Article

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

Danning Zhang 1, Yanshu Shi 1 and Weiwei Li 2,*

1 School of Economics, Liaoning University, Shenyang 110136, Liaoning, China; katherinezdn@126.com (D.Z.);
xiaoshitouok2019@126.com (Y.S.)
2 School of Business Administration, Northeastern University, Shenyang 110167, China
* Correspondence: ooweiweili@gmail.com; Tel.: +86-24-8624-1307

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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 the slowdown, 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.

| 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

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

(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]:

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

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]:

$$C = \frac{\sum_{i=1}^{n} (C_{\text{max}} - C_i)}{\max \left( \sum_{i=1}^{n} (C_{\text{max}} - C_i) \right)}$$  \hspace{1cm} (3)

where $C_{\text{max}}$ 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

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

where $w_d, w_c, w_b$ represent the weights of point centrality, betweenness centrality, and closeness centrality, respectively; $d(n_i)$ represents the number of network connections actually owned by a node, $g$ represents the number of network nodes, $d(n_i, n_j)$ 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 $[22]$: $C_{ij} = \left( P_{ij} + \sum_{q} P_{iq} P_{qj} \right)^2$  \hspace{1cm} (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 Lines     | 50                  | 50                 | 40                 | 43          | 17              |
| Density         | 0.2016              | 0.0857             | 0.1513             | 0.0975      | 0.1250          |
| Centralization  | 0.1923              | 0.2246             | 0.3020             | 0.1932      | 0.4101          |
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.](image1)

![Figure 7. Sub-groups of China’s sharing rental car industry.](image2)
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.

| 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        | 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                        | -                                    | 3 nodes                | 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.

| 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                | -                                    | 2 nodes               | 4 nodes                       |
| Dudu Bus Community | Dudu Bus   | 8 nodes          | 3 types             | 1 node                 | -                                    | 2 nodes               | 5 nodes                       |
| Pig Bus Community  | Pig Bus    | 3 nodes          | 2 types             | 2 nodes                | 1 node                               | -                     | -                             |

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.

| Sub-Group       | Leader       | Scale of Network | Ecosystem Diversity | Sharing Parking Enterprises | Automobile Manufacturing Enterprises | Third-Party Platforms | Insurance and Venture Capital | Universities |
|-----------------|--------------|------------------|---------------------|-----------------------------|--------------------------------------|-----------------------|-------------------------------|-------------|
| Youwei Parking  | Youwei Parking| 10 nodes         | 2 types             | 4 nodes                     | -                                    | 6 nodes               | -                             | -           |
| Dingding Parking| 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).

| 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.

![Figure 11. Comparison of three centrality indexes in sharing special car industry.](image-url)
Figure 12. Comparison of three centrality indexes in sharing rental car industry.

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

Figure 14. Comparison of three centrality indexes in sharing bus industry.
Figure 15. Comparison of three centrality indexes in sharing parking industry.

From Figures 11–15:

- Betweenness 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       |
| Betweenness centrality | Jingdong, Amap   | Atzuche           | Dida Chuxing| Dada Bus       |
|                      |                    |                   |             | 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 betweenness 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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References

1. Chase, R. Sharing Economy: Restructure New Business Model; Zhejiang People’s Publishing House: Hangzhou, China, 2015.
2. Alraeeini, M.; Zhong, Q.; Antarciuc, E. Analysing drivers and barriers of accommodation sharing in Dubai using the grey-DEMATEL approach. Sustainability 2019, 11, 5645. [CrossRef]
3. Zhao, D.; Xue, Y.; Cao, C.; Han, H. Channel selection and pricing decisions considering three charging modes of production capacity sharing platform: A sustainable operations perspective. Sustainability 2019, 11, 5913. [CrossRef]
4. Laurenti, R.; Singh, J.; Cotrim, J.M.; Toni, M.; Sinha, R. Characterizing the sharing economy state of the research: A systematic map. Sustainability 2019, 11, 5729. [CrossRef]
5. The Global Sharing Economy Will Grow 20 Times in Ten Years. Available online: https://tech.qq.com/a/20150415/023543.htm (accessed on 11 December 2019).
6. Annual Report on the Development of China’s Sharing Economy. Available online: http://www.sic.gov.cn/News/79/8860.htm (accessed on 11 December 2019).
7. Didi. Website. Available online: https://www.didiglobal.com/ (accessed on 11 December 2019).
8. CAR. Inc. Website. Available online: http://www.zuche.com/ (accessed on 11 December 2019).
9. Analysis on the Market and Development Trend of China’s Sharing Economy in 2018. Available online: http://www.askci.com/news/chanye/20180308/10072611926.shtml (accessed on 11 December 2019).
10. State Information Center. Annual Report on the Development of China’s Sharing Economy; State Information Center: Beijing, China, 2019.
11. Support and Guide the Healthy Development of Sharing Economy. Available online: http://www.sohu.com/a/298715392_274290 (accessed on 11 December 2019).
12. Brown, L.R. Building a Sustainable Society: Lester R. Brown a Worldwatch Institute Book; W.W. Norton: New York, NJ, USA, 1981.
13. Hamari, J. The Sharing economy: Why people participate in collaborative consumption. J. Assoc. Inf. Sci. Technol. 2016, 67, 2047–2059. [CrossRef]
14. Rong, C.H. Analysis on the relationship between material, credit and time-space economy of internet sharing mobility. Manag. Wold 2018, 4, 101–112.
15. Guo, Q.L.; Karimi, H.A. A methodology with a distributed algorithm for large-scale trajectory distribution prediction. Int. J. Geogr. Inf. Sci. 2018, 33, 833–854. [CrossRef]
16. Li, P.; Zhang, J.S. Is China’s energy supply sustainable? New research model based on the exponential smoothing and GM(1,1) methods. Energy 2019, 12, 236. [CrossRef]
17. Terroso-Saenz, F.; Muñoz, A.; Cecilia, J.M. QUADRIVEN: A framework for qualitative taxi demand prediction based on time-variant online social network data analysis. Sensors 2019, 19, 4882. [CrossRef]
18. Xu, Y.; Li, D. Incorporating graph attention and recurrent architectures for city-wide taxi demand prediction. ISPRS Int. J. Geo Inf. 2019, 8, 414. [CrossRef]
19. Gohari, S.; Medalen, T.; Aranya, R. Exploring the impact of complex multi-Level governance structures on the societal contribution of universities to knowledge-based urban development. Soc. Sci. 2019, 8, 279. [CrossRef]
20. Rappa, M. The utility business model and the future of computing service. IBM Bus. J. 2004, 43, 359–376. [CrossRef]
21. Li, H.J.; Tian, Y.X.; Li, W.J. Mobile internet thinking and traditional business reengineering. China Ind. Econ. 2014, 10, 135–146.
22. Luo, M.; Li, L.Y. Innovation of business model in internet era: From value creation perspective. China Ind. Econ. 2015, 1, 95–107.
23. West, J.; Wood, D. Evolving an open ecosystem: The rise and fall of the Symbian platform. Adv. Strateg. Manag. 2014, 30, 27–67.
24. Mikel, G.; Juan, C.M.; Jon, M.Z.E. Economic dynamics: The evolution of big internet business ecosystems, evidence for patents. Technovation 2014, 34, 177–187.
25. Stöckols, D. Social Ecology in the Digital Age: Solving Complex Problems in a Globalized World; Elsevier Academic Press: London, UK, 2018.
26. Carroll, G.R. Ecological Models of Organization; Ballinger Publishing: Cambridge, UK, 1988.
27. Shi, J.-G.; Si, H.; Wu, G.; Su, Y.; Lan, J. Critical factors to achieve dockless bike-sharing sustainability in China: A stakeholder-oriented network perspective. Sustainability 2018, 10, 2090. [CrossRef]
28. Choi, J.W.; Kim, H.Y. Preparation of study on social network analysis in the sharing economy of tourism field. Indian J. Public Health Res. Des. 2018, 9, 981–985. [CrossRef]
29. Lee, J.H.; Choi, J.W.; Kim, K.Y. Segmenting Korean millennial consumers of sharing economy services on social networking: A psychographic-based approach. J. Internet Comput. Serv. 2015, 16, 109–121.
30. Martin, P.F.; Florian, U.; Gohar, F.K.; Marko, S.; Andy, N.; Tobias, S. From goods to services consumption: A social network analysis on sharing economy and servitization research. J. Serv. Manag. Res. 2018, 2, 3–16.
31. Gao, S.Y.; Zhang, Y.; Liu, H.B. Social network analysis to the value creation of sharing economy business model. J. Tech. Econ. Manag. 2019, 7, 79–84.
32. Chen, Y.; Liu, F.Z.; Wu, J. Studying users’ interaction behaviors of sharing economic platform with 2-mode complex network analysis. Data Anal. Knowl. Discov. 2017, 1, 72–82.
33. Luo, J.D. Social Network Analysis; Social Sciences Academic Press: Beijing, China, 2015.
34. China Business Herald News Weekly. *China’s Automobile Sharing Economy Creates 5.5 Million Jobs in Three Years*; China Business Herald News Weekly, 2016. Available online: www.bbtnews.com.cn/2016/1021/165045.shtml (accessed on 11 December 2019).

35. Berg, R. Analysis and Forecast Report of China’s Sharing Mobility Market in 2018. 2018. Available online: www.199it.com/archives/529731.html (accessed on 11 December 2019).

36. Johnson, S.E. *Ecosystem Ecology*; Science Press: Beijing, China, 2018.

37. Michael, B.; Colin, R.; John, L. *Ecology: From Individual to Ecosystem*, 4th ed.; Higher Education Press: Beijing, China, 2016.

38. Zhao, D.Z.; Li, G. Development from network organization to business ecosystems. *Ind. Eng. J.* 2005, 1, 24–28.

39. Shi, L.; Chen, W.Q.A. Industrial ecology in China: Retrospect and prospect. *Acta Ecol. Sin.* 2016, 36, 7158–7167.

40. Liu, L.D. *Internet Ecosystem*; China Zhigong Publishing House: Beijing, China, 2018.

41. Moore, J.F. Predators and prey: A new ecology of competition. *Harv. Bus. Rev.* 1993, 71, 75–83.

42. Li, Q.; Jie, X.W. The value evaluation study of keystone corporation business ecosystem based on analysis of comparison between Huawei and ZTE. *Sci. Tech. Prog. Policy* 2012, 29, 110–114.

43. Paul, H. *The Ecology of Commerce*; Shanghai Translation Publishing: Shanghai, China, 2001.

44. Zhang, Z.; Wang, F.Y.; Zhang, Y.M. Cloud innovation and construction of internet finance ecosystem: Case study of Ali Fin-Cloud. *Res. Econ. Manag.* 2017, 38, 53–60.

45. Stanley, W.; Katherine, F. *Social Network Analysis: Methods and Handouts*; China Renmin University Press: Beijing, China, 2012.

46. Liu, J. *Introduction to Social Network Analysis*; Social Sciences Academic Press: Beijing, China, 2004.

47. Grinnell, J. The niche relationship of the California thrasher. *AUK* 1917, 34, 427–433. [CrossRef]

48. Gao, Y.B.; Wu, J.G. *Lectures in Modern Ecology: VIII: Advances in Community, Ecosystem and Landscape Ecology*; Higher Education Press: Beijing, China, 2017.

49. Lansiti, M.; Levien, R. *Keystones and Dominator: Framing the Operational Dynamics of Business Ecosystems*; Estados Unidos: Boston, MA, USA, 2002.

50. Burt, R.S. *Structural Holes: The Social Structure of Competition*; Harvard University Press: Cambridge, UK, 1992.

51. Simmel, G. *The Sociology of George Simmel*; The Free Press: New York, NY, USA, 1964.

52. Iimedia Research. *Annual Development Report of China’s Sharing Mobility (2017–2018)*; Iimedia Research: Guangzhou, China, 2018.

53. CBNData. *Big Data Analysis Report of China’s Sharing Mobility Industry in 2017*; CBNData: Shanghai, China, 2017.

54. Núñez, C.P.; Molina, M.V.; Corpas, I.F.A.; Cortés, G.F.J. Family businesses transitioning to a circular economy model: The case of Mercadona. *Sustainability* 2018, 10, 538. [CrossRef]

55. Yun, J.J.; Won, D.; Park, K. Entrepreneurial cyclical dynamics of open innovation. *J. Evol. Econ.* 2018, 28, 1151–1174. [CrossRef]

56. Yun, J.J.; Won, D.; Park, K. Dynamics from open innovation to evolutionary change. *J. Open Innov. Technol. Market Complex.* 2016, 2, 7. [CrossRef]

57. Yun, J.J.; Park, K.; Hahn, S.D.; Kim, D. Basic income with high open innovation dynamics: The way to the entrepreneurial state. *J. Open Innov. Technol. Market Complex.* 2019, 5, 41. [CrossRef]

58. Yun, J.J.; Zheng, L. micro- and macro-dynamics of open innovation with a quadruple-helix model. *Sustainability* 2019, 11, 3301. [CrossRef]

59. Yun, J.J.; Cooke, P.; Kodama, F.; Phillips, F.; Gupta, A.K.; Gamboa, F.J.C.; Lace, N. An open letter to Mr. Secretary general of the united nations to propose setting up global standards for conquering growth limits of capitalism. *J. Open Innov. Technol. Market Complex.* 2016, 2, 22.

60. Yun, J.J. How do we conquer the growth limits of capitalism? Schumpeterian dynamics of open Innovation. *J. Open Innov. Technol. Market Complex.* 2015, 1, 17. [CrossRef]