A METHOD FOR TENANT SELECTION OF CHINA'S CONSTRUCTION INDUSTRIAL PARKS THROUGH INDUSTRIAL SYMBIOSIS

Yang Zhou[1], Dong Wang, Guiwen Liu, Jun Wang and Kaijian Li

Faculty of Construction Management and Real Estate, Chongqing University, Chongqing, 400045, China

Offsite construction is an innovative alternative to conventional site-based construction. It requires building components to be fabricated before installing into their final locations. Construction industrial parks (CIPs), clusters of offsite construction companies, provide a common platform for above industrial activities to improve plant efficiency and achieve sustainable development. Even though a lot of CIPs already exist in China, several ecologic proposals of CIPs are still in progress but not achieved. The concept of industrial symbiosis (IS) can be applied to the existing CIPs to obtain environmental and economic benefits by sharing resources and information. Furthermore, strategy of designing a symbiosis network between companies in a CIP involves tenant selection to complement existing offsite construction companies. However, literature review shows that the eco-design of Chinese CIPs considering the potential integration of tenants in an eco-industrial parks (EIPs) framework is still lack in research. In this study, an access indicator system and a linear programming model are established to select tenants in a CIP. The access indicator system, proposed from the perspective of park-based level, comprises three primary indicators and fifteen secondary indicators. The linear programming model is proposed to assess the satisfactoriness of all indicators and can achieve multiple enterprises selection.

Keywords: China, industrial symbiosis, offsite construction, tenant selection

INTRODUCTION

China is construction dependent, the construction industry has also developing rapidly, creating many problems including low utilization efficiency of recourses and environmental disruption (Zhang 2014). Traditional construction methods are dominated by labour-intensive approaches involving the use of considerable onsite labour. Recent labour shortages in the industry have resulted in insufficient workers being available to undertake traditional construction projects, with resulting delays in production and delivery (Nawi, Lee and Nor 2011). These problems have unavoidably led to negative effects in the development of China’s society and economy. Therefore, how to revolutionize construction activities more effectively and cleanly has recently attracted an increasing interest from both the practitioners and academia. Offsite construction is an inventive manner with extensive advantages, challenging the anterior filed-construction (Pan and Sidwell 2011). Benefits from using such technologies have been widely studied and they mainly include reductions in cost, time, defects, health and safety risks, and

[1] zhouyang@cqu.edu.cn

Zhou, Y, Wang, D, Liu, G, Wang, J and Li, K (2017) A Method for Tenant Selection of China's Construction Industrial Parks Through Industrial Symbiosis *In:* Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference,* 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 611-620.

environmental impact and a consequent increase in predictability, whole life performance and profits (Pan and Sidwell 2011). In recent years, with the development of offsite construction, clustering of construction companies into construction industrial parks (CIPs) was adopted in China, such as Tiexi construction industrial park in Shenyang (Dai 2010). CIPs means that companies assemble collections of construction manufacturing and service business, and then put them together on a common property. The activities of CIPs involve the manufacture and pre-assembly of building components, elements or modules before installation into their final locations.

The scientific development of industries is often closely related to nature. The efficient and perfect food chain and the cycles of natural ecology have become aspirational subjects for research (Zhou *et al*., 2012). Industrial ecology (IE) is an emerging and multidisciplinary research field based on an analogy between industrial systems and ecological systems (Taddeo *et al*., 2012). IE brings the idea of resource cycling in natural systems to the current industrial clusters to achieve industrial symbiosis (IS) (Cote and Cohen-Rosenthal 1998) and supports sustainable local industrial development or redevelopment through the promotion and implementation of eco-industrial parks (EIPs) (Taddeo *et al*., 2012).

An EIP can result in the creation of a new industrial site or in the involvement of production plants already present in a given region (Taddeo *et al.* 2012). Given this, the basic principles of EIPs (Zhou *et al*., 2012), including industrial symbiosis, resource coupling, waste recycling, and pollution control, which can be applied to the CIPs to achieve maximal utilization of resources, maximal economic benefit, and minimal environmental pollution. An EIP has great stability and systematic efficiency when each member enterprise is suitable and compatible (Zhu *et al*., 2010). Therefore, the selection of suitable member enterprises plays an important role for the early planning and design of an EIP. A typical EIP consists of previously established anchor tenants and support tenants to follow (Ubando *et al*., 2016). The anchor tenants represent staple industry of the EIP, which serves to attract other enterprises to join the EIP. These new enterprises are known as candidate tenants act as either supplier or customer of these anchor tenants, whose entry creates new opportunities for integration. In considering the candidates for support tenants, a planning committee may be formed to assess the compatibility of the candidate tenants in the EIP (Lowe 1997). However, many local governments introduced EIP businesses to enhance economic growth regardless of the form of the eco-chains and networks of enterprise (Zhu *et al*., 2010).

The offsite construction-based firms, as the heart of the CIP, acts as the anchor tenants and provides synergistic collaborative network between various industries on specific by-product streams. A valuable method of quantitative evaluation for candidate tenants can effectively reduce negative environmental impacts on the CIP system. Literature review shows that the eco-design of Chinese CIPs considering the potential integration of candidate tenants in an EIP framework is still lack in research. Hence, in view of the importance of selection of suitable member enterprises for CIP programs, this study is aim to establish an evaluation model which provides a practice tool for optimal design CIPs in China. To be more specific, the objectives are (i) to establish an access indicator system for candidate tenants of CIPs; (ii) to provide a quantitative method for evaluating the suitability of an enterprise integrating into a CIP. This method is applicable to the CIPs towards ecological industry development.

Optimization Method of CIPs

Access Indicator System for Selecting Candidate Tenants on CIPs

Criteria for selecting indicators

Since the characteristics and the goals of EIPs vary, researchers have different opinions in the criteria for selecting indicators. To achieve the goal of selecting indicators to control member enterprises access to a CIP, this new criterion set is proposed combining the criteria described by Zhu (2010) and Valenzuela-Venegas (2016). It is worth noting that the indicators proposed by Zhu (2010) to evaluate new members in an EIP can be defined at enterprise-based level and park-based level respectively. The proposed CIP access indicator system does not include enterprise-based indicators, for the reason that the authors consider all the tenants are qualified with regard to national and local industrial policy, industrial planning and environmental requirements. Therefore, the criterion called boundary shows that the study only select the park-based indicators. The criteria the study adopt for selecting indicators and their description are shown in Table 1.

Table 1: Criteria for indicators choice and their description

Criterion	Description
Practicality	Indicators must be measurable and address calculation.
Relevance	Indicators must be relevant to the goal of CIP development and the long-term strategy of participating companies.
Boundary	Indicators must be set from the perspective of the park-based level.

The access indicator system

A variety of indicators is available for assessing CIPs. A literature search in ISI Web of Science's database is presented by Valenzuela-Venegas *et al*., (2016) to explore feasible sustainability indicators. As a result, the definition of 249 indicators is provided in a list. The authors filter the 249 indicators and other sustainability indicators that proposed by relevant research based upon the three criteria listed in the previous section, and propose an access indicator system (Table 2) for enterprises into a CIP. The fifteen indicators are filtered and classified as three primary indicators including industrial symbiosis, environment performance and economic benefit, according to the IS principles and the three dimensions of sustainability (environment, economic and social dimensions). The authors classify those indicators related to the social aspect as economic because they are also related to the economic performance. Because the type of the measure indicators has vital effects on the selection of correlation functions, the indicators should be classed according to certain principles. The authors classify these indicators into two categories based on their indicative function: positive indicator (P) and negative indicator (N). The positive indicator is the one that increases with its value; the negative indicator is the one that decreases with its value.

Identification of indicators

Park-based indicators include three primary indexes from F1 to F3 and fifteen measure indicators from I1 to I15. These categories and subcategories represent the requirements from a CIP.

5. F1: Industrial symbiosis. Lowe (1997) argues that the nature of an EIP is the interaction between enterprises and the environment. The authors second their point and consider interaction as a key factor to consider when selecting the member firms. Five measure indicators are set as follows:

- I1: Quantity of metabolic connectivity
  It measures the role of the tenant in improving existing CIP member businesses linkage through supplies or demands. The greater number of metabolic direct flows with the new member firm, the higher the score is.
- I2: Degree of metabolic connectivity
  The indicator is to measure the degree of the connectivity among the enterprises or factories in a CIP after introduction of the tenant. The formula calculates as follows:
  $$C = \frac{L}{S(S-1)/2} \quad (1)$$
  Where C is the degree of metabolic connectivity of the CIP; S is the number of member enterprises in the web; and L is the number of links after introduction of the new candidate tenant.
- I3: Geographical distribution of resource acquisition
  It measures the geographical distribution of obtaining main materials or resources from local clubs. The shorter the distance, the higher the score is.
- I4: Recycling rate of industrial water
  This indicator is used to evaluate the proportion of industrial water recycled in the tenant. The formula calculates as follows:
  $$C(\%) = \frac{Q_1}{Q_1+Q_2} \quad (2)$$
  Where C is the recycling rate of industrial water; Q1 is the total annual recycling industrial water used by the tenant; and Q2 is the total annual fresh water used by the tenant.
- I5: Recycling rate of by-product and solid wastes
  This indicator reflects the proportion of by-product or solid wastes reused and recycled in the tenant. The formula calculates as follows:
  $$C(\%) = \frac{Q_1+Q_2}{Q_1+Q_2+Q_3} \quad (3)$$
  Where C is the recycling rate of by-product or solid wastes; Q1 is the total annual recycling by-product or solid wastes produced by the tenant; Q2 is the total annual recycling by-product or solid wastes produced by the other member enterprises in the park and used by the tenant; and Q3 is the total annual raw materials used by the tenant.

6. F2: Environment performance. The goal of introducing new businesses into an EIP is to improve the industrial symbiosis and systematic efficiency. The environmental performance is expected to be improved after the entry of new members. Therefore, this is a key factor to consider. There are five measure indicators under the primary index.
   The indicators I6 to I10 measure the contribution of new business to the pollutants production of COD, air pollutants, CO2, wastewater and solid wastes in the park after the introduction of the candidate tenant. The calculation is as follows:
   $$C(\%) = \frac{Q_1-Q_0}{Q_0} \quad (4)$$
   Where C is the change rate of park COD, air pollutants, CO2, wastewater and solid wastes production respectively; Q0 is the park COD, air pollutants, CO2, wastewater and solid wastes production per year before the introduction of the candidate tenant; Q1 is the park COD, air pollutants, CO2, wastewater and solid wastes production per year after the introduction of the candidate tenant.
7. F3: Economic benefit. Economic benefit is the one key considered by both CIP developers and enterprise managers. There are many measures, but the authors select only the five applicable ones as follows:

- I11: Proportion of gross industrial output value
  It measures the contribution of new business to the gross industrial output value of the park after the introduction of the candidate tenant. The value is the ratio of the annual gross industrial output value of the tenant to the annual gross industrial output value of the whole park.
- I12: Industrial value-added per unit fresh water consumption
- This indicator measures the efficiency of water use in production as well as the level of technology and equipment. The value of the indicator is the ratio of the annual industrial value-added of the tenant to the annual fresh water consumption of the tenant. The unit is usually 10000 Yuan / m3.
- I13: Industrial value-added per unit energy consumption
- It measures the energy efficiency. The consumption of all the energy is calculated and converted to the number of standard coal using means conversion coefficients. The value is the ratio of the annual industrial value-added of the tenant to the total energy consumption of the tenant. The unit of this index is 10000Yuan/per unit t standard coal.
- I14: Industrial value-added per unit land consumption
- The indicator is to measure the efficiency of land use of the tenant. The value is the ratio of the annual industrial value-added of the tenant to its total land demand. Given the land supply is limited, the lower the ratio, the higher the score is. The unit of this index is per IVA/m2.
- I15: Employment contribution
- It measures new job created by the tenant. The greater number of job creation after the establishment of CIP cooperative network, the higher the score is.

Optimal Method for Selecting Candidate Tenants on CIPS

Problem statement

In designing a CIP and employing the concept of IS, the challenge is to select candidate tenants while satisfying the overall objective of the CIP. Firstly, the degree of industrial symbiosis of the CIP is maximized. Secondly, the environmental impact of the CIP is minimized. Lastly, the economic benefit improvement of CIP is maximized. In the research, the authors try to select the candidate tenants that meet the requirements of CIP development through the optimization methods. The following 0-1 variables were used to describe the selection of the tenants.

$$\boldsymbol{x_i} = \begin{cases} 1 & \text{Enterprise } i \text{ is selected} \\ 0 & \text{Enterprise } i \text{ is not selected} \end{cases} \quad (5)$$

Where xi is the tenant selection vector, i=1, 2, 3, … m. A xi-value of 1indicates the enterprise i was selected. A xi-value of 0 represents an unacceptable value of the enterprise i.

Evaluation method

The general process of the evaluation method is constructing an evaluation indicator system, confirming the weighting coefficients, establishing conjunction function and calculating. The practicability-oriented model should be as simple as possible and can be easily understood and operated by practitioners.

- Indicator weights assignment

Each indicator is of different importance to an overall goal. Therefore, different weights should be assigned. The aforementioned fifteen measure indicators are assigned weights based upon the widely used Analytic Hierarchy Process (AHP). The weight of the fifteen indicators and its normalized set are denoted as ωj, where j=1,2,…,15. 2)

- Normalization of values of the indicators

  In order to achieve an overall evaluation result, the result of various indicators need to be combined together (Zhou *et al*., 2012). As the units and magnitude of selected indicators are different, they need to be normalized first.

  For those indicators for which larger results are better,

$$k'_{ij} = \frac{k_{ij} - \min(k_{ij})}{\max(k_{ij}) - \min(k_{ij})} \qquad (6)$$

  For those indicators for which smaller results are better,

$$k'_{ij} = \frac{\max(k_{ij}) - k_{ij}}{\max(k_{ij}) - \min(k_{ij})} \qquad (7)$$

  Where k'ij is the normalized value of the indicator j of enterprise i, kij is the calculated value of this indicator, and max (kij) or min (kij) are the calculated maximum or minimum value of this indicator among all candidate tenants.

- Objective function

  The object Z of park total benefit is calculated using the following equation.

$$\max(Z) = \sum_{j=1}^{15} \sum_{i=1}^{m} \omega_j k'_{ij} x_i \qquad (8)$$

  The rule of evaluation is that an object is better by the access criteria if the value of its optimal degree is greater. Namely, the enterprises make maximal optimal degree for the park are the best candidates to be integrated with existing industrial chains in a CIP.

- Constrains

  Constrains here refers to the limited supplies of land, water and energy in the park (Zhu *et al*., 2010). The amount of land, water and energy used for tenants should be less than the total amount provided by the park. Thus new businesses can be admitted into the CIP only if their demand of the above resources does not exceed park carrying capacity. So three inequality constraints are proposed as follows:

$$\alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_m x_m \le A \qquad (9)$$

$$\beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_m x_m \le B \qquad 10)$$

$$\gamma_1 x_1 + \gamma_2 x_2 + \cdots + \gamma_m x_m \le C \qquad (11)$$

  Where αi, βi and γi are the annual demand of land, water and energy of candidate enterprise i respectively; A, B and C represent the total amount of land, water and energy provided by the park respectively.

DISCUSSION

Access Indicator System

The access indicator system provides straightforward evaluation items for the CIP developers and administrators. A remarkable feature of a real EIP is industrial symbiosis. The study design fifteen park-based indicators through the implementation of EIP, which are lacking in the previous studies to select candidate tenants. However, the measure indicators are not new. They have been used in some evaluation indicator systems of sustainability.

Table 2: Access indicator system for control of entry of enterprises into a CIP

Primary indicator	Secondary indicator	Unit	Reference
F1: Industrial symbiosis	I1: Quantity of metabolic connectivity (P)	-	SNDEP; Zhu *et al*., (2010); Dai *et al*., (2010); Phillips *et al*., (2006); Lu *et al*., (2012); Ohnishi *et al*., (2012)
	I2: Degree of metabolic connectivity (P)	-	Zhu *et al*., (2010); Dai (2010); Phillips *et al*., (2006); Lu *et al*., (2012); Ohnishi *et al*., (2012)
	I3: Geographical distribution of resource acquisition (N)	-	Phillips *et al*., (2006); Song *et al*., (2014)
	I4: Recycling rate of industrial water (P)	%	SNDEP; Zhu *et al*., (2010); Song *et al*., (2014); Dai *et al*., (2010); Su *et al*., (2013); Phillips *et al*., (2006); Geng *et al*., (2009)
	I5: Recycling rate of by-product and solid wastes (P)	%	SNDEP; Zhu *et al*., (2010); Song *et al*., (2014); Dai *et al*., (2010); Su *et al*., (2013); Phillips *et al*., (2006); Bai *et al*., (2014)
F2:Environment performance	I6: Change rate of COD emission (N)	%	Zhu *et al*., (2010); Song *et al*., (2014); Geng *et al*., (2009); Bai *et al*., (2014); Pakarinen *et al*., (2010); Azapagic and Perdan (2000)
	I7: Change rate of air pollutants emission (N)	%	Chen *et al*., (2012); Pakarinen *et al*., (2010); Behera *et al*., (2012);
	I8: Change rate of CO2 emission (N)	%	Park and Behera (2014); Pakarinen *et al*., (2010); Eckelman and Chertow (2013);
	I9: Change rate of wastewater generation (N)	%	SNDEP; Zhu *et al*., (2010); Su *et al*., (2013); Phillips *et al*., (2006); Geng *et al*., (2009); Bai *et al*., (2014); Chen *et al*., (2012);
	I10: Change rate of solid wastes generation (N)	%	SNDEP; Zhu *et al*., (2010); Song and Shen (2014); Su *et al*., (2013); Phillips *et al*., (2006); Geng *et al*., (2009)
F3: Economic benefit	I11: Proportion of gross industrial output value (P)	%	SNDEP; Zhu *et al*., (2010); Song and Shen (2014); Geng *et al*., (2009); Bai *et al*., (2014); Park and Behera (2014)
	I12: Industrial value-added per unit fresh water consumption (P)	10000 Yuan / m3	SNDEP; Zhu *et al*., (2010); Song and Shen (2014); Su *et al*., (2013); Phillips *et al*., (2006); Geng *et al*., (2009)
	I13: Industrial value-added per unit energy consumption (P)	10000 Yuan / t standard coal	SNDEP; Zhu *et al*., (2010); Song and Shen (2014); Phillips *et al*., (2006); Geng *et al*., (2009); Bai *et al*., (2014); Park and Behera (2014); Pakarinen *et al*., (2010)
	I14: Industrial value-added per unit land consumption (P)	m2/per IVA	Zhu *et al*., (2010); Azapagic and Perdan (2000)
	I15: Employment contribution (P)	-	Phillips *et al*.,(2006); Azapagic and Perdan (2000)

SNDEP= Standard for National Demonstration Eco-industrial Parks. COD=chemical oxygen demand. Standard coal is the coal whose net calorific value as received is 29.27 MJ. IVA=industrial value-added.

These indicators are also necessary for constructing an overall access indicator set in this study. For the selection of measure indicators, theoretically, the more indicators there are, the better it is to evaluate the candidate enterprises. However, considering practicality, it is easy to operate only when the number of indicator measures is small. In the indicator system, the most important indicators are the quantity and degree of metabolic connectivity because it measures the enhancement of industrial symbiosis.

In other word, even if an enterprise succeeds in clean production, it may not be the best candidate from the perspective of the industrial chains construction. The idea is similar to the access indicator system of EIP proposed by Zhu *et al*., (2010) where the starting point for developing an EIP by ranking plenty of candidate enterprises to match with existing industrial chains. However, there are some differences on criteria for selecting indicators. Firstly, indicators must be set from the perspective of the park-based level. The access indicator system focuses on how much candidate enterprises can improve sustainable development of the whole CIP, so enterprise-based indicators related to environmental requirements are not included. Secondly, indicators of the system must be measurable and the values of all indicators are quantifiable. The assignment of the value for an indicator is often influenced by subjective factors such as personal preference and professional knowledge. A valuable approach of quantitative evaluation for candidate enterprises can partly reduce the deviation.

Evaluation Method

The study have introduced the linear programming method to establish an evaluation model for CIPs. The selection of candidate enterprises for CIPs is typically a multi-objective problem. Even though plenty of research related to this work, only a few consider several objective selection. However, what gives concern is to formulate a function that can be take into account in the evaluation of multiple candidate tenants for eco-design of CIPs. Compared with the previous research, the improvement of our evaluation method is reflected in the realization of multi-objective selection. Specifically, those enterprises with top scores may be not the best choices for the park because of limited supplies of land, water and energy in the park. By contrast, the combination of multiple enterprises is sometimes more suitable for the park than a single high-score enterprise. In other word, the method can provide a result of combination of several candidate enterprises, which can be integrated into a CIP to enhance its systematic efficiency. In addition, the method of AHP is used widely to determine weights of indicators. The reason why the study do not discuss in detail here is that their own importance to the total goal varies with the location of CIPs.

CONCLUSIONS

It is a challenge for the developers and management teams of a CIP to select suitable tenants into the existing industrial chains among candidates, which all have advantages and disadvantages simultaneously. This study provides a quantitative method for selecting member tenants, which involves the establishment of both the access indicator system and the evaluation model.

The access indicator system is proposed from the perspective of park-based level, which includes three primary indicators and fifteen secondary indicators. The categories and subcategories are selected according to the principles of practicality, relevance and boundary. Although some indicators are also used in other indicator systems, it is a new idea to combine them together with to construct a comprehensive access indicator system as a control tool for candidate tenants of CIPs. The evaluation model of linear programming method has been applied to establish a way to control enterprises’ access to a CIP. The study have made some improvements on the evaluation model, which can achieve multiple tenants' selection.

REFERENCES

Azapagic, A and Perdan, S (2000) Indicators of sustainable development for industry. *Process Safety & Environmental Protection*, **78**(4), 243-261.

Bai, L, Qiao, Q, Yao, Y, Guo, J and Xie, M (2014) Insights on the development progress of national demonstration eco-industrial parks in China. *Journal of Cleaner Production*, **70**, 4-14.

Behera, S K, Kim, J H, Lee, S, Suh, S and Park, H S (2012) Evolution of 'designed' industrial symbiosis networks in the Ulsan Eco-industrial Park: 'Research and development into business' as the enabling framework. *Journal of Cleaner Production*, **29-30**, 103-112.

Chen, C H, Liu, W L, Chiou, I J and Liaw, S L (2012) Methodology and system of total quantity and sustainability management for industrial parks. *Environmental Engineering & Science*, **29**(10), 934-945.

Cote, R P and Cohen-Rosenthal, E (1998) Designing eco-industrial parks: A synthesis of some experience. *Journal of Cleaner Production*, **6**(3), 181-188.

Dai, T (2010) Two quantitative indices for the planning and evaluation of eco-industrial parks. *Resources, Conservation and Recycling*, **54**(7), 442-448.

Eckelman, M J and Chertow, M R (2013) Life cycle energy and environmental benefits of a US industrial symbiosis. *International Journal of Life Cycle Assessment*, **18**(8), 1524-1532.

Geng, Y, Zhu, Q, Doberstein, B and Fujita, T (2009) Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China. *Waste Management*, **29**(2), 996-1002.

Lowe, E A (1997) Creating by-product resource exchanges: Strategies for eco-industrial parks. *Journal of Cleaner Production*, **5**(1), 51-65.

Lu, Y, Su, M, Liu, G, Chen, B, Zhou, S and Jiang, M (2012) Ecological network analysis for a low-carbon and high-tech industrial park. *Scientific World Journal*, 2012(6) [305474].

Nawi, M N M, Lee, A and Nor, K M (2011) Barriers to implementation of the industrialised building system (IBS) in Malaysia. *Built & Human Environment Review*, **4**(2), 34-37.

Ohnishi, S, Fujita, T, Chen, X, Fujii, M, (2012) Econometric analysis of the performance of recycling projects in Japanese Eco-Towns. *Journal of Cleaner Production*, **33**, 217-225.

Pakarinen, S, Mattila, T, Melanen, M, Nissinen, A and Sokka, L (2010) Sustainability and industrial symbiosis. The evolution of a Finnish forest industry complex. *Resources, Conservation & Recycling*, **54**(12), 1393-1404.

Pan, W and Sidwell, R (2011) Demystifying the cost barriers to offsite construction in the UK. *Construction Management and Economics*, **29**(11), 1081-1099.

Park, H S and Behera, S K (2014) Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks. *Journal of Cleaner Production*, **64**(2), 478-485.

Phillips, P S, Barnes, R, Bates, M P and Coskeran, T (2006) A critical appraisal of an UK county waste minimisation programme: The requirement for regional facilitated development of industrial symbiosis/ecology. *Resources, Conservation & Recycling*, **46**(3), 242-264.

Song, X and Shen, J (2014) Modeling and NSGA-II-IFD algorithm solution of the industrial planning for eco-industrial parks based on multi-objective optimization. *China Population, Resources & Environment*, **24**(9), 68-74.

Su, B, Heshmati, A, Geng, Y and Yu, X (2013) A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production*, **42**, 215-227.

Taddeo, R, Simboli, A and Morgante, A (2012) Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site. *Journal of Cleaner Production*, **33**, 22-29.

Ubando, A T, Culaba, A B, Aviso, K B, Tan, R R, Cuello, J L and Ng, D K S (2016) Fuzzy mixed integer non-linear programming model for the design of an algae-based eco-industrial park with prospective selection of support tenants under product price variability. *Journal of Cleaner Production*, **136**(Part B), 183-196.

Valenzuela-Venegas, G, Salgado, J C and Díaz-Alvarado, F A (2016) Sustainability indicators for the assessment of eco-industrial parks: Classification and criteria for selection. *Journal of Cleaner Production*, **133**, 99-116.

Yu, F, Han, F and Cui, Z (2014) Evolution of industrial symbiosis in an eco-industrial park in China. *Journal of Cleaner Production*, **87**(1), 339-347.

Yunus, R and Yang, J (2014) Improving ecological performance of industrialized building systems in Malaysia. *Construction Management and Economics*, **32**(1-2), 183-195.

Zhang, X, Skitmore, M and Peng, Y (2014) Exploring the challenges to industrialized residential building in China. *Habitat International*, **41**, 176-184.

Zhou, L, Hu, S Y, Li, Y, Jin, Y and Zhang, X (2012) Modeling and Optimization of a Coal-Chemical Eco-industrial System in China. *Journal of Industrial Ecology*, 16(1), 105-118.

Zhu, L, Zhou, J, Cui, Z and Liu, L (2010) A method for controlling enterprises access to an eco-industrial park. *Science of the Total Environment*, **408**(20), 4817-25.