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Research on the construction strategies of eco-industrial clusters

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ABSTRACT

Industrial cluster is an industrial organization mode formed from many enterprises and inter-related institutions with a certain geographic concentration. It is an effective way for the development of regional economy, and featured with agglomeration, symbiosis, flexibility, embeddedness, etc. Industrial eco-system is a recycling-oriented industrial system, in which the waste of one process can be utilized as the resource of a closed loop system, or becomes inputs for a new process, and ultimately all the materials, energy and information are sustainable used. Industrial ecosystem is characterized by the market-driven initiative, material flow circularity, the cooperation of industrial clusters and dynamic sustainability. Eco-industrial cluster can be categorized as the main-sub-industry derivative mode, multi-industry symbiosis mode, or artery- vein-industry circular mode

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Introduction

The origin of the "cluster" comes from ecology, which refers to the biological populations living in the same habitat with the symbiotic relationship. M. Potter (1990)^[1] combined the two word industry and cluster together and proposed the concept of "Industry cluster". He pointed out that the industry cluster is geographic concentration of interconnected companies and institutions in a particular field. It is consisted by interrelated enterprises, specialized suppliers, service providers, manufacturers of related industries, as well as the industrial spatial organization of related institutions with the great advantage of sustainable competitiveness. Industrial cluster is one of the most popular topics of economic research as a unique and widespread form of industrial organization. Especially under the economic globalization, regional competition is an important form of international competition. As an important industrial organization mode to enhance regional competitiveness, industrial cluster is an effective way for the development of regional economy, as well as the bright spot for regional economic growth, and even the foundation of national competitiveness. Industrial cluster is characterized by agglomeration, symbiosis, flexibility, embeddedness and innovation etc.

Spatial agglomeration

Industrial cluster is a collection of a large number of related enterprises gathering in a particular geographic area with highly dense economic activities. The spatial agglomeration is an external manifestation and basic characteristic of industrial cluster. On one hand, the enterprises in the cluster share a variety of resources to save the costs of productions; on the other hand, it is easier for them to build mutual trust and cooperation, and reduce transaction costs and trading risk, thus improving the efficiency of market transaction.

Symbiosis

Industrial cluster symbiosis means that the enterprises in the cluster are mutually beneficial and complementary, and just like an organic combination which has to grow and develop together. By reducing various types of cost, the member enterprises in the

cluster region can get more benefits than those stay alone in other regions. The advantage of industrial cluster symbiosis comes from the following two aspects: the first one is the benefit of economy of scale. The enterprises within the industrial cluster are in the same related industry chain, and take the advantage of geographic concentration to carry on the production and sale together through joint venture, cooperation, and alliance etc. Thereby the competitiveness of industrial clusters can be greatly improved with the benefits and efficiency of economy of scale achieved. The second one is the benefit of cost-effective. The member enterprises within the cluster can share technology, information, material resources and infrastructure, and thus the production and transaction costs can be reduced.

Cooperation and Competitiveness

With the foundation of specialization and collaboration, the enterprises in the cluster generally have higher productivity, and may closely coordinate to achieve the superiority of group efficiency based on their specialization and collaboration. The competition widely exists in the cluster, but is more often an inter-enterprise collaborative relationship. It makes the individual enterprise not only maintaining sufficient initiative as well as the high vigilance and sensitivity to cope with the "survival of the fittest" competition in the market, but also collaborating with each other and achieving development together.

Embeddedness

Local embeddedness refers to the economic behavior deeply embedding the local social relations. Enterprises in the cluster usually have the same or similar social and cultural background and system environment, and further the common cluster language, background knowledge and trading rules are deeply embedded in the behaviors of the enterprise economic activity. Therefore the reliability and predictability of the enterprise economic activity can effectively prevent all kinds of opportunistic behaviors, reduce transaction costs, and promote the knowledge dissemination^[2].

The current theories mainly focus on the positive external effects of the cluster such as knowledge dissemination,

information sharing, economies of scale effectiveness, Transaction cost reduction, and local brand establishment etc. These positive effects are considered as both the reason that the industry cluster forms, as well as the important result that the industry cluster causes. However the in-depth analysis and discussion on the problems of cluster pollution and negative external ecological effects are often lacking in the related theories. The most operations of the industry cluster are still the "resources - products - pollution emissions" linear economy development mode. The high concentration of numerous enterprises will lead to large amount of emissions of various pollutants, and thus result in the heavy pollution around the region of the cluster. In addition, the increasing scarcity of the resources and the drastic deterioration of the environment have become a bottleneck which restricts the sustainable, healthy and stable development of the industry cluster. Therefore, it is important to integrate cycling economy and industrial ecology, and build the ecological industry cluster based on the natural ecosystem. This will improve the efficiency of the use of natural resources, reduce pollution emissions, and thus form a healthy development mode. It has great significance for the sustainable development of industry clusters, and will be the only way to achieve the transformation of economic development mode and low-carbon economy in the future.

The Characteristics of Industrial Eco-system

In 1989, Frosch A. and Gallopoulos first proposed the concept of Industrial eco-system^[3]. They pointed that "traditional industrial activity patterns should be transmitted into to a more complete model: industry ecosystem. In this system, energy and material consumption is optimized, waste discharge is minimized, and the waste of a production process becomes the raw materials of another production process".

Industrial eco-system is an industrial recycle system with the most optimum production, the most suitable consumption and the minimum waste evolved from the existing industrial system by using the waste of one process as the raw material of another one, finally a recycle flow is set up for material resources, energy, human resources and information etc. The related study in this field is mainly focused on three levels (Evans and Stevenson, 2000)^[4]. The first level is for an enterprise to explore internally how to best utilize all sorts of resources and minimize waste emission by making the production process collective. The corresponding technologies include clean production, green manufacture etc. The second level is to consider the cooperation of different enterprises within an industrial system with the enterprises to simulate the producer, consumer and dissolver of the natural eco-system and to form an Eco-Industry Chain in which the enterprises are chained together by resources. Greater economic, environmental and social effects and benefits are achieved through co-existence and co-operation. The third level is to set up an industrial co-existence network in a region or a country, and achieve material recycling in a wider area.

Market-Driven Initiative

In natural ecosystems, organisms choose their own habitat space and reproduction of life based on the most appropriate survival guidance. In the same way, enterprises of economic system choose the most favorable living environment for development based on the orientation of minimum cost and maximum efficiency. The purpose of businesses is to pursue profit and the most fundamental driving force of business behavior is market-oriented. With more stringent government

environmental enforcement, the cost to deal with pollution and waste for an upstream business alone has been rising. If they can cooperate with the downstream businesses who accept the waste as raw material, the upstream companies can save pollution processing costs; and the downstream firms can also be free or have very favorable price to get raw materials. So the upstream and downstream enterprises form a "food chain" under the market guidance, an ecological agglomeration, and eventually the formation of the industrial ecosystem. Therefore, the emergence and development of an industrial ecosystem is the mimic natural ecosystem's phenomenon of species coexistence and material recycling without external specific interventions. Meanwhile, it is driven by the law of market-value, followed by the process of self-aggregation development from scratch, and achieved in positive externalities through multi-level resources and energy usage during the process of development. A lot of practice shows that the characteristics of self-evolution of the ecosystem in the industry are prevalent.

The Cycle of Material Flows

The most perfect property of natural ecosystem is characterized by its cyclical factor. Ecological environment and renewable natural resources can be restored and balanced as well as biological species in a harmonious and stable environment survive and multiply. To mimic the natural eco-system, industrial ecosystem adds the feedback mechanism in the traditional linear manufacturing process. In the system, waste can be cycled through the different production process in the multi-level usage of industrial system. So, we can achieve economic efficiency, environment of low-polluting, low energy consumption, ecological harmony and sustainable development, and therefore, to form the ideal state - "the request and give-back to the nature system from human must be balanced".

The cooperation of industrial clusters

The traditional industrial cluster is only a certain superposition of related businesses within the region, but an industrial ecosystem is composed of a series of producers, consumers, and decomposers in a region to imitate natural systems with resources (including raw materials, products, information, personnel, etc.) as a link to form transference and cooperative relations in industrial clusters, essentially a collection of various partnerships by the eco-industrial chain business model. Therefore, it is essential for an industrial ecosystem to have the mechanism of cooperation between enterprises. Through cooperation, the system will achieve closed loop circle, reduction of material, and multi-level use of energy. Enterprises in the system will improve the viability and profitability, while reduce the negative ecological impacts of industrial activities to save resources and protect environment.

The Sustainability of the Dynamic Adjustment

From an economic point of view, sustainable development is the economic development without reducing the environment quality and destroying natural resources, that is economically sustainable; from the natural point of view, the emphasis is on the coordination between economic development and natural resources under the environmental carrying capacity, this is ecological sustainability. Building an industry ecosystem is a continuous improvement process, not only a gradual adjustment process, but also a dynamic process according to market demand and technical changes to adjust partners and develop new supply and demand relationships. In this process, the linear flow of material (open) system is gradually replaced by cycle (closed) system to achieve the changes of weakening of anti-ecological

characteristics and the increasing of industrial ecological characteristics. Ultimately we will build the industrial ecosystem to reduce the natural resources consumption and negative environmental impact, reduce pollution, conserve resources, protect the ecological environment, and achieve, at the same time, economic and social sustainable development.

Construction mode of Eco-Industry cluster

Main-sub-industry derivative mode

The eco-industry clusters in this mode rely on one or more production as main industry, from which a variety of sub industries are derived and support each other, and achieve the recycling and effective use of the resource. The Structure of the mode and the corresponding resource utilization process is shown in Figure 1. The center of the figure is the main industry, from which several sub industries are derived [5]. Sub industry 1 and 2 use the emission from the main industry, and provide some renewable resource to the main industry or provide some product to the market. Sub industry 3 absorbs the emission of the main industry and derives another sub industry while providing some renewable resource to the main industry. There may be multiple main industries in the cluster. Some sub industries may not independently provide products to the market, but mainly transform the emission of main industries or sub industries into renewable resources which can be reused within the cluster.

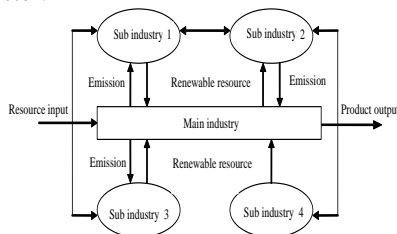


Figure 1 Main-sub-industry derivative mode

Shanghai's Baogang Group takes the steel production as its main industry, while produces the cement and new building material using the steel-making generated wastes such as the Blast furnace slag, steel slag, pulverized coal ash, sludge and dust etc with technology treatment, and generates electricity using the recycled waste heat. This makes the steel and iron, building materials, electricity and other industries developing coordinately, achieving recycling and effective utilization of some resources, and forming the eco-industry cluster with main-sub derivative mode.

Multi-industry symbiosis mode

This eco-industry mode is generally formed by two or more interdependent industries in a region with the symbiotic relationship of Interdependence, common development, and complementary advantage. Figure 2 shows the mode structure and resource utilization process. Four different industries cluster symbiotically. Each industry has its own resource input and product output, makes use of the emissions each other, and thus achieves the recycling and effective utilization of resource.

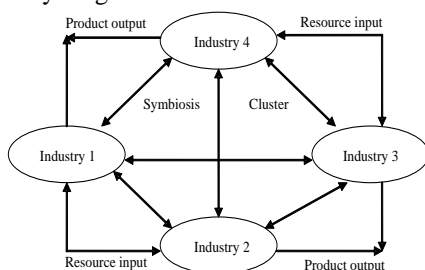


Figure 2 Multi-industry symbiosis cluster mode

Artery-vein-industry circular mode

Artery industry refers to the industries formed from raw material mining, production, distribution, consumption and waste. Vein industry refers to the industries which transform waste into renewable resources. These two types of industries are closely integrated to form a complete circular economy. They gather in a certain area and form an eco-industry cluster mode, i.e. artery and vein industry circular mode. Figure 3 shows the mode structure and resource utilization process. The left is the artery industry. The wastes generated from its consumed products are recycled, and enter the vein industry, which will be transformed to renewable resources after dismantling and processing, and finally come back to artery industry and make some products for the market.

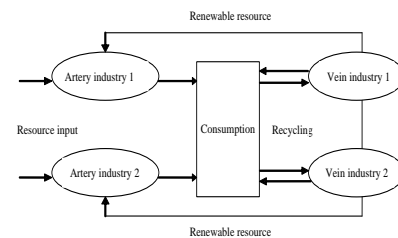


Figure 3 Artery and vein industry circular mode

The traditional development mode of industrial clusters has good economic benefit in the industrial system but has bad impact on the eco-environment, which indicates that it is economical inside but uneconomical outside. The development mode of eco-industrial cluster takes into account both of the internal and external benefits of the industry together. This interconnected enterprise development mode not only enhances economic benefit inside the industrial cluster such as cost reduction, transaction cost reduction, etc, but even more importantly also greatly improve the industrial negative externality such as waste reduction, pollution reduction, etc. The eco-industrial cluster is a new industrial development mode to promote the harmony between human beings and nature in the current economic conditions, as well as the most effective way to change the mode of economic development and achieve sustainable development [6]. The construction of eco-industrial cluster involves not only the functional orientation of the region, the industrial type selection and eco-environment construction, but also the fundamental changes in policies and regulations, belief and values, scientific and technological levels, quality of the population and lifestyle, consumption patterns and humanistic environment, and so on. Therefore, we must make a right choice of the systems and development directions in the construction of eco-industrial cluster.

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