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An emergy-based hybrid method for assessing industrial symbiosis of an industrial park

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ABSTRACT

Industrial park development has become a critical strategy to promote economic development in many countries since 1980s. Particularly, China is one key country to adopt such a method on enhancing its industrialization. However, rapid industrial park development has resulted in many issues, including resource depletion, environmental emissions and pressure on responding climate change. Industrial symbiosis has been proved that it has positive impacts on promoting resource utilization efficiency. Therefore, effective performance evaluation can help recognize the key barriers on industrial symbiosis of industrial parks so that more appropriate policies can be raised by considering the local realities. Emergy synthesis is one feasible method on addressing the contribution of local ecosystem to industrial park development due to its innovative perspectives and mature methodology, while impact, population, affluence, technology (IPAT) formula and index decomposition analysis (IDA) are suitable for identifying and quantitatively calculating the key impacts of various factors. This paper integrated emergy synthesis, IPAT formula and IDA methods together to investigate the impact factors of industrial symbiosis in an industrial park. A case study approach at Dalian Economic Development Area (DEDA) was carried out so that such an effort can be tested. The results show that waste reutilization by industrial symbiosis in DEDA increased by 3.0E+20 seJ from 2006 to 2010. Technological pressure for waste utilization by industrial symbiosis and energy structure of an industrial park had made negative effects on the waste reutilization from 2006 to 2010 in DEDA, while the efficiency of non-renewable energy consumption and emergy scale of an industrial park played positive effects on the waste reutilization. Among the four impact factors, technological pressure for waste utilization and the efficiency of non-renewable energy consumption took more significant impacts on the industrial symbiosis of DEDA than the other two factors, which contributed −1.92E+21 seJ and 2.18E+21 seJ for the waste reutilization by industrial symbiosis respectively.

1. Introduction

Over the past few decades, a large amount of resource has been globally consumed due to rapid economic growth and poor resource management. In order to respond to this urgent issue, industrial ecology was raised as an innovative strategy to decouple economic growth and resource consumption by encouraging industrial systems to mimic natural ecosystems (Geng and Cote, 2002). One key element of industrial ecology, namely industrial symbiosis (IS), has gained increasing attention, which can be categorized conceptually as collective resource optimization based on by-product exchanges and utility sharing among disparate yet typically co-located facilities. IS was defined as a physical exchange of materials, energy, water, and/or by-products to promote resource utilization efficiency between traditionally separate industries with the intent of promoting collective competitive advantage (Chertow, 2000). Through nearly twenty years' development, industrial symbiosis has grown up from a curiosity to a meaningful business

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strategy and has been practiced at various scales, including eco-industrial parks (Cote and Cohen Rosenthal, 1998; Boix et al., 2012), industrial ecosystems (Cote and Hall, 1995; Wallner and Narodoslawsky, 1996; Geng et al., 2007; Bain et al., 2010), industrial recycling networks (Schwarz and Steininger, 1997; Zhang et al., 2011), and by-product synergies (Forward &Mangan, 1999; Zhang et al., 2010).

In China, the central government planned and developed economic and technological zones as one way of developing industrial parks to stimulate economic development across the whole country in the early 1980s (Geng and Zhao, 2009). Particularly, due to its comprehensive advantages on attracting foreign investment, improving technological abilities, and concentrating industrial activities through appropriate zoning, industrial park has become one key economic development strategy by the Chinese governments at different levels (Geng and Cote, 2003, 2004). Through nearly thirty years' development, industrial parks have greatly contributed to national economic development, leading to national economic transformation with higher economic efficiency. For instance, in year 2011, industrial parks at national level completed a gross domestic production (GDP) with a value of 47 million US dollars per square kilometer, 59.2 times higher than the national average level and 7.9 times higher than the average level of 36 major cities. However, rapid development of industrial parks also created some problems, such as resource depletion and environmental pollution, and very recently increasing pressure on responding climate change. In order to deal with these emerging issues, Ministry of Environmental Protection of People's Republic of China (MEP) initiated eco-industrial park (EIP) project in 2002 (Geng and Zhao, 2009). To date, there are 85 EIPs approved by MEP (see Fig. 1). However, due to a lack of consideration of IS, these indicators have some common problems, such as a lack of prevention-oriented indicators, weak connection and interaction, a lack of interacted information (Geng and Zhao, 2009, 2013a; Su et al., 2013). Therefore, it is critical to establish convincible indicators so that the overall effects of IS in these industrial parks can be scientifically evaluated.

Academically, various studies on IS have been carried out. Regarding the impact factors of IS, previous studies focused on the description of the barriers of IS. For instance, Sakr et al. (2011) studied upon the Egyptian context for the identified EIP success and limiting factors, including the creation of symbiotic relationship, information sharing and awareness, financial benefits, organizational structure, and legal and regulatory framework. Taddeo et al. (2012) pointed out that the history of the long-standing industrial cluster influenced the presence and the role played by some key drivers, especially local community, which proved to be crucial in preventing the full implementation of the EIP. In general, the impact factors of IS were concluded such as the distances between various enterprises, scales and diversity of industrial clusters, economic conditions, etc (Lowe et al., 1995; Chertow, 2000, 2003; Ehrenfeld and Gertler, 1997). With regard to the evaluation of IS, most of previous studies focused on the efficiency evaluation. For instance, Zhang (2010) evaluated the eco-efficiency of an industrial park by applying material flow analysis (MFA). Wesley (2011) analyzed the waste emission scenarios in a mining industrial area in Peru by employing life cycle assessment (LCA). Dong et al. (2013) evaluated the carbon footprints generated by the IS within an industrial park in Shenyang, China. However, these studies mainly evaluated the efficiency of waste utilization improved by IS, but did not address those impacts factors driving the success of IS, such as the contribution of local ecosystem, and

Fig. 1. Distribution of eco-industrial park projects in China.

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