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Synergy Degree Evaluation Based on Synergetics for Sustainable Logistics Enterprises

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Received: 3 June 2018; Accepted: 25 June 2018; Published: 27 June 2018

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Abstract: Today, logistics activities have become a major source of pollution that affects the environment and green logistics is becoming a hot topic. A logistics company's operating strategy determines the direction of logistics activities and impact degree of logistics activities on the environment. And in logistics enterprises, there is a direct relationship between efficiency and collaboration as collaboration can reduce logistics costs and the negative impact of the bullwhip effect and increase the service level. Synergy degree evaluation, therefore, is crucial to analyze collaboration, identify vulnerabilities, promote development and is also a key step in building a green logistics system. This paper employs Synergetics to comprehensively evaluate the synergy degree in sustainable logistics enterprises. First, Synergetics is introduced to evaluate the synergy degree of sustainable logistics enterprises and the basic Synergetics principles are presented. Second, based on the Law of the Factors of Production, the synergy elements and logistics enterprise content is divided into three main factors: subject elements, object elements and facility and equipment elements. Then, a measurement model and framework for the synergy degree of logistics enterprises is built. Finally, a case study is given to verify the effectiveness of the proposed model and framework. It was found that the higher the logistics enterprise synergy degree, the higher the efficiency.

Keywords: logistics enterprise; sustainable; Synergetics; synergy degree; synergy elements

1. Introduction

With the development of sustainable development theory and ecological economics theory, people began to realize the impact of logistics activities on the environment. According to ECOFYS (2010) [1], around 15% of 2010 global greenhouse gas emissions resulted from transportation, which is one of the most important parts of logistics [2]. And logistics becomes a main pollution sources and resource user [3] and green logistics gains great attention among both academics and practitioners [4] to make urban delivery more efficient and sustainable from both the operations and environmental standpoints [5]. A logistics company's operating strategy determines the direction of logistics activities and the impact of logistics activities on the environment.

These days, for an enterprise to remain competitive and successfully achieve their strategies basing on a green logistics system, they need to collaborate to achieve qualitative and quantitative performance advances [6], share risks under environmental uncertainties [7], access complementary resources [8], reduce transaction costs [9], enhance productivity [10] and economic performance [3], achieve a stronger competitive position and gain sustained market advantage [11,12].

Collaboration has been studied extensively since the 1980s, with a significant amount of research having focused on supply chain collaboration. Cao and Zhang [12] examined the nature of supply chain collaboration and found that it could improve collaborative advantage and had a bottom-line influence on firm performance, which enabled the supply chain partners to achieve synergies and superior performance. Many organizations, such as Dell and Wal-Mart, have achieved mutual benefits from supply chain collaboration [13,14]. Multi-enterprise collaboration has also been examined. For example, Kefah [15] developed an integrated Game Theory (GT) approach for the coordination of multi-enterprise Supply Chains (SCs) in a competitive uncertain environment. Improving the collaboration between large and small-medium enterprises in the automobile production sector has been shown to be important for the profitability and sustainability of the collaborating companies [16]. However, there has not been a great deal of research into inter-departmental collaboration within an enterprise even though this could have a major influence on cost effectiveness and shipping time efficiency [17–19].

In addition to this, synergy and complexity have a great impact on each other. The greater the degree of synergy among members, the more obvious synergy effects and the more complex coordination behaviors are produced [20]. An integrated supply model was proposed to formulate the problem of consignment-store-based complex supply chain optimization [21]. Tamás Bányai et al. demonstrated an enhanced harmony search algorithm to find the optimum make-or-buy solution of a given maintenance related supply chain complexity problem [22] and Danping Lin et al. have taken complexity as the technical factor when they adopt Internet of Things (IOT) in the agricultural supply chain [23].

Methods to achieve operational and supply chain integration have been suggested by drawing upon advanced enterprise information technology [24] and employing goal congruence [8], decision synchronization [14], resource sharing [13], incentive alignment and collaborative communication [25–27]. Z.X. Guo et al. [28] have proposed a radio frequency identification RFID-based intelligent decision support system architecture, which can easily be integrated with production decision-making as well as production and logistics operations in the supply chain. Wulan and Petrovic [29] developed a fuzzy logic methodology with sustainable interoperability for collaborative enterprise risk identification and evaluation that could assist either the collaboration facilitator or the enterprise users. Agent technology has also been applied to manufacturing enterprise integration and vertical enterprise collaboration [30]. The integrated scheduling problem of production and transportation operations has been emphasized to meet due dates and to reduce costs for manufacturing enterprises [31]. Ruohomaa and Kutvonen [32] proposed a trust management system in which autonomous enterprises separately used automation to make private trust decisions about their membership in each collaborative venture. Roberto Tadei et al. [33] have introduced an ICT solution and integrated the e-grocery Supply Chain with a reference business model to achieve the efficiency required in the urban logistics.

Research has tended to ignore enterprise collaborative analyses when investigating the consequences of enterprise collaboration. Synergy degree evaluations, for example, can easily identify an enterprise's collaborative state and the relationships between internal departments. When weaknesses are defined, it is easier to identify solutions to improve departmental cooperative efficiency, which in turn would improve customer demand responsiveness and service quality [34] and realize the purification of logistics environment and make full use of logistics resources. Thus, synergy degree evaluation is a key step and is conducive to for the construction of a green logistics system. With this aim in mind, this paper applies a synergy degree evaluation to sustainable logistics enterprises to enhance supply chain collaboration. In logistics enterprises, there is a direct relationship between efficiency and collaboration as collaboration can reduce logistics costs and the negative impact of the bullwhip effect and increase service levels, market share and capacity [35]. Collaborative freight transportation is an emerging solution to make urban good movement more efficient, competitive and sustainable of the last mile [36]. Logistics collaboration is also required within firms from the procurement of raw materials to the delivery of products and services to end-users and to the return of slow sales and disposables [37]. Tyan et al. [38] claimed that a new strategy between logistics vendors and customers could be developed by applying Synergetics to transportation management. Further, developing synergy between logistics enterprises could assist them to remain competitive and sustainable across the supply chain.

However, to determine the success of the logistics activities, it is necessary to have a method that can measure the degree of synergistic collaboration [39] at the different resource and information sharing levels as well as between two or many entities. Zhenggang et al. [40] provided a performance measurement system for evaluating the low-carbon logistics' sustainable and proposed strategies from the 6 perspectives to develop the logistics enterprise in China. Measuring the degree of collaboration can assist members identify their shortcomings [41] and benchmark their current practices against the best-in-class performers [39]. Therefore, here we propose that to accurately measure performance. There needs to be objective measures, subjective measures, as well as a consideration of the facility and equipment elements. The objective measures allow for an analysis of the degree of compact from upstream to downstream, the departmental abilities and the state stability for each service in terms of personnel development and equipment.

This research introduces Synergetics to comprehensively evaluate the synergistic degree in sustainable logistics enterprises based on the Law of Factors of Production. The main contribution of this paper is to propose a measurement model and framework to assess the synergy degree in logistics enterprises, which is an integrated strategy that realizes economic development, resource conservation and environmental protection. Thirty order parameters from seven aspects of the logistics enterprises are selected to establish the evaluation index system.

The remainder of this paper is organized as follows. The basic principles behind Synergetics, literature review of Synergetics and a Synergetics applicability analysis for the evaluation of synergy degree in sustainable logistics enterprises are presented in Section 2. The synergy elements and content analysis for the logistics enterprises based on the Law of Factors of Production are given in Section 3. Section 4 presents the measurement model and framework and a case study is conducted to evaluate the effectiveness of proposed model in Section 5. Section 6 gives the conclusions and future research directions.

2. Synergetics

2.1. Basic Principles of Synergetics

Studies on Synergetics have found that system stability is affected by a fast variable and a slow variable. When a system interacts with the outside world, the system becomes instable, at which time, the fast variable moves rapidly from an unstable state to a stable state to encourage the system to evolve to a new steady state. On the contrary, the slow variable often moves from a steady state to a non-steady-state, which then encourages the system to evolve to a new stable state. Therefore, the fast variable is the stable system mode and the slow variable is the unstable system mode, both of which control the evolutionary system direction. Self-organization means that the fast and slow variables are related and restricted during the migration process and are a macroscopic reflection of the cooperative movement. The slow variable, which is called the order parameter in the system, is the core concept in Synergetics that determines the evolutionary direction of the system, leads to the formation of new structures and reflects the order degree of the new structures. Logistics systems are complex because of the many factors. Although the order parameter plays a lead role in the evolutionary direction of the system, the mutation and dissimilation of the other variables can weaken the function of the original order parameter. In this system, each element has certain growth and certain dynamics. Because of the interference of the many external factors, the original order parameter may be gradually replaced, causing the fast variable to evolve into an order parameter under an external function. There are usually many order parameters in the system that have both a competitive and cooperative relationship. The synergistic effects between the order parameters is the key to the system moving from disorder to order. The collaborative Synergetics system mode is shown in Figure 1.

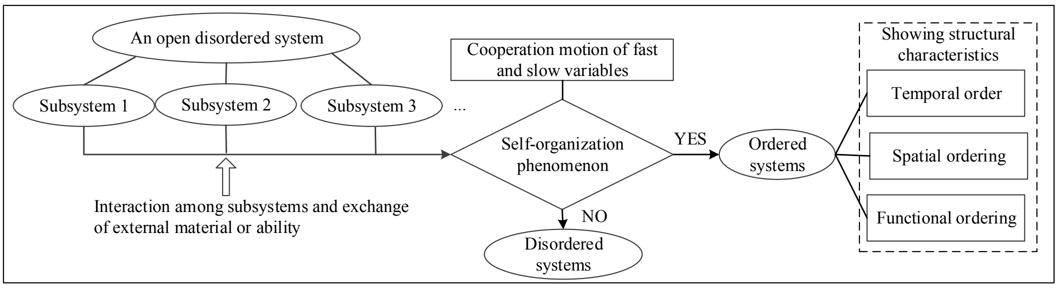

Figure 1. Collaborative system process under Synergetics.

2.2. Literature Review of Synergetics

Based on research into laser theory, Synergetics was first proposed by Haken [42] in the early 1970s. The aim of Synergetics is to explore the evolutionary law of all factors from disorder to order and the collaborative interactions with external materials, information and abilities. The identified factors are part of a complex system that has several sub-systems [43]. Synergetics, therefore, is a method for studying a stable system from one steady-state to another [44]. Research on Synergetics has focused on how a system spontaneously evolves into an ordered structure in time, space and function through its own internal synergy. Synergetics has been applied to many fields such as educational science, social governance, business management and transportation and logistics [45]. In recent years, Synergetics has been included as part of civil engineering, geological exploration, computer science and sports disciplines [46] and has been heavily applied to business management. Research into and the application of Synergetics for logistics has focused on qualitative research with a major focus on logistics management and the supply chain such as the commodity supply process, collaborative operations of the supply chain, the coordinated development of regional logistics and so on. Gajda [47] combined synergetic theory with strategic alliances to achieve a beneficial maximum for all business entities and consumers within the alliance. Tyan et al. [38] claimed that a new strategy could be developed for logistics vendors and customers if Synergetics were applied to transportation management as installation and equipment utilization would increase substantially and transportation costs and delivery times would decrease through effective collaborative management between the customers and the logistics vendors. Cremer [48] successfully applied Synergetics to road infrastructure and a traffic information control system, further innovating the Synergetics applications. Sacaluga and Prado [49] examined the Spanish food supply chain and found that collaborative logistics could assist companies to respond quickly to customer needs. Sandberg [50] analyzed logistics collaborations in supply chain management in Sweden and found that there was a direct relationship between logistics collaboration and collaborative performance and that effective supply chain management was able to increase the logistics synergy degree. It was also found that the inconsistencies in the common goals of the supplier and consumer were common reasons why logistics collaboration was difficult to effectively execute.

In summary, while the theoretical foundations of Synergetics are relatively complete, there has been little related research on the synergetic measurement of logistics enterprises.

2.3. Applicability Analysis of Synergetics for Logistics Enterprises

Synergetics is an open systems theory that involves the study of new structural order through the interactions of various components. Stank and Keller [37] defined collaboration as a process of decision-making, communication and distribution between two or more subjects in a system to achieve multiple expectations with limited resources. Logistics systems are open, complex and stochastic systems composed of many subsystems with multiple subjects and multiple levels that have random fluctuations and a dynamic development process in which each subsystem evolves from disorder to order. Therefore, starting from the factors of production, this paper analyzes the synergetic mechanism in sustainable logistics enterprises and takes specific agricultural logistics enterprises as examples to analyze the synergy degree.

In general, logistics enterprises mutually cooperate to realize a main function and also cooperate with external social economic bodies to complete a specific economic behavior. At the same time, each department in the logistics company has its own functions and powers and is an independent competitive and cooperative unit that develops its own complex dynamic network operating system based on some rules. Once the system develops, it has its own rules and laws. Therefore, a self-organizing operation develops and a corresponding order forms in accordance with certain laws and rules that can be increased or decreased. Logistics enterprises not only provide customer service to their suppliers, retailers and cooperative logistics providers but also cooperate with each department within the enterprise. Therefore, logistics enterprises have open, interactive features that are able to redistribute their resources to adjust and change their internal and external environments. Logistics enterprises have inherent collaboration because of the many complex systems between the departments and service objects, all of which have advanced, mutually operating rules. When logistics enterprises attain a certain level, they develop systems functions to meet environmental changes. As logistics enterprises coordinate their development, there is a spontaneous synergistic effect from the cooperative efforts of the many internal and external environmental factors. Therefore, synergy results in self-organizing logistic enterprises, with the cooperation between all subsystems being the direct result of the ordered structure [51]. Accordingly, logistics enterprises are within Synergetics scope; through the interactions with the outside world, a cooperative movement develops that can result in significantly better economic performance.

3. Synergy Elements and Synergy Content Analysis

Based on the theory of the three productivity factors, this paper divides the sustainable logistics enterprise elements into three standards: laborers, labor objects and labor tools. Logistics enterprises establish cooperative relationships with upstream and downstream enterprises and then integrate the material resources of these enterprises to provide their logistics services. The laborers standard refers to the logistics enterprises and their related cooperative enterprises, the labor objects standard refers to the products and services offered by the logistics enterprises and the labor tools standard refers to the facilities and equipment that need to be integrated by the enterprises. In this paper, the laborers are the subject elements of the logistics enterprises' synergistic elements, the labor objects are the object elements and the labor tools are the facility and equipment elements. In actual operations, logistics enterprises have seamless connections with the logistics links through mutual cooperation and information and resource sharing. Synergy involves four main aspects: (1) synergy between the subject, object and facility and equipment elements; (2) synergy within the subject elements; (3) synergy within the object elements; and (4) synergy within the facility and equipment elements.

3.1. Synergy between the Subject, Object and Facility and Equipment Elements

The main operating body of the logistics enterprise involves the enterprise itself as well as the upstream and downstream cooperative enterprises. On the one hand, the spatial distribution determines the route, direction and process of the logistics service for the transportation products; however, at the same time, while the cooperative mode between the subjects significantly affects the operational efficiency, a reasonably operating system enables the facilities to efficiently operate and quickly respond. On the other hand, the facilities and equipment should match with the main body and object of the enterprise to ensure an optimal allocation of resources; therefore, the synergy between the subject, object and facility and equipment elements assist the logistics enterprises to achieve high profit, high efficiency and high quality.

3.2. Synergy within the Subject Elements

Synergy within the subject elements refers to an effective collaboration between the supplier, manufacturer, wholesalers and retailers. Coordination and cooperation between the subjects from the source of production to the retailers and wholesalers can ensure that the product is always in the controllable environment necessary to maintain quality. To realize synergy within the subject elements, logistics companies need to develop a series of plans that cover such elements as the collaboration, the framework agreements, the logistics processes and the technological applications. Synergy within the subject elements not only helps to reduce logistics costs but also promotes the rapid and effective transfer of products from the upstream enterprises to the downstream enterprises.

3.3. Synergy within the Object Elements

Object elements are the logistics enterprise products that provide the logistics services. Therefore, the purpose of the logistics enterprise object element collaboration is to meet the transportation conditions, storage conditions (such as temperature and pressure, etc.) and timeliness conditions (such as shelf life restrictions). Therefore, to maintain product value, the shorter the logistics time, the higher the logistics efficiency and the lower the corresponding logistics costs.

3.4. Synergy within the Facility and Equipment Elements

Logistics enterprise operations require multiple resources such as human resources, transportation resources, storage resources and logistics information resources; therefore, effective resource collaboration helps to improve the operational level of the enterprises. The logistics enterprise completes the product's operational logistics through the utilization of transportation equipment, storage equipment and other resources to effectively satisfy the service demands of the upstream and downstream enterprises. Therefore, transportation and storage equipment synergy is not only beneficial to effective equipment utilization but can also reduce ineffective equipment inputs to transportation and storage. Facilities and equipment collaboration is also closely related to personnel operations and the application of information technology; that is, inventory management, transportation planning and automatic inventory replenishment in logistics enterprises cannot be realized without the support of information technology. Therefore, facilities and equipment synergy can improve the overall synergy and operational efficiency. The specific synergy elements and content are shown in Figures 2 and 3.

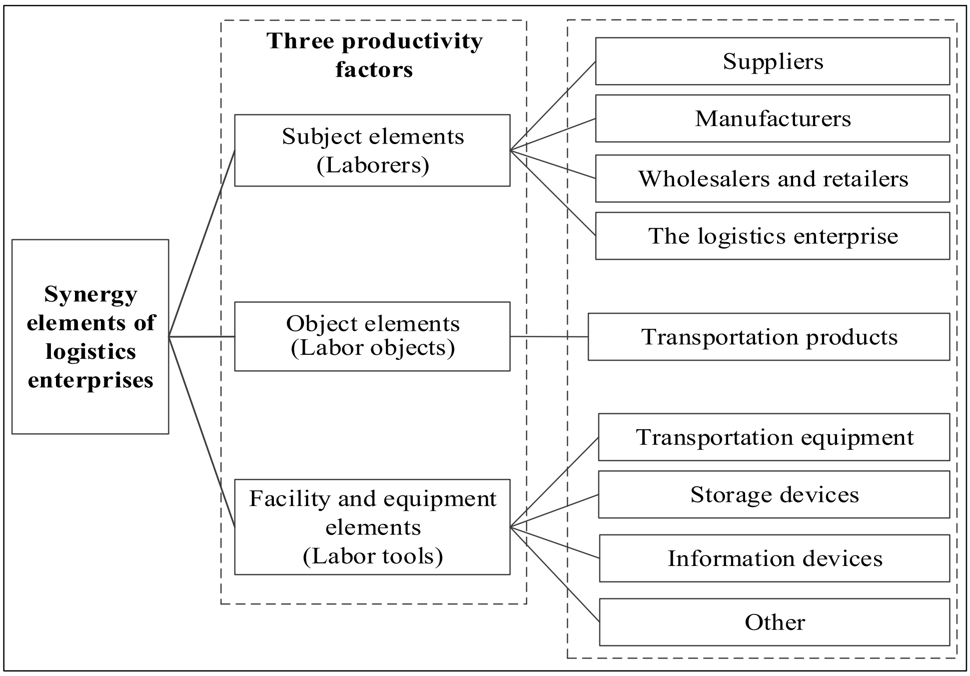

Figure 2. Logistics enterprise synergy elements.

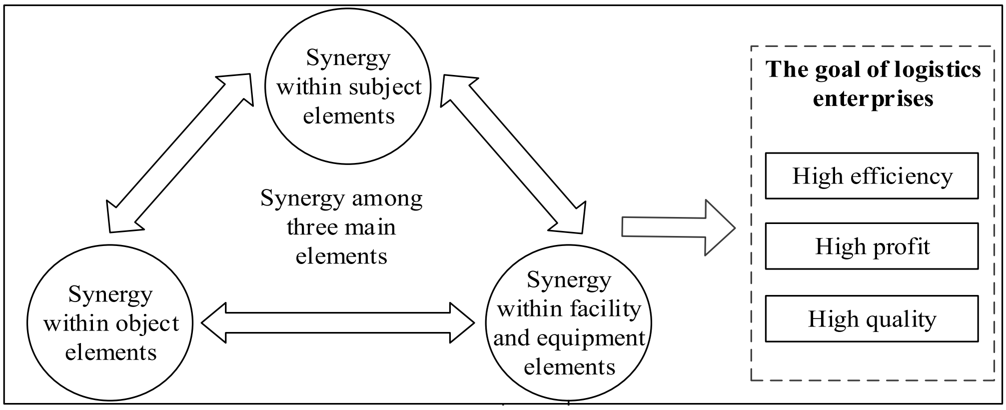

Figure 3. Logistics enterprise synergy content.

4. Measurement Model for Synergy Degree

It is assumed that the logistics enterprises' subject elements, object elements and facility and equipment elements are respectively $S = (S_1, S_2, S_3)$ and the jet order parameter for the collaborative elements $S_i(i = 1, 2, 3)$ is S_{ij}. From the positive and negative order parameters and the synergy degree $U_{T_n}(S_{ij})$ of the order parameter S_{ij} for the synergy elements, S_i at a certain point in time $T_n(n = 1, 2, \cdots, n)$ can be calculated as follows [52];

$$U_{T_n}(S_{ij}) = \begin{cases} \frac{S_{ij}^{T_n} - S_{ij\min}^{T_n}}{S_{ij\max}^{T_n} - S_{ij\min}^{T_n}}, \text{(When } S_{ij} \text{ is a positive order parameter)} \\ \frac{S_{ij\max}^{T_n} - S_{ij}^{T_n}}{S_{ij\max}^{T_n} - S_{ij\min}^{T_n}}, \text{(When } S_{ij} \text{ is a negative order parameter)} \end{cases} \tag{1}$$

where $S_{ij}^{T_n}$ is the value of the order parameter S_{ij} at time T_n. $S_{ij\max}^{T_n}$ and $S_{ij\min}^{T_n}$ are the maximum and minimum values for the order parameter S_{ij}. The greater the value of $U_{T_n}(S_{ij})$, the higher the synergy degree between the order parameter S_{ij} and the synergy element S_i. A linear weighted sum method is used to calculate the synergy degree $U_{T_n}(S_i)$ of the logistics enterprises at time T_n [52]:

$$U_{T_n}(S_i) = \sum_{j=1}^{k} \sigma_{ij} U_{T_n}(S_{ij}), \sigma_j > 0, \sum_{j=1}^{k} \sigma_j = 1 \tag{2}$$

where σ_{ij} is to the jth weight of synergy element S_i. The greater the value of $U_{T_n}(S_i)$, the higher the synergy degree S_i at time T_n. The initial time T_1 is given and relative to T_1, the total synergy degree of the logistics enterprises at time T_n can be calculated using the following equations [53]:

$$U_{T_n} = \sqrt[3]{\theta \sum_{i=1}^{3} \left| U_{T_n}(S_i) - U_{T_1}(S_i) \right|} \tag{3}$$

$$\theta = \frac{(U_{T_n}(S_i) - U_{T_1}(S_i))_{\min}}{\left| U_{T_n}(S_i) - U_{T_1}(S_i) \right|_{\min}} \tag{4}$$

where U_{T_n} is the synergy degree at time T_n that is relative to the initial time T_1. When U_{T_n} is positive, this indicates that the enterprise is has a cooperative development status through the interaction of the various synergy elements. The greater the value of U_{T_n}, the better the overall coordination of the logistics enterprises and the stronger the overall competitiveness of the enterprises. Conversely, the smaller the value of U_{T_n}, the lower the synergy degree. When U_{T_n} is negative, this indicates that at least one of the three synergy elements is developing in the direction of disorder.

Compared with the initial time T_1, the enterprise is in a non-cooperative development stage. As θ is the synergy decision function, only when is satisfied, is the synergy degree positive.

To measure the synergy degree, first, to avoid a comparison of the data at different levels and dimensions, a standard deviation formula is adopted to deal with the order parameters of each synergy element, the formula for which is as follows:

$$\hat{S}_{ij}^{T_n} = \frac{S_{ij}^{T_n} - \bar{S}_{ij}}{R_i} \tag{5}$$

where $\bar{S}_{ij}$ is the average of S_{ij} at all the points in the measurement time and R_i is the sample standard deviation for synergy element S_i.

Second, the order parameter weights are calculated using the correlation coefficient method. The weights reflect the influence of the order parameters, with the greater the absolute value of the correlation coefficient between the order parameters, the higher the degree of interaction and the greater the weight. Finally, the synergy degree is measured by taking the standardized data and weights into the evaluation model. The measurement framework for the synergy degree for the logistics enterprises is shown in the following Figure 4.

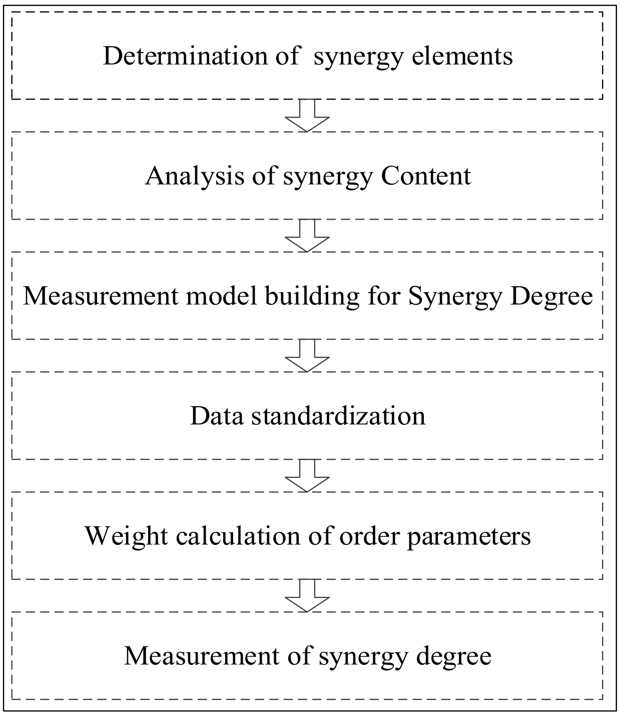

Figure 4. Measurement framework for synergy degree of the logistics enterprises.

5. Case Study

To test the scientific nature and maneuverability of the synergy degree measurement model, this paper used data from 18 consecutive periods of the ZA agricultural logistics enterprise. ZA agricultural logistics enterprise represents a class of stable, small and medium-sized companies seeking to improve and progress in the transportation, storage and distribution of agricultural products; therefore, they have established long-term cooperative transportation and distribution relationships with suppliers such as agricultural product breeding bases and cooperatives as well as retailers such as supermarkets. At present, the enterprise plans to take cold chain logistics as their core business to increase input. When the enterprise receives demand information from suppliers or retailers, after sorting, it takes the goods from the suppliers and distributes them to the agricultural product retailers.

5.1. Evaluation Index System for the Synergy Degree

The construction of an evaluation index system for sustainable logistics enterprises is the basis for the examination of the synergy degree between the enterprises. In this paper, the operation characteristics of the logistics enterprise were first combined, after which the data for the selection principles related to the operations were collected for 7 aspects; logistics staff, product attributes, logistics equipment, customer journeys, logistics safety, logistics efficiency and logistics effectiveness; which in total had 30 order parameters. The data collection indicators for the logistics enterprises are shown in Table 1.

Table 1. Data collection indicators for the logistics enterprises.

Indexes	Sub Indexes	Definition or Calculation
Logistics staff	Amount of logistics staff	The number of logistics personnel (employees engaging in logistics activities)
	Logistics staff rate	Percentage of logistics personnel
	Logistics staff training rate	Percentage of trained logistics staff every month
	Logistics staff turnover	Percentage of resigned logistics staff
Product attributes	Amount of logistics products	Number of logistics products
	Total value of logistics products	The total price of logistics products
Logistics facilities	Amount of refrigerated trucks	Number of refrigerated vehicles
	Unit vehicle mileage	Average mileage of each vehicle
	Full load rate of refrigerated trucks	Ratio of vehicle full load times to total delivery times
	Utilization rate of cold storage volume	Percentage of the average use space of cold storage
	Investment in information systems	Amount of investment used by enterprises for information systems
	Information exchange	Percentage of information exchange within the enterprise
	Recycling rate of packaging materials	Percentage of recycled packaging materials
Logistics safety	Cold storage temperature retention rate	Percentage of accumulated time of rated temperature
	Cold insulation transportation performance	Percentage of the time of temperature within the permitted range in transportation
Customer journey	Number of suppliers	Number of suppliers
	Number of retailers	Number of retailers
	Supplier satisfaction rate	Satisfaction degree of supplier
	Retailer satisfaction rate	Satisfaction degree of retailer
	Supplier order accuracy	Percentage of the exact orders of the supplier
	Retailer order accuracy	Percentage of the exact orders of the retailer
	Supplier order fulfillment rate	Percentage of the actual delivery orders of the supplier
	Retailer order fulfillment rate	Percentage of the actual delivery orders of the retailer
	Return rate of products	Percentage of returned goods
Logistics efficiency	On-time order response rate	Percentage of order response in time
	On-time delivery rate	Percentage of delivery in time
	Ordering cycle of retailer	Average ordering time of a retailer
	Order response time	Time between placing an order and accept the order
Logistics effectiveness	Income	Revenues created by logistics activities
	Total cost	All expense that logistics activities include

From the division of the synergy elements shown above, the evaluation index system for the logistics enterprises was established, as shown in Table 2.

Table 2. Evaluation index system for logistics enterprises.

Synergy Elements	Order Parameters	Sequence	Property
Subject elements	Number of suppliers	1	+
	Number of retailers	2	+
	Supplier satisfaction rate	3	+
	Retailer satisfaction rate	4	+
	Supply order accuracy	5	+
	Retailer order accuracy	6	+
	Supplier order fulfillment rate	7	+
	Retailer order fulfillment rate	8	+
	Return rate of products	9	-
	Ordering cycle of retailer	10	-
	Order response time	11	-
	Income	12	+
	Total cost	13	-
Object elements	Amount of Logistics products	14	+
	Total value of logistics products	15	+
	Cold storage temperature retention rate	16	+
	Cold insulation transportation performance	17	+
	On-time order response rate	18	+
	On-time delivery rate	19	+
Facility and equipment elements	Amount of logistics staff	20	+
	Logistics staff rate	21	+
	Logistics staff training rate	22	+
	Logistics staff turnover	23	-
	Amount of refrigerated trucks	24	+
	Unit vehicle mileage	25	+
	Full load rate of refrigerated trucks	26	+
	Cold storage volume utilization rate	27	+
	Investment in information systems	28	+
	Information exchange	29	+
	Recycling rate of packaging materials	30	+

Note: + represents positive order parameter; - represents negative order parameter.

5.2. Measurement of the Synergy Degree

Operational data for 36 consecutive months of the ZA agricultural logistics enterprise were selected as samples and every 2 months as a period of time. The actual data for all synergy elements are shown in Appendixs A and B. Using the standard deviation formula to standardize the data in Appendixs A and B, the weights for each order parameter for the synergy elements were calculated using the correlation coefficient method, the results for which are shown in Table 3.

Table 3. Weights for the order parameters of the synergy elements.

Order Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
weight	0.10	0.09	0.05	0.06	0.07	0.07	0.03	0.05	0.09	0.10
Order Parameter	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
weight	0.10	0.09	0.10	0.17	0.17	0.21	0.06	0.20	0.19	0.10
Order Parameter	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
weight	0.03	0.04	0.01	0.11	0.08	0.12	0.13	0.12	0.13	0.13

The standardized data and weights were then brought into the measurement model. The total synergy degree and the synergy degree for the subject elements, object elements and facility and equipment elements for the ZA agricultural logistics enterprise relative to the initial moment were calculated, the calculation results for which are shown in Table 4 and Figure 5.

Table 4. Degree of synergy for the ZA agricultural logistics enterprise.

Time	Synergy Degree for the Subject Elements	Synergy Degree for the Object Elements	Synergy Degree for the Facility and Equipment Elements	Total Synergy Degree
T_1	−0.191	0.030	0.116	-
T_2	−0.257	0.085	0.219	−0.878
T_3	−0.081	0.228	0.227	0.748
T_4	−0.126	0.298	0.373	−0.839
T_5	−0.117	0.313	0.419	−0.871
T_6	−0.022	0.471	0.444	0.979
T_7	0.126	0.539	0.565	1.084
T_8	0.297	0.639	0.599	1.165
T_9	0.178	0.607	0.599	1.126
T_{10}	0.265	0.497	0.712	1.150
T_{11}	0.314	0.499	0.726	1.166
T_{12}	0.258	0.620	0.713	1.178
T_{13}	0.431	0.634	0.766	1.233
T_{14}	0.433	0.720	0.788	1.257
T_{15}	0.523	0.799	0.775	1.289
T_{16}	0.461	0.771	0.915	1.299
T_{17}	0.458	0.751	0.893	1.290
T_{18}	0.422	0.849	0.894	1.303

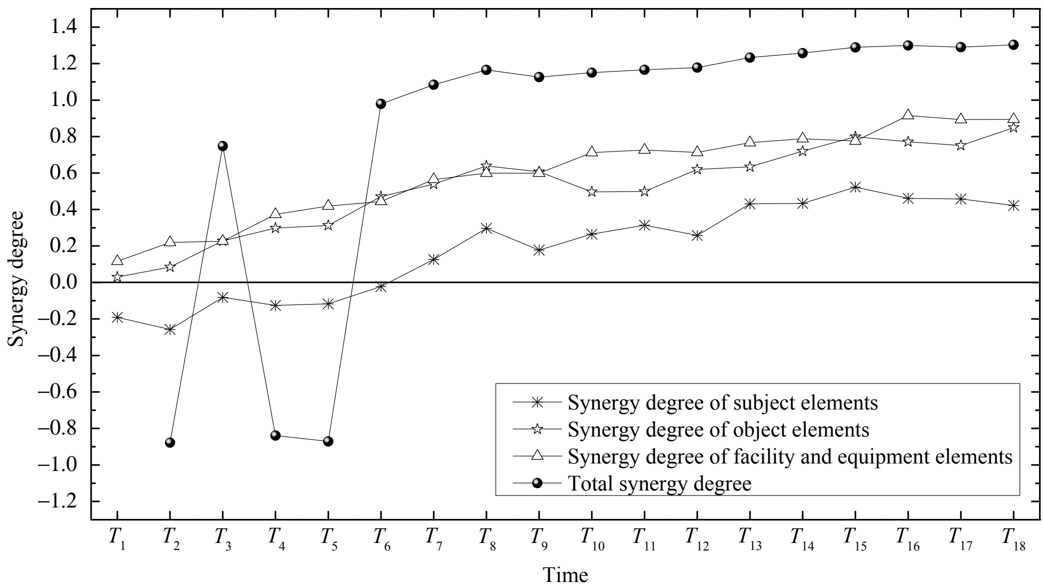

Figure 5. Synergy degree Comparisons.

5.3. *Synergy Analysis*

(1) Synergy analysis of the subject elements

It can be seen from Figure 5 that the synergy degree of the subject elements was negative in and before the T_6 time period and positive after the T_7 time period. During the data acquisition period, the synergy degree of the subject elements all fluctuated and in time segments T_2, T_9 and T_{12} the synergy degree decreased significantly. Generally speaking, there were slow growth and obvious fluctuation characteristics. Compared to the synergy degree of the object elements and the facility and equipment elements, the synergy degree of the subject elements was always lower. Therefore, it can be seen that in these 18 observation periods, the cooperation between the ZA agricultural logistics enterprise and its upstream and downstream enterprises was not ideal, resulting in lower profitability and lower customer service.

(2) Synergy analysis of the object elements

As shown in Figure 6, the synergy degree of the object elements was positive in all 18 time-segments and also showed an upward shock. In the observation period, the synergy degree of the object elements could be divided into two stages: with an increase in the logistics quantities of the agricultural products in the T_1~T_8 stages, the synergy degree of the object elements maintained steady growth; as the logistics quantities of the agricultural products dropped and then significantly fluctuated in the T_9~T_{18} stages, the synergy degree of the object elements fluctuated. As the ZA agricultural logistics enterprise also had an unstable state because of transport aging, transportation service levels and cold storage protection, it was unable to provide customers with sustainable and stable agricultural logistics services.

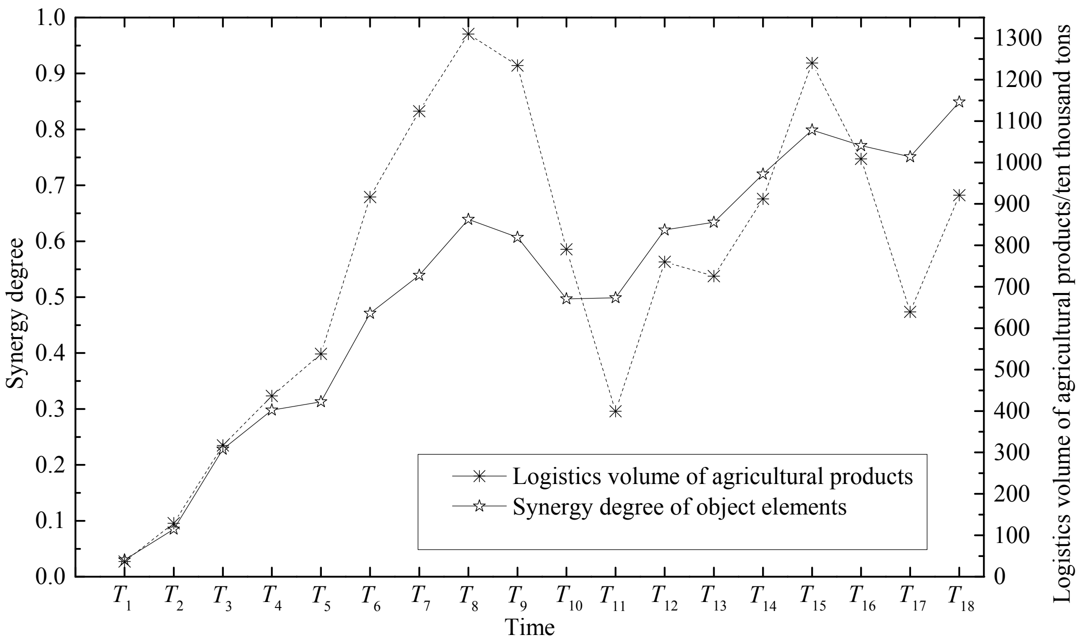

Figure 6. The relationship between the synergy degree of the object elements and the agricultural product logistics volume.

(3) Synergy analysis of the facility and equipment elements

As shown in Figure 5, the synergy degree of the facility and equipment elements was positive in all 18 time-segments and also had a similar synergy degree upward shock as the object elements; however, there were no significant fluctuations. The agricultural logistics enterprise has improved steadily in its quality of logistics professionals, its utilization of the logistics facilities and enterprise informatization and has developed a relatively stable management system for the facilities and equipment.

(4) Analysis of the total synergy degree

As shown in Figure 5, the total synergy degree of the enterprises could be divided into two stages. In the T_1~T_6 stages, the total synergy of the enterprise was both positive and negative with significant fluctuations, with the lowest being -0.878, which indicated that there was disordered development and instability; therefore, it was unable to achieve the enterprise operating objectives. In the T_6~T_{18} stages, the total synergy degree of the enterprise remained stable, indicating a slow, steady and orderly development, with the profits, efficiency and enterprise quality all concurrently improving. From the development trends of the total synergy degree, we can draw the following conclusions. In the observation period, the ZA agricultural logistics enterprise developed gradually from an initial instability to a steady state; however, the overall enterprise development was very slow and the enterprise growth rate small.

6. Conclusions

The utilization of the Synergetics concept for the analysis of logistics systems and the green logistics system construction is very valuable. Measuring the synergy degree of logistics enterprise can assist enterprises in improving profits, operational efficiency and service quality, which enables enterprises to achieve sustainable development and integrate the economy, society and environment. And the greater the degree of synergy, the closer the relationship between inter-departmental within the enterprise is. The high degree of synergy is conducive to effective management for directors, such as, effective access to information, integrated utilization of resources, the decision accuracy improvement and rapidness of the measures' enforcement. Therefore, the synergy within enterprise should be highly valued by managers. As sustainable logistics enterprises are open and interactive, Synergetics can be applied to examine the upstream and downstream synergies. In this paper, the collaborative partners were defined using production factor theory, a logical framework and evaluation index system established to assess the synergy degree of sustainable logistics enterprises and a synergy degree measurement model constructed. Finally, the ZA agricultural logistics enterprise was given as a case example for the evaluation of its coordination degree. It was found that the overall development of the ZA agricultural logistics enterprise was very slow, the cooperation with the upstream and downstream enterprises not ideal and the profitability and customer service low. As a higher synergy degree indicates higher efficiency, enterprises should make full use of new technologies and new models to strengthen their operations and management and enterprise decision-makers should pay close attention to national policies to keep pace with the economic development trends. In future studies, we plan to enlarge the observation period and compare this proposed framework with other synergy degree measurement methods.

Author Contributions: Data curation, Z.H.; Investigation, J.H., Q.L. and H.Z.; Methodology, Q.L. and H.Z.; Visualization, Y.S.; Writing—original draft, J.H., Y.S. and H.Z.; Writing—review & editing, Z.H. All authors read and approved the final manuscript.

Funding: This research was funded by [National Planning Office of Philosophy and Social Science] grant number [13CGL127] and [Science and Technology Plan Program of Sichuan Province] grant number [2018ZR0066].

Acknowledgments: The authors would like to thank the School of Transportation and Logistics, Southwest Jiao tong University for their support and the financial support from the National Planning Office of Philosophy and Social Science (Grant No. 13CGL127) and Science and Technology Plan Program of Sichuan Province (Grant No. 2018ZR0066).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript and in the decision to publish the results.

Appendix A

Table A1. Order parameters for the subject elements at the ZA agricultural logistics enterprise.

Parameter Number	1	2	3	4	5	6	7	8	9	10	11	12	13
T_1	6	16	187	190	198	196	192	190	4.0	6	48	7.9	80.4
T_2	8	20	183	189	195	195	191	192	3.9	6	48	9.2	80.5
T_3	10	24	186	190	198	198	192	190	3.5	6	48	20.1	75.8
T_4	19	34	187	190	195	195	193	191	3.4	6	48	22.4	74.9
T_5	24	36	183	**188**	195	195	188	192	3.1	6	48	24.1	68.8
T_6	28	38	188	192	195	195	192	193	3.3	6	48	38.1	65.4
T_7	32	40	186	189	196	196	190	190	3.0	4	24	48.9	63.5
T_8	37	42	188	192	198	198	190	195	2.9	4	24	60.3	60.8
T_9	38	42	183	189	197	195	190	193	2.9	4	24	60.1	59.2
T_{10}	40	48	187	191	197	197	190	194	2.9	4	24	58.9	58.9
T_{11}	41	48	190	195	197	197	194	197	3.0	4	24	36.7	57.8
T_{12}	42	48	184	190	197	197	192	192	2.6	4	24	45.9	55.3
T_{13}	44	60	188	193	198	198	191	196	3.0	2	16	51.4	56.0
T_{14}	46	60	187	193	198	198	192	190	2.7	2	16	63.9	53.8
T_{15}	48	60	190	193	198	198	193	195	2.4	2	16	81.1	53.1
T_{16}	50	64	186	192	198	198	191	190	2.4	2	16	69.6	52.4
T_{17}	52	67	187	192	197	197	193	194	2.4	2	16	54.7	51.8
T_{18}	54	70	185	188	198	197	189	190	2.4	2	16	67.3	52.1

Appendix B

Table A2. Order parameter for the object elements and facility and equipment elements at the ZA agricultural logistics enterprise.

Parameter Number	Object Elements						Facility and Equipment Elements										
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
T_1	36.8	32	157	179	100	180	106	17.3	6.3	12.6	12	6659.6	20	10	2.5	15	13
T_2	129.1	120	162	176	106	180	190	22.4	6.4	13.7	20	6877.8	20	10	3	20	16
T_3	316.9	298	168	181	111	184	227	23.6	6.2	11	20	6292.7	20	10	3	20	16
T_4	436.4	409	170	188	116	184	221	15.6	6.2	18.8	26	6545.6	30	20	4	60	50
T_5	537.9	507	174	172	110	187	242	20.8	5.1	16	40	5624.0	30	20	4	60	50
T_6	916.6	876	176	182	128	185	257	17.7	6.1	9.8	40	6249.1	30	20	4	60	50
T_7	1123.9	1090	180	178	121	188	253	21.3	6.6	17.5	40	5348.1	40	26	6	100	80
T_8	1310.3	1280	182	183	128	189	256	21.5	6.9	24.0	40	6192.7	45	28	6	100	80
T_9	1234.3	1200	184	176	130	188	254	22.2	5	13.2	40	6018.1	50	30	6	100	80
T_{10}	790.5	780	187	180	116	189	253	20.6	5.1	18.2	40	5726.4	60	36	8	140	100
T_{11}	399.4	474	190	188	132	189	252	18.5	6.2	6.9	40	6038.1	60	36	8	140	100
T_{12}	760.1	726	192	177	133	195	247	18.0	4.2	15.5	40	6435.1	60	36	8	140	100
T_{13}	725.7	705	194	186	136	193	264	17.7	6.5	19.4	40	5415.3	80	42	8	140	100
T_{14}	912.4	882	196	184	145	194	272	20.2	6.2	9.3	40	6052.0	80	42	8	140	100
T_{15}	1240.4	1198	196	186	141	195	268	17.1	5.9	20.1	40	5434.5	80	42	8	140	110
T_{16}	1009.0	984	198	180	151	195	266	19.9	6.3	11.8	42	6128.8	100	48	10	160	120
T_{17}	639.4	605	199	183	162	197	251	19.1	6	12.2	42	5636.1	100	48	10	160	120
T_{18}	921.2	896	200	190	161	198	261	32.6	3.8	5.5	42	5011.6	100	48	10	160	120

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