploo, V.; Nazneen, A.; Kosuru, A.; Shankar Nag, U. Digital health care in public private partnership mode. *Telemed. E-Health* **2021**, *27*, 1363–1371. [CrossRef]
- 60. Kwayu, K.M.; Kwigizile, V.; Lee, K.; Oh, J.; Nelson, T. Automatic topics extraction from crowdsourced cyclists near-miss and collision reports using text mining and Artificial Neural Networks. *Int. J. Transp. Sci. Technol.* **2022**, *11*, 767–779. [CrossRef]
- 61. Shen, Z.; Ji, W.; Yu, S.; Cheng, G.; Yuan, Q.; Han, Z.; Liu, H.; Yang, T. Mapping the knowledge of traffic collision Reconstruction: A scientometric analysis in CiteSpace, VOSviewer, and SciMAT. *Sci. Justice* **2022**, *63*, 19–37. [CrossRef]
- Yang, J.; Lu, W.; Hu, J.; Huang, S. A novel emerging topic detection method: A knowledge ecology perspective. *Inform. Process. Manag.* 2022, 59, 102843. [CrossRef]
- 63. Chen, X.; Cheng, G.; Wang, F.L.; Tao, X.; Xie, H.; Xu, L. Machine and cognitive intelligence for human health: Systematic review. *Brain Inform.* **2022**, *9*, 1–20. [CrossRef]
- 64. Zhao, L.; Yang, S.; Wang, S.; Shen, J. Research on PPP Enterprise Credit Dynamic Prediction Model. *Appl. Sci.* **2022**, *12*, 10362. [CrossRef]
- 65. Karakosta, C.; Mylona, Z.; Karásek, J.; Papapostolou, A.; Geiseler, E. Tackling covid-19 crisis through energy efficiency investments: Decision support tools for economic recovery. *Energy Strategy Rev.* **2021**, *38*, 100764. [CrossRef]

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.