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China's Sharing Economy of Mobility Industry: From Perspective of Industrial Ecosystem

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Abstract: The development of China's sharing economy has slowed down significantly after experiencing the savage growth since the beginning of 2018 and has entered the turning point of structural adjustment. Factors including homogeneous and single profit model, excessive reliance on capital, and the immaturity of win-win industrial ecosystem are major bottlenecks. Therefore, how to overcome the obstacles is a key issue to be solved urgently. In view of the sharing economy's characteristics of industry integration and cross-boundary symbiosis, the concept of sharing economy industrial ecosystem was put forward. Furthermore, social network analysis (SNA) was used to solve the problem of weak synergy in the development of China's sharing economy and strive to break through the development bottleneck in order to realize the optimization of China's sharing industry ecosystem and the sustainable development of industry. Specially, we proposed a fusion framework of industrial ecosystem and SNA including macro, meso, and micro dimensions. Macro analysis is based on the fusion of ecological environment in ecosystem theory and density analysis in SNA. Meso analysis is based on the fusion of ecological communities in ecosystem theory and subgroup analysis in SNA. Micro analysis is based on the fusion of an ecological niche in ecosystem theory and centrality analysis in SNA. It was found that the ecosystem of sharing mobility industry has been basically established, and the ecological diversity is good, including sharing mobility, third-party platform, automobile manufacturing, insurance and venture capital enterprises and universities. In addition, some sharing enterprises, typically represented by Didi, are upgrading their strategies to ecological development through cross-border integration. Mobile payment plays a vital role in developing China's sharing mobility industry.

Keywords: sharing economy; sharing mobility industry; industrial ecosystem; theory of social network analysis; network transport perspective

1. Introduction

With the rapid development of the internet, the sharing economy, represented by companies like Uber and Airbnb, have quickly spread around the world, characterized by providing services and revenue at a marginal cost below that of professional organizers in order to share the idle resources through social platforms [1–4]. It is predicted that the global sharing economy market is expected to grow from $15 billion in 2015 to $335 billion by 2025 [5]. In China, the transaction volume of the sharing economy in 2017 was about 4,920.5 billion yuan, an increase of 47.2 percent over previous year, and the average annual growth rate will be more than 30% in the next five years [6]. Take the sharing mobility industry for example, from 2015 to 2018, the penetration rate of sharing mobility users among Internet users increased from 26.3% to 43.2% and the industry includes many sub industries such as sharing a bicycle, sharing a special car, sharing a rental car, sharing carpooling, sharing the

bus, sharing parking and so on [5]. Didi, a representative sharing mobility enterprise, is a one-stop mobility platform that covers many businesses such as special car, carpooling, Valet driving and bus sharing, and has entered 26 cities in China including Beijing, Shanghai, Guangzhou and so on [7]. CAR.Inc, another representative sharing mobility enterprise, was founded in September 2007 with its headquarters in Beijing. As the leader of China's car rental industry, it has set up more than 1000 service outlets in 169 cities across the country and has more than 13,000 self-owned motorcades. Now it has also entered the field of sharing the special cars business [8]. However, at the beginning of 2018, China's sharing economy suffered a sharp slowdown, and a large number of sharing economy enterprises encountered a big drop in profits and were forced to lay off a significant part of the workforce or merged and acquired [6]. The root of hindering the sustainable development of China's sharing economy lies in the lack of a clear profit model and win-win idea, which leads to product homogeneity and the prevalence of suicide marketing [9]. Besides, problems such as excessive reliance on capital, immaturity of social credit system and the lack of synergy industrial network are also the key bottlenecks that restrict the industrial synergy effect of the sharing economy [10]. Although China's sharing economy has exposed many problems, we cannot deny that it is playing an important role in stabilizing and expanding employment, promoting the equalization of public services and accelerating the integration with the real economy in China, and it still has a huge market potential and good development prospects [9,11]. Therefore, it is an urgent and significant issue to break through the bottlenecks and promote China's sharing economy's sustainable development. Generally speaking, sustainable development means to achieve the development by controlling population growth, protecting resource base and developing renewable energies [12]. When the definition is extended to economics, especially for industrial development— sustainable development means that under the premise of maintaining the quality of natural resources and the services provided, adhering to the concept of coordination and win-win, the net benefits of industrial development will be increased to the maximum in a long period of time. Therefore, for the sharing economy, sustainable development is to break the current development bottleneck, maintain sustainable profits and coordinated rapid development of industry in order to provide better services for consumers.

Sharing economy industry is a branch of internet industry [13,14]. Many successful innovation modes and development experience of the internet industry can be used as reference for the sharing economy. The first is the reference of methodology, as the method to study the route optimization of transportation network and energy conservation can be used in the sustainability development of sharing mobility industry [15,16]. The second is the reference of demand analysis, as the measurement and prediction of users' demands through the internet platform can also be used in the research on sharing mobility industry [17,18]. Besides, strategies and governance structure of internet industry also can be used in the sharing economy [3,19]. Research on the ecological development of the internet industry has attracted the attention of researchers in recent years, which was developed to investigate the significance of the ecological path of the internet industry, showing that the collaboration of the whole industrial ecosystem can accelerate the process of innovation, save cost, and improve the efficiency of innovation [20–22]. Some scholars have made a series of studies on specific cases such as Google, Apple, Amazon, and Symbian in the context of digital age [23–25]. The introduction of ecological perspective breaks the narrow perspective of the internet industry and forms a broader perspective to study the symbiosis between internet enterprises and stakeholders [26]. Similarly, ecological development is also applicable to the sharing economy industry, such as from the perspective of stakeholders [27] or system map [4]. The study on sharing economy research is just in its infancy, mostly based on case studies, and lacks the clear mechanism design and path guidance for sustainable development. Therefore, it is urgent to introduce the ecological perspective and establish a systematic framework of sharing economy industry with a broad vision.

A widely accepted approach to study the ecosystem is the theory of social network analysis (SNA), which provides a new analytical thinking for the coordinated symbiosis and can properly describe the complex and diverse social interaction of a system like industries [28–32]. SNA contains the systematic

framework and analytical methods in many interdisciplinary studies, especially in economics and management. It provides a new viewpoint of network structure and builds a bridge between micro network subject (individual behavior) and macro network structure (whole network phenomenon) [33]. Therefore, we introduced SNA to China's sharing economy industry to study how to solve the obstacles of weak synergy effect and to realize the sustainable development of industrial ecosystem. In detail, we firstly established a fusion framework of ecosystem and SNA, with three-dimensional analysis including macro, meso, and micro analysis. Then, the fusion framework was applied to the comparative analysis of five China's sharing mobility sub-industries.

The rest of the paper is organized as follows. Section 2 provides a brief introduction of the study case. Section 3 constructs the fusion framework of ecosystem and SNA with three dimensional analysis. The results and analysis are shown in Section 4. Conclusions, suggestions and future works are outlined in Section 5.

2. Study Cases

Sharing mobility industry is one of the most representative industries in China's sharing economy. Despite theslowdown, the sharing mobility industry is playing a very important role in improving urban traffic efficiency, reducing congestion and improving resource utilization in China [6]. Since 2016, China's sharing mobility industry has reached 1.77 billion orders per year, created 5.5 million jobs and attracted 23.4 billion US dollars in investment [34]. It is predicted that, with the increasing demand and the support policies to be released, the market size of China's sharing mobility industry will continue to grow at an annual rate of over 80% in the future, exceeding the global growth rate [35].

Sharing mobility industry includes many sub-industries. Considering the representativeness and comparability, five sub-industries closely related to automobile industry were analyzed, including sharing a special car, sharing a rental car, sharing carpooling, sharing the bus and sharing parking industries. The brief profiles of these five sub-industries are shown in Table 1.

Table 1. Specifications of the five sharing mobility sub-industries.

Sub-Industry	Business Model	Representative
Sharing special car	It refers to the information matching and mutual selection between passengers and vehicles through the internet platform, with dedicated drivers to provide mobility reservation services	Didi Special Car, No 1 Special Car
Sharing rental car	It refers to the use of internet car rental platform by consumers to rent idle vehicles nearby, driving by themselves, so as to meet the short-term demand for mobility use	CAR.Inc. Wukong Zuche
Sharing carpooling	It refers to the use of internet carpooling platform to find idle vehicles and passengers who have the same or similar travel routes with the owner, and share the cost of travel	Didi Carpooling, Acting Appointment
Sharing bus	It refers to passengers customizing their routes through internet platforms to meet their needs for commuting or touring around	Didi bus Pig Bus
Sharing parking	It refers to the use of other people's idle parking spaces by means of internet parking platform so as to effectively alleviate the difficulty in finding parking spaces in big cities	Youwei Parking, Dingding Parking

3. Methods

3.1. Research Framework

Generally, a widely accepted approach to study the factors affecting the ecosystem is carried out from three dimensions including the macro dimension related to the ecological environment analysis, meso dimension related to the ecological community analysis and micro dimension related to the ecological niche analysis [36–44]. The theories of density, subgroup and centrality in SNA are

well matched, respectively. Therefore, we established the fusion framework of SNA and the sharing economy industrial ecosystem from three dimensions, as shown in Table 2.

Table 2. Fusion framework of sharing economy industrial ecosystem and social network analysis.

Dimension	Purpose	Sharing Economy Industrial Ecosystem (To Be Analyzed)	SNA (Analysis Methods)
Macro (Ecological environment matching density analysis)	Analyze the maturity of sharing economy's ecological environment, to know the degree of resource support and influence from the industrial ecosystem for each enterprise	Ecosystem scale	Quantities of nodes and network connections
		The degree of closeness between members in industrial ecosystem	Density index
		The degree of industrial ecosystem cohesion	Centralization of a network
Meso (Ecological community matching subgroup analysis)	Analyze the operation of ecological community to know whether small groups exist and their characteristics	Industrial ecological community	Subgroup or clique analysis
Micro (Ecological niche matching centrality analysis)	Analyze the hub nodes to know whether leading enterprises and bridge enterprises exit, which play important roles in the development of industrial ecosystem	Identification of dominant species	Node centrality
		Identification of key species	Double identifications of Burt Structural Hole and Betweenness Centrality

3.2. Macro Dimension Analysis

For the natural ecological environment, it includes factors like space capacity, climate, topography, and others, which provide resource support for living organisms. As far as the sharing economy industry is concerned, the ecological environment is the industrial space composed of sharing economy enterprises, manufacturing enterprises, mobile payment enterprises, insurance and venture capital enterprises, governments, and universities, etc. [6]. The maturity of the industrial ecological environment depends on the close interactions among the enterprises and organizations. Therefore, the macro dimensional analysis focuses on the scale of industrial ecosystem and the interactions among members so as to explore the extent to which each enterprise can obtain resource support from the industrial ecological environment.

In SNA, density analysis can be matched with the ecological environment of sharing economy industrial ecosystem, which is the most important indicator to analyze the degree of tightness between nodes in the network. In this paper, the scope of traditional density analysis has been expanded to a comprehensive measurement to include three aspects, the network scale of the industrial ecosystem, traditional density index and cohesion index.

(1) Network scale of the industrial ecosystem.

Let N represent the number of nodes in a network, and L represent the number of connections between nodes in the network. Generally, for the network with a larger scale, the ecological diversity and the maturity of the ecological environment are better. Without loss of generality, for a network G, we have

$$N = \{n_1, n_2, \ldots, n_n\},\ L = \{l_1, l_2, \ldots, l_n\}. \tag{1}$$

(2) Density indicator.

Generally, the higher the network density is, the closer the interactions between the nodes are. The density indicator is measured by the ratio of the number of connections actually existing in the network to the number of connections that may exist, and is calculated by [22]:

$$Density = \frac{2L}{N(N-1)} \tag{2}$$

where L is the number of connections between nodes and N is the number of nodes in the network.

(3) Cohesion indicator.

Based on the analysis of scale and density of the network, cohesion indicator (denote *C*) is used to identify whether there is clustering around some hub nodes or decentralized. Cohesion indicator *C* is calculated by [22]:

$$C = \frac{\sum_{i=1}^{n} (C_{\max} - C_i)}{\max\left[\sum_{i=1}^{n} (C_{\max} - C_i)\right]} \quad (3)$$

where $C_{\max}$ is the maximum centrality of each node and C_i is the centrality of Node *i*.

3.3. Meso Dimension Analysis

The study on ecological community belongs to the meso dimension analysis, referring to a group of interdependent population occupying a certain space and living in a specific region or natural environment with similar natural resource needs. Since different ecological communities constitute the ecosystem, the ecosystem can be regarded as a whole network, and each ecological community can be regarded as an ego network. For sharing the economy industry, because of its remarkable cross-border convergence characteristics, there must be several different communities, such as the sharing economy enterprise community, mobile payment community, manufacturing enterprise community and so on. Each community has its own ego network structure and behavior characteristics.

Subgroup analysis in SNA can be matched with the ecological community of sharing economy industrial ecosystem, which is to find the subgroups according to the density of network relations between nodes, and to study the symbiotic relationships and behavioral characteristics between and within subgroups. Subgroup analysis includes two aspects. One is to analyze the internal relationship structure of subgroups, and the other is to compare the frequency ratio between internal members and external members to determine whether the characteristic of core-edge exits [45]. Widely accepted approaches to analysis subgroups includes *C* − *hierarchical* analysis based on the reciprocity, *n* − *cliques* and *n* − *clan* based on the reachability, *k* − *plex* and *k* − *core* based on the degree, *component* analysis and *Lambdaset* based on the internal and external relations of subgroups [46]. Component analysis was adopted in the paper to use the drawing function of software UCINET to judge subgroups by deleting a considerable number of relational links called cutpoints [34].

3.4. Micro Dimension Analysis

Ecological niche refers to the position occupied by a population in the ecosystem and its functional relationship with related populations [47]. From the perspective of niche, some nodes can be called dominant species or keystone species depending on the amount of resources they own, which determine the scale and nature of the ecological community [48]. The dominant species control a large amount of energy flow in the ecosystem and play an important role in controlling the community environment, while the key species play an important role in maintaining the biodiversity and system robustness of the network. Many studies have shown that enterprises in business ecosystems have their own niches [49], as well as sharing economy industrial ecosystems.

Analysis on the centrality of a point in SNA can be matched with the ecological niche of the sharing economy industrial ecosystem. The superiority and privilege of a node in the network can be measured by judging the location of a node in the network structure. If a node has a greater centrality, it is called a dominant species that represents more status advantages and privileges. While if a node is at the connection point of two sub-groups, it is called key species, that is, once removed, the network is no longer connected. Centrality and Burt structural hole were used to identify the dominant species and key species, respectively in the paper.

(1) Dominant species

Centrality indexes are the most commonly used indicator to measure the location and the power of nodes including three sub-indexes. The first one is the point centrality. It measures the power of a node. The second one is the betweenness centrality that measures a node's ability to control resources. The last one is the closeness centrality. It measures a node's ability not to be controlled by the others. On this basis, this paper constructed a comprehensive index *CI* by integrating the three centrality indexes [22], such that

$$CI = w_d \frac{d(n_i)}{g-1} + w_c \left[\sum_{j=1}^{g} d\left(n_i, n_j\right) \right]^{-1} + w_b \sum_{j<k} (n_i)/g_{jk} \quad (4)$$

where w_d, w_c, w_b represent the weights of point centrality, betweenness centrality, and closeness centrality, respectively; $d\left(n_i\right)$ represents the number of network connections actually owned by a node, g represents the number of network nodes, $d\left(n_i, n_j\right)$ represents the distance between node i and node j, and g_{jk} represents the number of shortcuts between two nodes.

(2) Key species

Key species are closely related to the theories of Simmel Connection and Burt Structural Hole [50,51]. Here we used the Burt Structural Hole (abbreviated as C_{ij}, representing Network Constraint Index) to identify the key species and validated by Betweenness Centrality, which was calculated by [22]:

$$C_{ij} = \left(P_{ij} + \sum_{q} P_{iq} P_{qj} \right)^2 \quad (5)$$

where P_{ij} is the direct input; $\sum_{q} P_{iq} P_{qj}$ is the indirect input; P_{iq} is the proportion of the relationships invested in node q in the total relationships of node i. P_{qj} is the proportion of the relationships invested in node j in the total relationship of node q.

4. Results and Discussion

The actual data were extracted from two aspects. One is from the industrial research reports including Annual Development Report of China's Sharing Mobility from 2017 to 2018 and Big Data Analysis Report of China's Sharing Mobility Industry in 2017 [52,53]. The other is from the data collection on web by Baidu Searching, up to December 31st, 2018 Through the information provided by the research reports and Baidu searching, we can determine whether there is cooperation between two sharing economy enterprises or organizations. If there is cooperation, it will be recorded as 1, if there is no cooperation, it will be recorded as 0. Therefore, a 0–1 matrix will be formed, which will be used as the input data, and corresponding indexes including density, centralization of graph, sub-group and centrality will be calculated by UCINET software.

4.1. Results and Discussion of Macro Dimension Analysis

To more clearly observe the network structure of five sharing mobility sub-industries, we drew graphics by UCINET software as shown in Figures 1–5. Comparison of indicators including scale, density and centralization of network included in macro dimension among five sub-industries are shown in Table 3.

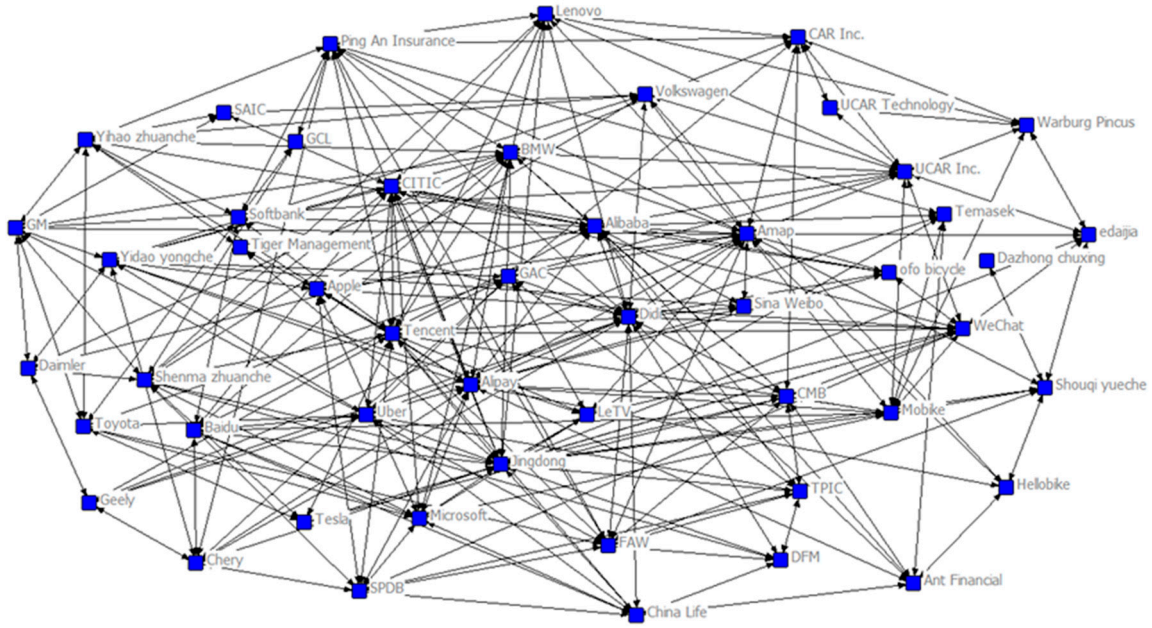


Figure 1. Network of China's sharing special car industry.

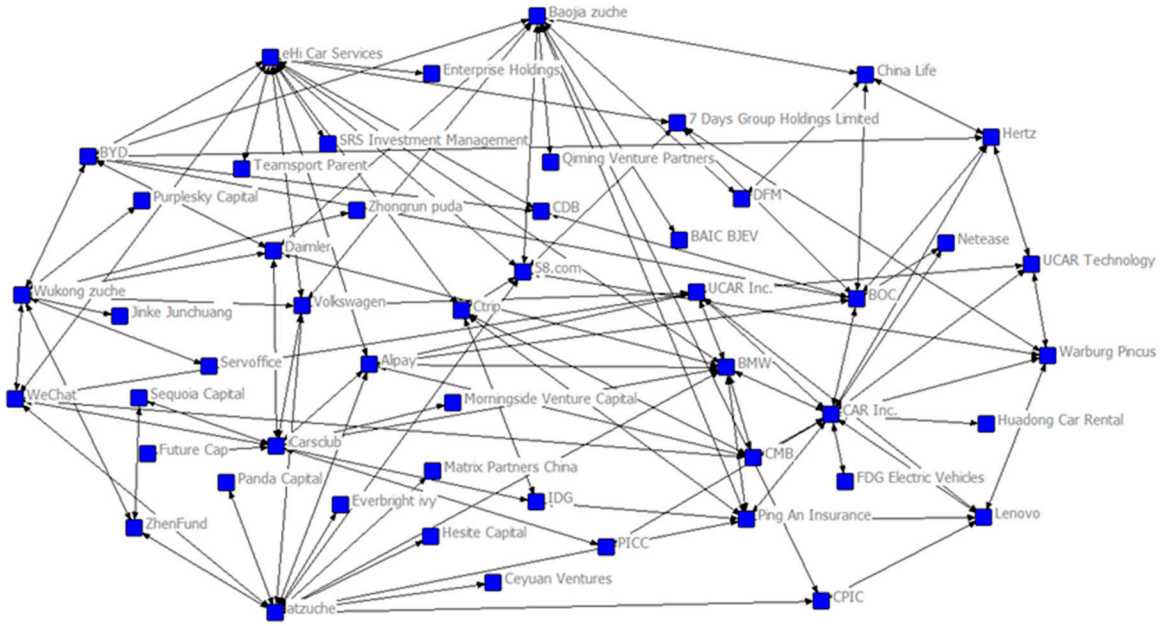


Figure 2. Network of China's sharing rental car industry.

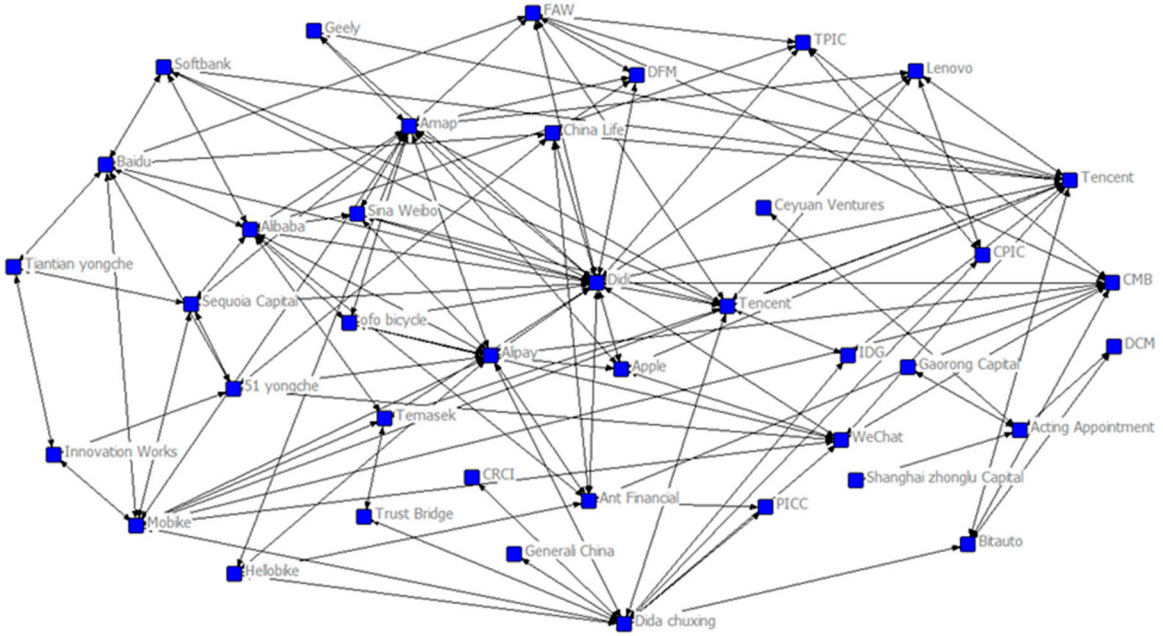


Figure 3. Network of China's sharing car pooling industry.

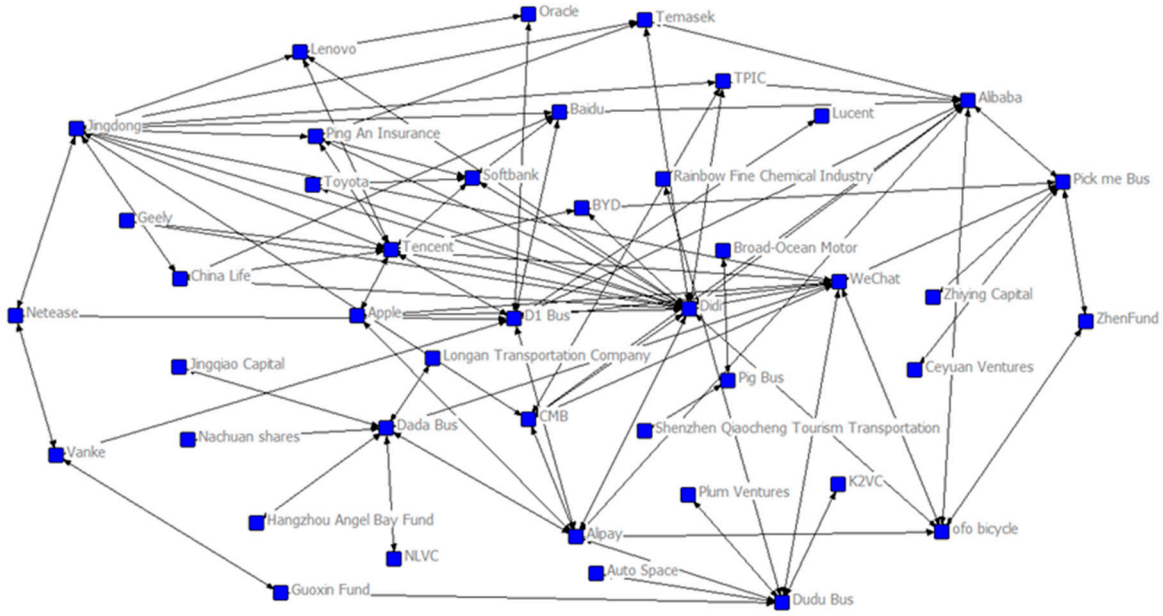


Figure 4. Network of China's sharing bus industry.

Table 3. Comparison of macro dimension analysis of China's five sharing economy sub-industries.

Industry		Sharing Special Car	Sharing Rental Car	Sharing Carpooling	Sharing Bus	Sharing Parking
Scale	Nodes	50	50	40	43	17
	Lines	494	210	236	176	34
Density		0.2016	0.0857	0.1513	0.0975	0.1250
Centralization		0.1923	0.2246	0.3020	0.1932	0.4101

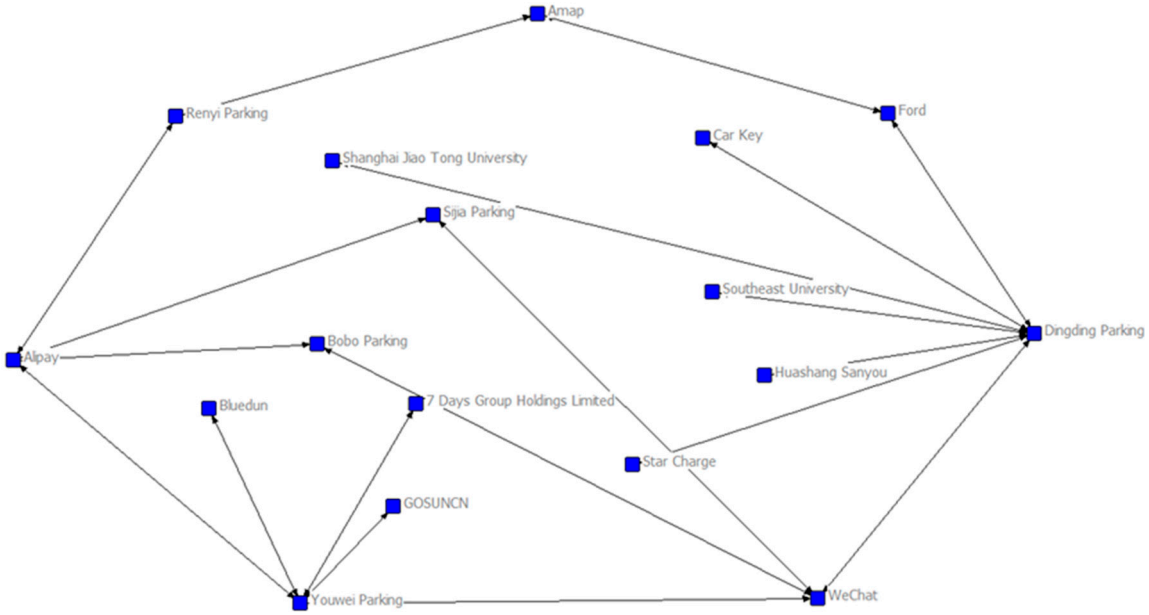


Figure 5. Network of China's sharing parking industry.

From Figures 1–5 and Table 3:

The sharing special car industry is the most mature, while the sharing parking industry is just in its infancy according to the network scale of the ecosystem. Furthermore, the five sub-industries have roughly formed four kinds of development patterns based on the combination analysis of density and centralization.

(1) High Density-Low Centralization Pattern

Sharing special car industry is a typical example of this pattern, which is characterized by more network connections and closer interactions among the nodes in the network. The pattern shows that the nodes in the network can get good resources supported from ecological environment. In addition, hub nodes are few and limited in impact, which shows all the nodes in the network are more equal, and not easily affected by hub nodes with strong autonomy.

(2) Low Density-High Centralization Pattern

Sharing parking industry is a typical example of this pattern, which is characterized by less network connections and looser interactions among the nodes in the network. The pattern shows that the nodes in the network have limited resources supported from the ecological environment. In addition, a distinct small group structure and hub-nodes with strong impact have been formed. Owing to the low density, the interactions between nodes only occur within the subgroup.

(3) High Density-High Centralization Pattern

Sharing carpooling industry is a typical example of this pattern, which is characterized by close interactions and hub nodes with strong impact. The pattern shows that there are good interactions among nodes and small group structure has been formed. In addition, nodes in the network can not only obtain resources from the industrial ecological environment, but also from the small group ecological environment. Meanwhile, the nodes in the network have strong interdependence, but with weak autonomy.

(4) Low Density-Low Centrality Pattern

Sharing bus and sharing rental car industries are the typical examples of this pattern, which are characterized by neither good interactions nor hub nodes are formed within the industrial ecosystem. The pattern shows that the nodes in these two industries are independent of each other and difficult to obtain resources supported from the ecological environment.

4.2. Results and Discussion of Meso Dimension Analysis

All of the five sharing mobility sub industries have formed distinct sub-group structures as shown in Figures 6–10.

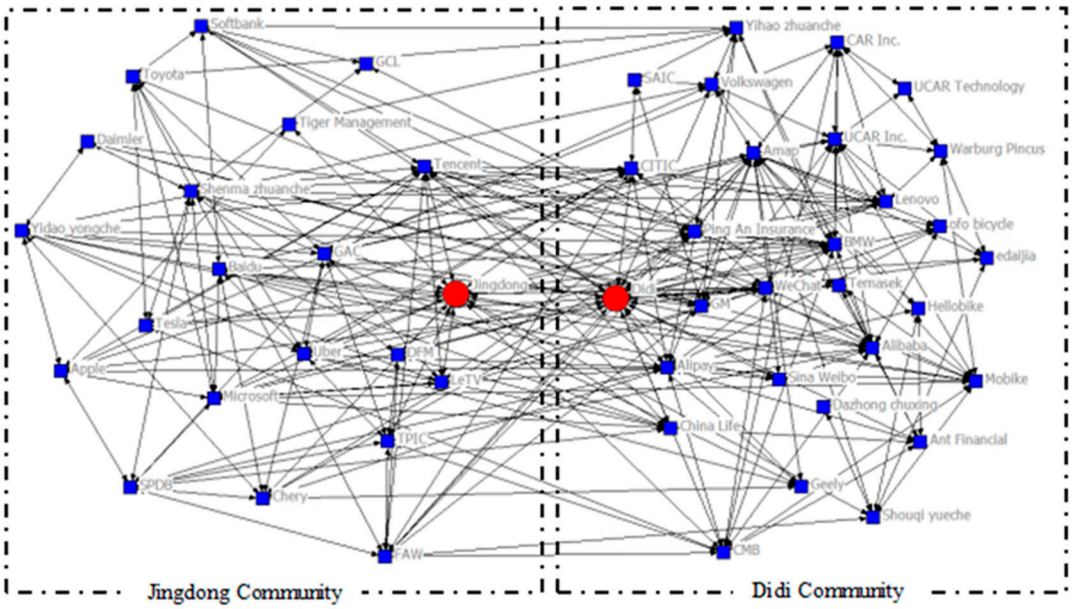


Figure 6. Sub-groups of China's sharing special car industry.

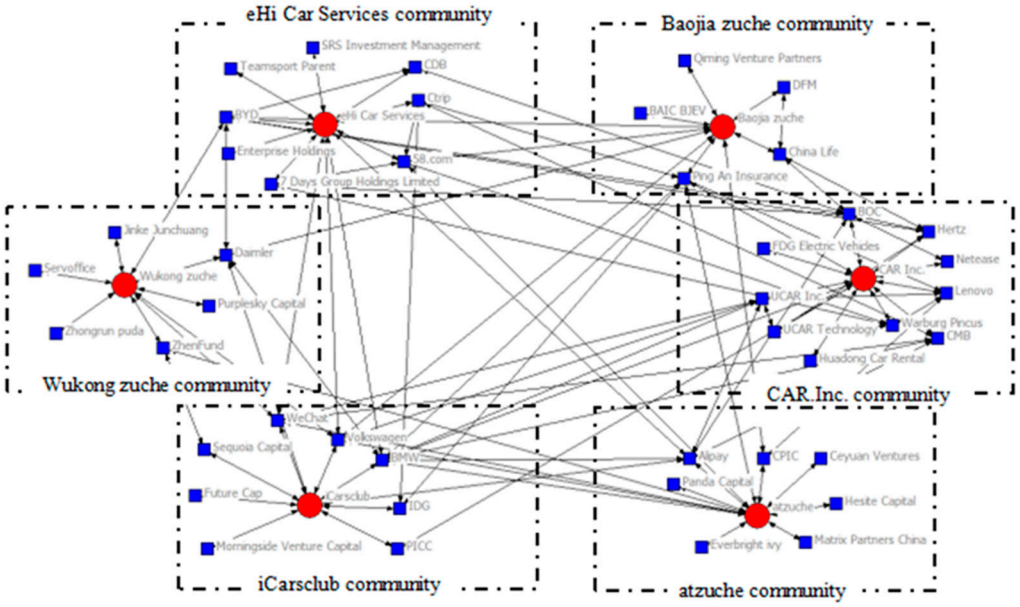


Figure 7. Sub-groups of China's sharing rental car industry.

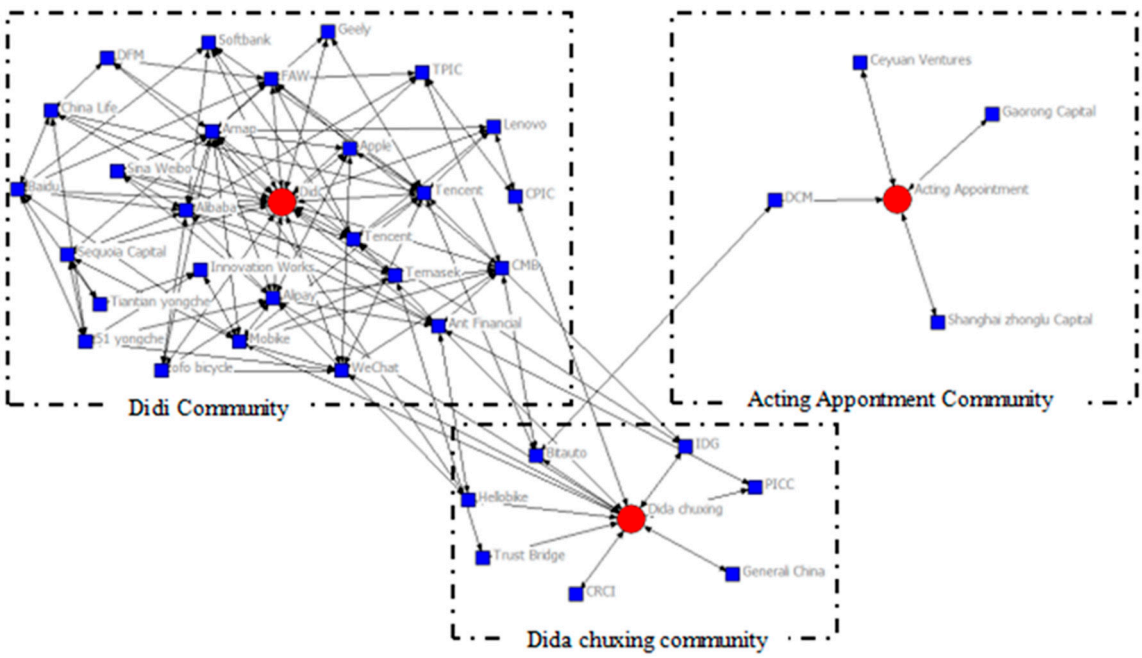


Figure 8. Sub-groups of China's sharing carpooling industry.

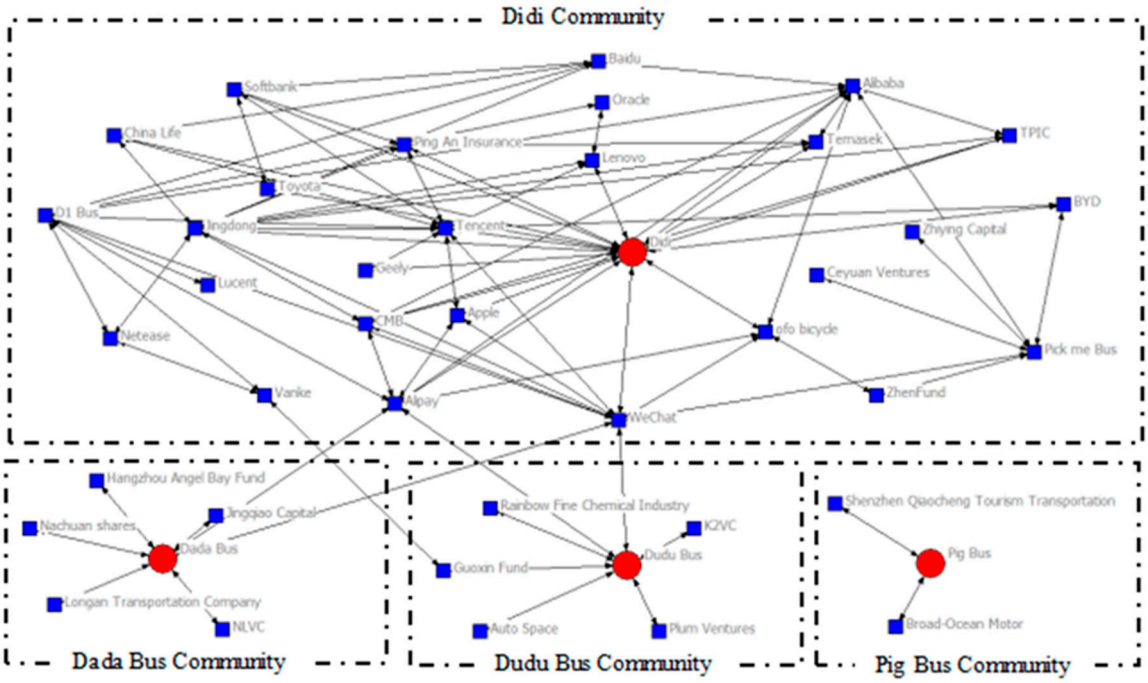


Figure 9. Sub-groups of China's sharing bus industry.

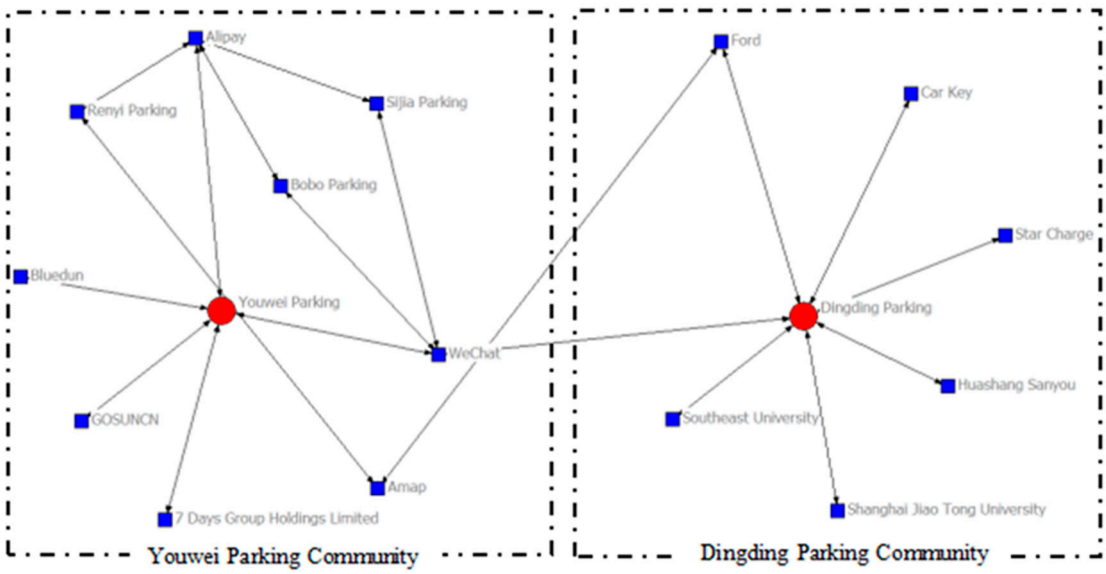


Figure 10. Sub-groups of China's sharing parking industry.

(1) Sharing special car industry

Sharing special car industry has formed two subgroups with different natures, as shown in Table 4.

Table 4. Sub-groups of China's sharing special car industry.

Sub-Group	Leader	Scale of Network	Ecosystem Diversity	Sharing Special Car Enterprises	Automobile Manufacturing Enterprises	Third-Party Platforms	Insurance and Venture Capital
Didi Community	Didi	30 nodes	4 types	8 nodes	5 nodes	9 nodes	8 nodes
Jingdong Community	Jingdong	25 nodes	4 types	3 nodes	7 nodes	6 nodes	9 nodes

Comparing the two communities, the following conclusions can be drawn:

- Didi Community was more focused on the sharing special car market, manifested by the fact that there are more powerful sharing special car enterprises in this community. On the contrary, Jingdong Community focused more on the strategic industrial distribution of new energy vehicles.
- Twelve automobile manufacturing enterprises are involved in two communities, which indicates that the sharing special car industry and automobile manufacturing industry have achieved good integration. Furthermore, the business model of sharing economy has been playing an important role in the transformation and upgrading of traditional automobile manufacturing industry.
- Nodes including Tencent, Ping An Insurance, CITIC Group, CMB and China Life are typical Simmel Connections, which showed that third-party platform, insurance and venture capital enterprises were playing media roles in maintaining the network connectivity of industrial ecosystem.

(2) Sharing rental car industry

Sharing rental car industry has formed six subgroups led by rental car enterprises of the same nature, with regular snowflake structure, as shown in Table 5.

Table 5. Sub-groups of China's sharing rental car industry.

Sub-Group	Leader	Scale of Network	Ecosystem Diversity	Sharing Rental Car Enterprises	Automobile Manufacturing Enterprises	Third-Party Platforms	Insurance and Venture Capital
CAR Inc. Community	CAR Inc.	12 nodes	4 types	4 nodes	1 node	2 nodes	5 nodes
Wukong zuche Community	Wukong zuche	12 nodes	4 types	1 node	2 nodes	1 node	5 nodes
eHi Car Services Community	eHi Car Services	9 nodes	4 types	2 nodes	1 node	3 nodes	3 nodes
iCarsclub Community	iCarsclub	9 nodes	4 types	1 node	2 nodes	1 node	5 nodes
Atzuche Community	Atzuche	9 nodes	3 types	1 node	-	2 nodes	6 nodes
Baojia zuche Community	Baojia zuche	7 nodes	4 types	1 node	2 nodes	1 node	3 nodes

Comparing the six communities, the following conclusions can be drawn.

- The network scales of the six communities were relatively balanced, and CAR Inc. Community had a typical cross-industry development trend, while the other communities were still focusing on car rental market.
- New energy vehicles and sharing rental car industries were closely integrated, as BYD, BAIC and FDG Electric Vehicles had formed close strategic cooperative relations with sharing rental car enterprises.
- WeChat, Alipay, 58.com, BYD and Ping An Insurance were Simmel Connections.

(3) Sharing carpooling industry

Sharing carpooling industry has formed three subgroups led by sharing rental car enterprises of the same nature, as shown in Table 6.

Table 6. Sub-groups of China's sharing carpooling industry.

Sub-Group	Leader	Scale of Network	Ecosystem Diversity	Sharing Carpooling Enterprises	Automobile Manufacturing Enterprises	Third-Party Platforms	Insurance and Venture Capital
Didi Community	Didi	26 nodes	4 types	5 nodes	3 nodes	8 nodes	10 nodes
Dida Chuxing Community	Dida Chuxing	12 nodes	3 types	2 nodes	-	3nodes	7 nodes
Acting Appointment Community	Acting Appointment	5 nodes	2 types	1 node	-	-	4 nodes

By comparing the three communities, the following conclusions can be drawn.

- Although Didi, Dida, and Acting Appointment are all carpooling enterprises, there are still significant differences in their markets positioning. Didi has highlighted the orientation of the ecological development strategy to develop the sharing special car and sharing rental car business simultaneously. Dida Chuxing, whose predecessor is a carpooling enterprise, is in the period of strategic adjustment and shifting to the ecological development mode. Dida Chuxing opened up the taxi and hitchhiking market at the beginning of 2018. While Acting Appointment was still deeply focusing on the sharing carpooling market.

- Compared with the sharing special car and rental car industries, the diversity of the sharing carpooling industry was the weakest, and the cooperation between automobile manufacturers and carpooling enterprises was relatively rarely. On the contrary, insurance and venture capital enterprises existed in every community and played important roles.
- As the important link between Didi and Dida Chuxing communities, Wechat and Alipay were Simmel connections, which showed that mobile payment had an important impact on the development of the sharing carpooling.

(4) Sharing bus industry

The sharing bus industry has formed four subgroups with the same nature, but different scales led by sharing bus enterprises, as shown in Table 7.

Table 7. Sub-groups of China's sharing bus industry.

Sub-Group	Leader	Scale of Network	Ecosystem Diversity	Sharing Bus Enterprises	Automobile Manufacturing Enterprises	Third-Party Platforms	Insurance and Venture Capital
Didi Community	Didi	28 nodes	4 types	3 nodes	3 nodes	12 nodes	10 nodes
Dada Bus Community	Dada Bus	8 nodes	3 types	2 nodes	-	2nodes	4 nodes
Dudu Bus Community	Dudu Bus	8 nodes	3 types	1 node	-	2nodes	5 nodes
Pig Bus Community	Pig Bus	3 nodes	2 types	2 nodes	1node	-	-

Comparing the four communities, the following conclusions can be obtained.

- The development scale of the four communities was not balanced, among which Didi Community had a typical ecological development trend, while the other enterprises were focusing on sharing bus business.
- As Longan Transportation Company, Shenzhen Qiaocheng Tourism Transportation and Broad-Ocean Motor were involved, it can be seen that traditional bus transport enterprises and new energy automobile manufacturing enterprises were also seeking transformation through sharing economy.
- WeChat and Alipay were Simmel Connections, almost existing in every community, which showed that mobile payment was also playing a very important role in the development of sharing bus industry.

(5) Sharing parking industry

Sharing parking industry has formed two subgroups with the same nature, but the scale is relatively small and the industry is still in its infancy, as shown in Table 8.

Table 8. Sub-groups of China's sharing parking industry.

Sub-Group	Leader	Scale of Network	Ecosystem Diversity	Sharing Parking Enterprises	Automobile Manufacturing Enterprises	Third-Party Platforms	Insurance and Venture Capital	Universities
Youwei Parking Community	Youwei Parking	10 nodes	2 types	4 nodes	-	6 nodes	-	-
Dingding Parking Community	Dingding Parking	8 nodes	4 types	2 nodes	3 nodes	1 node	-	2 nodes

By comparing the two communities, the following conclusions can be drawn.

- The development scale of the two communities was relatively small, but the ecosystem diversity of Dingding Parking Community was stronger than that of Youwei Parking Community, which not only includes charging piles manufacturing enterprises, but also universities.
- As the industry is still in its infancy, investment prospects are not clear, so insurance and venture capital enterprises played little supporting role in the development of the industry.
- Wechat is the typical Simmel Connection.

4.3. Results and Discussion of Micro Dimension Analysis

(1) Dominant species

Dominant species of five sharing mobility sub-industries were identified as shown in Table 9 (According to the comprehensive centrality index, only the top five nodes are selected for dominant species analysis).

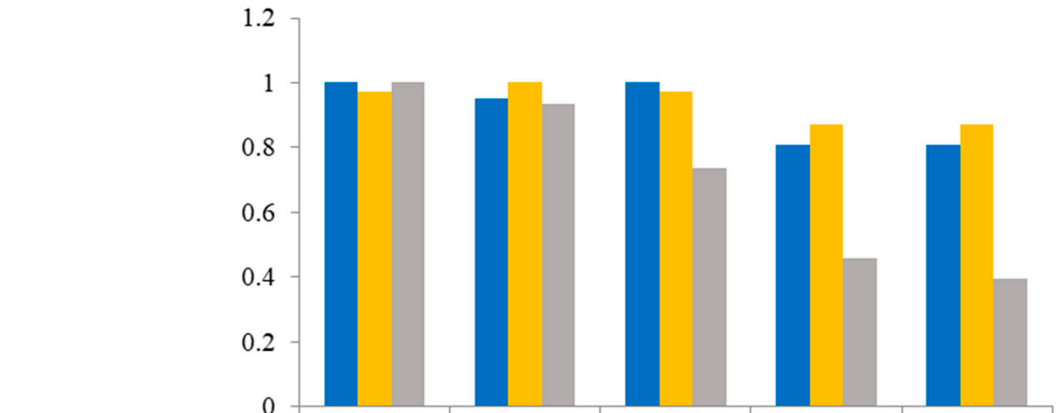
Table 9. Dominant species of five sharing economy sub-industries.

Rank	Sharing Special Car	Sharing Rental Car	Sharing Carpooling	Sharing Bus	Sharing Parking
1	Jingdong	atzuche	Didi	Didi	Dingding Parking
2	Amap	UCAR	Dida Chuxing	Wechat	Wechat
3	Didi	eHi Car Service	Tencent	Dada Bus	Youwei Parking
4	Alipay	Baojia Zuche	Bitauto	Alipay	Alipay
5	Tencent	BMW	Mobike	Dudu Bus	Ford

From Table 3:

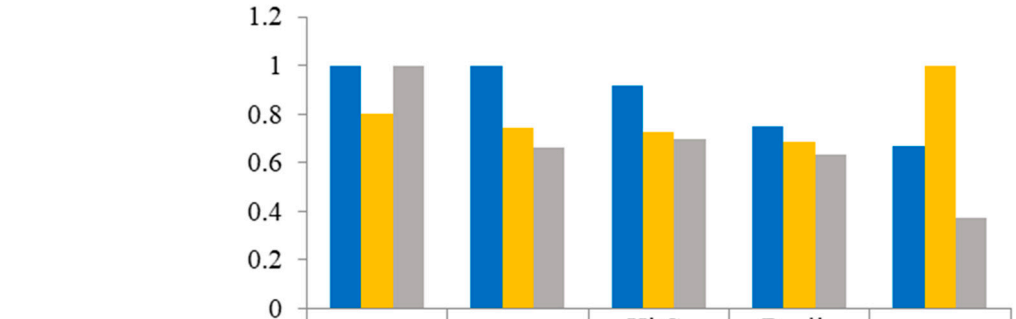
- Didi, Wechat, and Alipay are dominant species in three sub-industries simultaneously, indicating these enterprises were hub nodes in these industrial ecosystems, with strong leadership and the ability of controlling resources.
- Mobile payment has been playing a vital role in China's sharing mobility industry proved by WeChat and Alipay becoming the dominant species of four sub industries.
- Leading enterprises in China's sharing mobility industry are adopting the strategy of ecological development, as Didi has become the dominant species of three sub-industries simultaneously.

Deconstruct the *CI* to carry out a thorough comparative study of point centrality, closeness centrality and betweenness centrality among five industries, as shown in Figures 11–15.



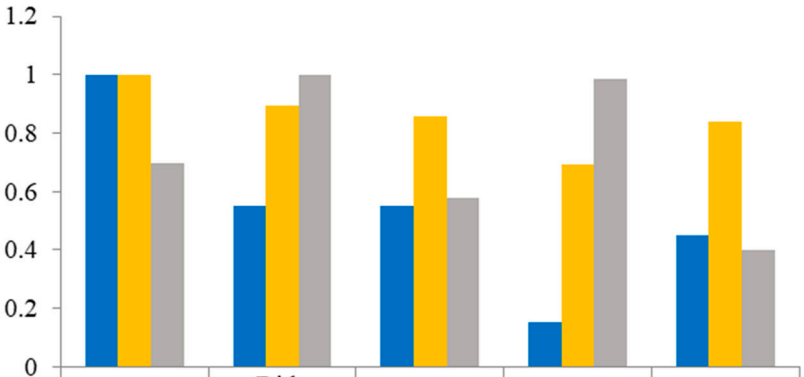
	Jingdong	Amap	Didi	Alipay	Tencent
Point Centrality	1	0.9524	1	0.8095	0.8095
Closeness Centrality	0.9728	1	0.9728	0.8706	0.8706
Betweenness Centrality	1	0.9352	0.7372	0.4571	0.3947

Figure 11. Comparison of three centrality indexes in sharing special car industry.



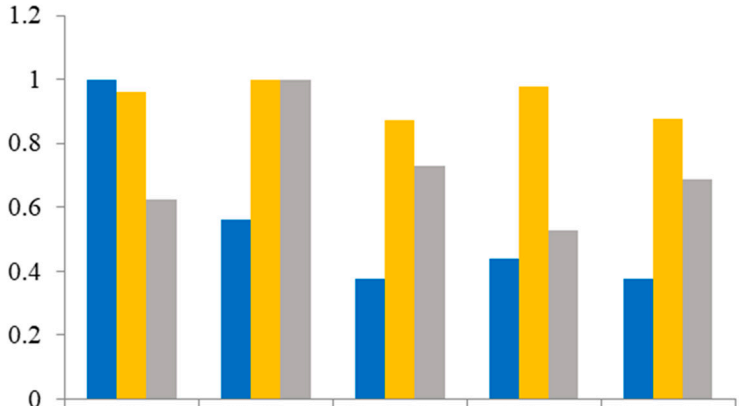
	atzuche	CAR Inc.	eHi Car Services	Baojia zuche	BMW
Point Centrality	1	1	0.9167	0.75	0.6667
Closeness Centrality	0.8007	0.7416	0.7226	0.6857	1
Betweenness Centrality	1	0.6626	0.6985	0.6340	0.3748

Figure 12. Comparison of three centrality indexes in sharing rental car industry.



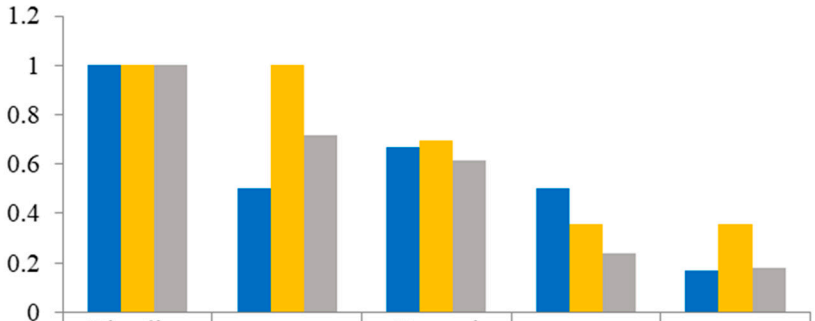
	Didi	Dida chuxing	Tencent	Bitauto	Mobike
Point Centrality	1	0.55	0.55	0.15	0.45
Closeness Centrality	1	0.8951	0.8569	0.6914	0.8385
Betweenness Centrality	0.6953	1	0.5762	0.9831	0.3988

Figure 13. Comparison of three centrality indexes in sharing carpooling industry.



	Didi	WeChat	Dada Bus	Alipay	Dudu Bus
Point Centrality	1	0.5625	0.375	0.4375	0.375
Closeness Centrality	0.9612	1	0.8728	0.9775	0.8774
Betweenness Centrality	0.6244	1	0.7271	0.5283	0.6862

Figure 14. Comparison of three centrality indexes in sharing bus industry.



	Dingding Parking	WeChat	Youwei Parking	Alipay	Ford
Point Centrality	1	0.5	0.6667	0.5	0.1667
Closeness Centrality	1	1	0.6966	0.3553	0.3553
Betweenness Centrality	1	0.7192	0.6119	0.2397	0.1781

Figure 15. Comparison of three centrality indexes in sharing parking industry.

From Figures 11–15:

- Betweeness centrality is the main factor that affects the *CI* of sharing carpooling and sharing bus industries, which indicates that the ability to control resources such as information and capital is the key factor to determine the dominant species of these two industries.
- Point centrality is the main factor that affects the *CI* of sharing special car and sharing rental car industries, which indicates that the number of network relations based on industrial cooperation is the key factor to determine the dominant species of these two industries.
- For the sharing parking industry, the differences of three centrality sub-indexes are very large, while Dingding Parking has absolute advantages in all the three sub-indexes.

(2) Key species

Based on the double identification of the Burt Structural Hole and the betweenness centrality, the key species of the five sharing mobility sub-industries are shown in Table 10.

Table 10. Key species of the five sharing sub-industries.

	Sharing Special Car	Sharing Rental Car	Sharing Carpooling	Sharing Bus	Sharing Parking
Burt Structural Hole	Amap, Jingdong	Atzuche	Dida Chuxing	Dudu Bus Dada Bus	Dingding Parking
Betweeness centrality	Jingdong, Amap	Atzuche	Dida Chuxing	Wechat	Dingding Parking

From Table 10:

- The results of Burt Structural Hole and betweenness centrality are highly consistent in the four industries except sharing bus industries.
- Dudu Bus, Dada Bus and Wechat were all key species in sharing bus industry. According to the structural hole, the index Constra of Dudu Bus and Dada Bus were both 0.143, both ranking first. The index Constra of Wechat was 0.152, ranking third. According to the betweeness centrality, the index of Wechat was 247.8, ranking first, followed by Dudu Bus and Dada Bus with the index values of 180.1 and 170, respectively. To sum up, all the three enterprises are key species.
- Some nodes are not only dominant species but also key species, including Jingdong, Amap, Atzuche, Dida chuxing, Dudu Bus, Dada Bus and Youwei Parking, which indicates these nodes not only have strong leadership and the ability of controlling key resources, but also maintain the network connectivity and integrity of sharing mobility industrial ecosystem.

5. Conclusions and Discussion

After the rapid growth of China's sharing economy industry, bottlenecks including the simplicity of the profit model, the lack of supervision system and great dependence of venture capitals have been exposed [9,10]. However, it is generally believed that the sharing economy industry will still play an important role in realizing the optimal allocation of resources and fostering new economic impetus in the future. Accordingly, in view of the fact that the theoretical research in this field lags behind the development of reality, we established a research framework for the integration of industrial ecosystem and SNA from the macro, meso, and micro dimensions. Then the framework is applied to China's sharing mobility industry including sharing special car, sharing rental car, sharing carpooling, sharing bus and sharing parking industries. The analysis results indicate that the ecosystem of sharing mobility industry has been basically established, and the ecological diversity is good, including sharing mobility, third-party platform, automobile manufacturing, insurance and venture capital enterprises and universities. In addition, some sharing enterprises, typically represented by Didi, are upgrading their strategies to ecological development through cross-border integration. Mobile payment plays a vital role in the developing of China's sharing mobility industry.

5.1. Discussion and Significance

As a new business model, the sharing economy has exposed many problems in development and entered a critical adjustment period. However, in sharp contrast, the research of the sharing economy is just in its infancy, and most of them take case analysis and specific industries as research objects [23–25], which cannot provide clear mechanism design and path guidance for the sustainable development of the whole industry. Therefore, we integrated the two theories of ecology and SNA, and constructed a new industrial analysis framework, and then applied it to the study on sharing economy, which makes contributions in the following aspects. First, through literature review, this paper may be an earlier exploratory study on the development of the sharing economy industry at home and abroad by building a fusion research framework, which can provide a more systematic research idea for the sustainable development of industrial ecosystem. Secondly, we put forward the concept of industrial ecosystem of sharing economy, which not only guarantees the inheritance of the common characteristics of the ecosystem, but also highlights the personalized characteristics of the development of sharing economy. Finally, this analysis framework is applied to the comparative analysis of five sub industries in China's sharing mobility industry, so as to put forward the optimization of the industrial ecosystem and the countermeasures for the sustainable development of the industry.

Based on the findings above, in view of the individual problems existing in the sharing mobility industry and the common problems existing in the sustainable development of the sharing economy industry, we put forward the following suggestions [18,54].

(1) Attach equal importance to development and supervision firstly and introduce the targeted and encouraging policies to protect and encourage the industrial innovation. More importantly, as the development stages, scales and modes of sharing mobility sub-industries are different. For example, the sharing special car industry has 50 nodes and 494 network connections, while the sharing parking industry only has 17 nodes and 34 network connections. Therefore, the policies should avoid the mistake that one size fits all and strengthen the classification guidance so as to promote targeted and effective industrial policies.

(2) Authorities should focus on building a good industrial ecological environment from the aspects of strengthening the infrastructure construction, improving data statistics and highlighting development priorities. As the comprehensive centralities of Wechat in sharing bus industry and Alipay in sharing special car industry are 0.85 and 0.71 respectively, both two enterprises are hub nodes in the industrial ecosystem. Therefore, the development of China's sharing economy industry should not rely on sharing enterprises solely, mobile payment enterprises, automobile manufacturing enterprises, especially new energy automobile manufacturing enterprises are

all involved and playing vital roles. Furthermore, under the background of the slowdown of venture investment, the authorities should guide sharing enterprises to establish the strategic development concept of co-construction and co-governance.

(3) To explore a clear and efficient profit model and cultivate entrepreneurs' innovative spirit is the key. Driven by venture capital, China's sharing economy has developed from scratch, as 17 insurance and venture capital enterprises in sharing special car industry, 24 enterprises in sharing rental car industry,21 enterprises in sharing carpooling industry and 16 enterprises in sharing special car industry, which occupy a large share in the ecosystem network. However, insurance and venture capital enterprises are neither dominant nor key species in sharing mobility industry, which shows that decentralized investment and the lack of rationality are also important problems for restricting the development of China's sharing economy. Therefore, how to scientifically guide capital to the rational investment and build an incentive innovation atmosphere to cultivate entrepreneurs' innovative spirit is the booster to the sustainable development of China's sharing economy in the period of structural adjustment.

5.2. Limitations and Future Research

This paper is not without its limitations. For simplicity, the demands for users were ignored, which also affects the sustainable development of China's sharing economy, especially based on the age structure. Besides, the framework has only been applied in sharing mobility industry and it needs to be verified in other sharing economy sub-industries.

Valuable topics remain for future research. Firstly, a predictive demand model for sharing economy users will be studied and to analyze the mechanism of the influence from the demand side on the supply side. Secondly, apply the framework to other sharing industries for verification and improvement. Thirdly, the role and mechanism of sharing economy industry in the transformation and upgrading of traditional manufacturing industry will be studied systematically. Finally, the industrial ecosystem of sharing economy is also an innovation system, so open innovation dynamics is the future research focus. At present, many scholars have made a lot of fruitful achievements in this field [55–60], which provide a solid foundation for the follow-up study of this paper.

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