# Nature-based Solutions for Industrial Logistic Parks.

To cite this article: E Agudo-Sierra and M Llaguno-Munitxa 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1122** 012007





# Nature-based Solutions for Industrial Logistic Parks.

**E Agudo-Sierra[1] and M Llaguno-Munitxa[1]**

[1] UCLouvain – Pl. de l'Université 1/ 1348 Louvain-la-Neuve/ Belgium

E-mail: elena.agudosierra@uclouvain.be

**Abstract**. The growth of logistic cities and freight villages to meet the increasing demand of e-commerce is unstoppable. This strategic sector has boomed during the COVID-19 pandemic, and it is estimated that by 2025, 138 million sqm of additional e-commerce areas will be built worldwide. Only in the last decade, the European logistic construction activity has tripled. Endless cities of asphalt and concrete have been built to host e-commerce companies, posing severe environmental threats such as desertification, loss of ecosystem and wildlife. Seeking to resolve these challenges, the United Nations Industrial Development Organization has proposed an international framework for Eco-Industrial Parks, with environmental guidelines for rainwater management, biodiversity preservation, or creation of recreational areas amongst others. However, prior studies and recommendations focused on the formulation of resilient spatial planning solutions for industrial logistic areas are yet very limited, and comprehensive literature reviews are still lacking. Aiming to address this research gap, this paper includes a review of recent investigations and projects focused on the study of resilient solutions for the design of industrial logistic areas. A bibliometric analysis of the literature published in Scopus database from 1992 to 2022 concerning terms such as Industrial Park, Eco-Industrial Park, or Nature-based Solutions is presented. The results reveal that the connection between Industrial Logistic Parks and Nature-based Solutions is very weak, or almost non-existent. This paper also discusses the project Plataforma Central Iberum -one of the largest industrial logistic spaces (3.5 million sqm) built in Spain- as a case study. This project is one of the first Industrial Logistic Parks developed in this country where nature-based solutions such as the integration of rainwater wetlands, load-bearing permeable pavements, green v-ditch medians, and natural self-sustaining infrastructure parks with diverse native plant species, were implemented. Overall, this paper aims to highlight the urgency to discuss and adopt Nature-based Solutions to render Industrial Logistic Parks more resilient.

## 1. Introduction

The world changed after March 14, 2020 - or at least in Spain. We would have to change this day to about a week earlier or later - the 18th of March in Belgium, the 17th in France, the 16th in Germany, the 9th in Italy, or the 23rd in the United Kingdom – for other countries in Europe. Confinements, coupled with mobility restrictions and other measures to protect public health, were implemented globally, reducing economic activity in most sectors and countries [1]. According to the International Monetary Fund (IMF) in the 2021 World Economic Outlook (WEO) report, the decline of the world economy as measured by Global GDP was reduced by 3.1% in 2020 [2], with a negative impact on "most" sectors, with the exception of digital sectors, such as e-commerce [1].

Millions of people made use of e-commerce. Electronic commerce was "the easiest and safest way forward", due to the retail store closures. A quick action, a click or tap on a computer or smartphone, became the new "normal" to purchase food, clothes, anything really. New users in countries such as

Australia and Germany grew in both 35%, while regular users in countries such as Vietnam and India also grew 57% and 55%, respectively [3]. These rises are confirmed by the worldwide retail figures which reported sales for $3.3 trillion in 2019, $4.2 trillion in 2020, and $4.9 trillion in 2021 [4].

In the last two years, over 500 studies focusing on the impact of COVID-19 on e-commerce have been published. However, most of these works have been published in specialized journals on Economics and Business, Statistics, Natural Sciences, or Social Sciences. This article focuses on the study of land use development associated to e-commerce infrastructure. While recent literature has repeatedly addressed the advantages of Nature-based Solutions (NbS) linked to the urban environments of cities to mitigate urban environmental stressors, enhance biodiversity and socio-cultural integration, and promote overall well-being [5,6,7], literature focusing on the strategies to aim for the development of resilient and nature-based logistic industrial parks is still very limited [8,9,10]. In the last decade, authors and international organizations, such as United Nations Industrial Development Organization (UNIDO) or European Union (EU), have published studies to define and discuss concepts such as Industrial Park (IP) [11,12], Eco-Industrial Park (EIP) [13,14,15] and NbS [16,17] to generate the main guidelines for new industrial developments without detailing specific solutions in the field of urban planning or designing. Building on this work, and seeking to contribute to the understanding of the state of the art of the strategies to aim for the formulation of resilient logistic industrial parks, this study points to inquire the published literature through a bibliometric analysis as other papers has already done in the past concerning this topic [18,19].

The article is organized as follows. Section 2 presents the bibliometric analysis. In Section 2.1, 2.2, 2.3 and 2.4 the database details, the results, the conclusions, and re-analysis are discussed. Section 3 presents the NbS implemented in the case study Plataforma Central Iberum. Section 4 presents the conclusions.

## 2. Bibliometric Analysis

### *2.1. Data and Analysis Method*

The data were obtained through the Scopus website (a search performed on April 1, 2022). Together with Web of Science and Google Scholar, Scopus is one of the largest and most widely used databases for bibliometric analysis [20]. Initially, an analysis was made upon the terms also currently used to determine EIP (Table 1), as detailed in the UNIDO international document [15].

**Table 1.** Search results of keywords from the Scopus database.

| No. | Code | Keywords | No. Art. |
|---|---|---|---|
| 1 | AFK | "Eco Industrial Park" | 813 |
| 2 | AGL | "Eco Economic Zone" | 63 |
| 3 | CFK | "Low carbon Industrial Park" | 22 |
| 4 | AFN | "Eco Industrial Cluster" | 13 |
| 5 | BFM | "Sustainable Industrial Area" | 10 |

First term: (A) eco, (B) sustainable, (C) low carbon, (D) green, (E) circular.

Second term: (F) industrial, (G) economic, (H) technological, (I) investment, (J) manufacturing,

Third term:(K) park, (L) zone, (M) area, (N) cluster, (O) estate.

Two restrictions were imposed for the query of the term "Eco-Industrial Park". The publications where the term was used in the title, abstract, or keywords were sought to restrict the search to only the publications that considered EIP as an important aspect of the work. The second was the publication period which was constrained from 1995 (the year of the first publication in Scopus, despite 1992 was the year when the term was first coined) to 2022.

### *2.2. Analysis Results*

The search came across 813 publications. These publications were divided into subgroups based on the language, country of origin, or type of publication amongst others to aim to identify the critical points and trends focusing on the area of spatial land use planning .

*2.2.1. Journals and Countries*. Most of the publications were written in English (750 publications and 92.2%), and the second most prevailing language was Chinese (60 publications, 7.4%). China is the first country in the number of publications worldwide (287) and the second in the total of citations (5433).

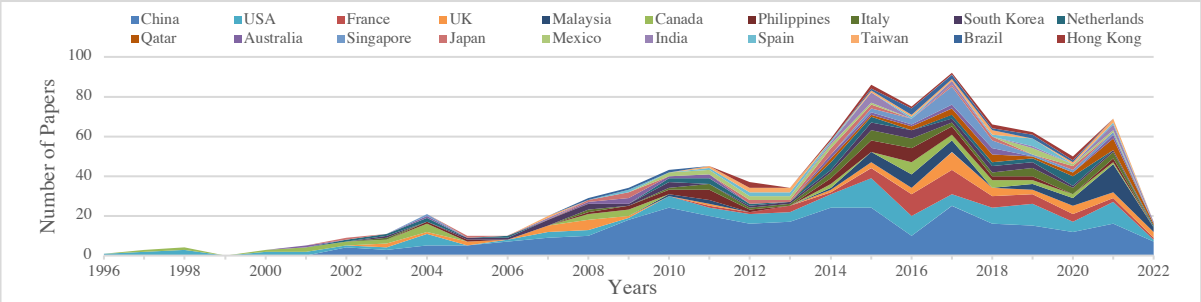
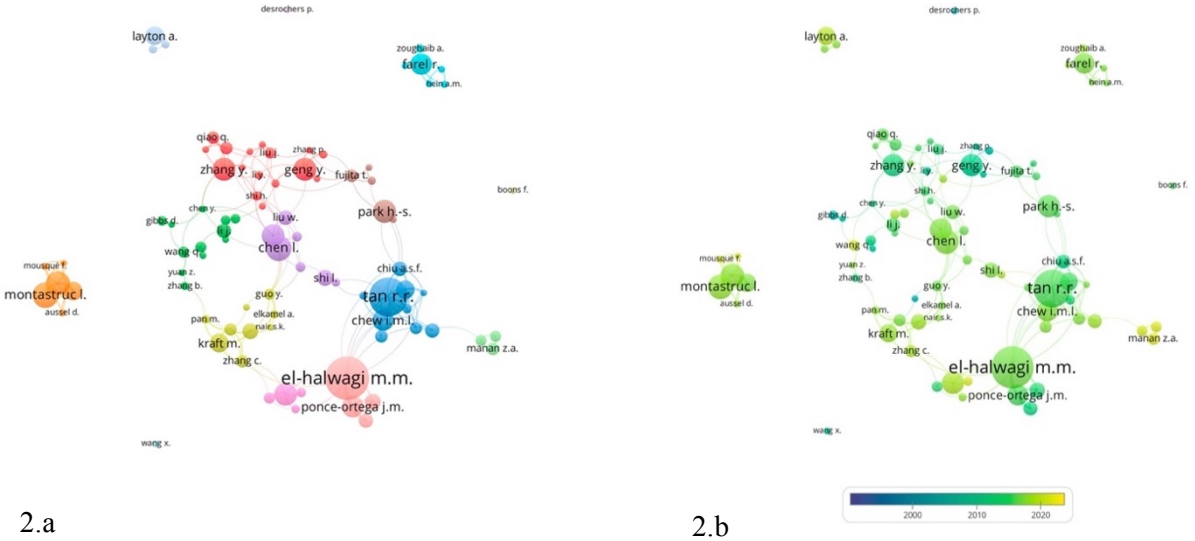



**Figure 1.** Number of "eco industrial park" related papers published by countries over the years. ***The period from 1996 to 2022 is shown. The year 1995 has been ignored given that only 2 articles were published in 1995 and their metadata was incomplete.

The distribution based on the type of publication was as follows: article (520 publications and 64.0%), conference paper (173 publications and 21.3%), book chapter (50 publications and 6.1%), review (36 publications and 4.4%), conference review (16 publications and 2.0%), short survey (6 publications and 0.7%), book (5 publications and 0.6%), note (3 publications and 0.4%), and editorial (1, 0.1%). As shown in Figure 1, the trend in the number of publications has been irregular in the last ten years, with 2015 and 2017 being the years when most papers were published. However, an increase is observed since 2020, which is potentially associated to the growth in e-commerce linked to the COVID-19 pandemic.

*2.2.2. Authors and Institutions*. The studied 813 publications were written by 1490 authors, of whom a significant proportion (1042 authors and 69.9%,) appears in only one publication, (218 authors and 14.6%) appear in at least three publications, and (25 authors and 1.7%) are credited in ten or more publications. This result confirms that a significant contribution of publications on the topic of EIP, is only carried out by a few authors.




2.a 2.b

**Figure 2.** Author collaboration network for publications associated with the term eco-industrial park. a) Network visualization representing the main 15 clusters of collaboration with different colors, and b) Overlay visualization representing the year of publication.

The authors' collaboration network (i.e. co-authorship) on the term "eco-industrial park" has been analyzed using a network visualization. In Figure 2, the circle size depicts the number of publications, while the thickness of the connection lines reflects upon the frequency of the collaboration. The principal investigators identified through this study are: El-Halwagi (Texas A&M University Engineering), Tan (De La Salle University), Montastruc, and Boix (Institute National Polytechnique de Toulouse), and Chen (Tsinghua University). These main authors show different ways to link with others. On the one hand, El-Halwagi, Chen and Tan are connected with other clusters or between them (El-Halwagi and Tan). On the other hand, Monstratuc and Boix are isolated in their own cluster.

*2.2.3. Subject Areas and Keywords*. The paper keywords enable the identification of critical points and emerging trends over different periods [21]. With this purpose, from 1995 to 2022, the study period was divided into four sub-periods, and the 25 most used keywords per sub-period were analyzed (Table 2).

**Table 2.** Author keywords (top 25 frequency used in four different periods).

| **Period 1 (1995-2001)** | **Period 2 (2002-2008)** | **Period 3 (2009-2015)** | **Period 4 (2016-2022)** |
|---|---|---|---|
| **Keyword (freq)** | **Keyword (freq)** | **Keyword (freq)** | **Keyword (freq)** |
| Eco-Industrial Parks (6) | Eco-Industrial Parks (34) | Eco-Industrial Park (186) | Eco-Industrial Park (208) |
| Ecosystems (4) | Eco-Industrial Park (33) | Industrial Management (85) | Industrial Symbiosis (113) |
| Environmental Protection (4) | Industrial Ecology (32) | Industrial Ecology (82) | Sustainable Development (95) |
| Eco-Industrial Park (3) | Sustainable Development (29) | Industrial Symbiosis (74) | Industrial Ecology (74) |
| Ecology (3) | Ecology (17) | Industry (73) | Eco-Industrial Parks (72) |
| Industrial Ecosystems (3) | Eurasia (15) | Sustainable Development (59) | Circular Economy (52) |
| Industrial Symbiosis (3) | Environmental Impact (14) | Eco-industrial Parks (55) | Industrial Economics (50) |
| United States (3) | Industrial Symbiosis (13) | Parks (53) | Sustainability (48) |
| Design (2) | Asia (12) | China (33) | Eco-Industrial Park (EIP) (47) |
| Efficiency (2) | Industrial Development (12) | Environmental Protection (29) | Industrial Parks (43) |
| Industrial District (2) | Sustainability (12) | Optimization (29) | Industrial Research (41) |
| Industrial Ecology (2) | Far East (11) | Ecology (28) | China (40) |
| Industrial Ecosystem (2) | Industry (10) | Industrial Research (27) | Optimization (40) |
| Industrial Management (2) | China (9) | Environmental Management (26) | Decision Making (39) |
| Kalundborg (2) | Environmental Management (9) | Eco-Industrial Park (EIP) (25) | Ecology (37) |
| Recycling (2) | Environmental Protection (9) | Circular Economy (24) | Environmental Impact (29) |
| Sustainability (2) | Industrial District (9) | Industrial Parks (24) | Article (28) |
| Sustainable Development (2) | Ecosystems (8) | Recycling (23) | Energy Efficiency (26) |
| Agglomeration Economies (1) | Industrial Economics (8) | Economics (20) | Costs (25) |
| Budget Control (1) | Industrial Management (8) | Environmental Impact (19) | Environmental Management (25) |
| By-producer (1) | Parks (8) | Industrial Development (18) | Industrial Emissions (24) |
| Canada (1) | Recycling (8) | Water Conservation (18) | Industrial Plants (24) |
| Characteristics (1) | Eco-industrial Development (6) | Energy Utilization (17) | Economics (23) |
| Choctaw (1) | Economic Development (6) | Planning (17) | Industrial Development (23) |
| Community (1) | Public Policy (6) | Energy Efficiency (16) | Economic And Social Effects (22) |

*2.3. Analysis Conclusions*

The analysis of the keywords related to EIP, revealed the lack of association with the urban planning, development, and design fields. Following this initial study, NbS was also queried through the bibliometric study. In the last decade, NbS has become a recurrent term in publications associated to urban planning, resilience and environmental well-being. The European Commission has named NbS as one of the ten structural environmental research and innovation areas [17].

### *2.4. Re-Analysis: "IP", "EIP" and "NbS"*

With the keyword-based analysis, no association was found between EIP and NbS. A second analysis was developed using the terms "Industrial Park", "Eco-Industrial Park" and "Nature-based Solutions", and quantifying the number of publications as the main criterion to measure the relevance of the topics. This second analysis is carried out based on the search for the three terms separately and combined with each other to have a general and comparative view. For this study, the restriction of "Title, Abstract, Keywords" was eliminated, and the term was sought all across the text. The first search ("Industrial Park") identified 23,328 documents, the second ("Eco-Industrial Park") 4,447 documents, the third ("Nature-based Solutions") 6,300 documents, the fourth ("Industrial Park" and "Nature-based Solutions") 51 documents, and the fifth ("Eco-Industrial Park" and "Nature-based Solutions") 17 documents. The results show that the literature around the concepts of NbS and industrial parks are scarce. The study also showed that the first publication that associated these two terms was not published until 2018, and thus the study of NbS for industrial areas is a novel field. The study also showed that the relevance of this field is increasing, given that in the last year, the publications tripled compared to previous years.

As shown in the bibliometric study, research focusing on NbS for the design of industrial logistic areas is still limited, however the study identified some isolated project examples that are worth reviewing to discuss the potential evolution of this field of research. In the following section the NbS incorporated in the project Plataforma Central Iberum (PCI) will be discussed.

## 3. Industrial Logistic Park and Nature-based Solutions

### *3.1. Context*

PCI is an Industrial Logistic Park located in the center of Spain, in the town of Illescas (Toledo), 35 km south of Madrid (Figure 3). Its development began in 2006 as a planning innovation that aimed to transform almost 3.5 million sqm of rural reserve land into urban industrial land. An area of 3,453,234 sqm of land was developed in 7 phases of execution that evolved from 2011 to 2021. These development generated 2 million sqm of logistic industrial land, from which 438,000 sqm were dedicated to the road network, 310,000 sqm to the green and blue infrastructure, and the rest belong to the ground for infrastructure and equipment.


**Figure 3.** Plataforma Central Iberum. *Urban Castilla la Mancha, 2021.*

### *3.2. Sustainability*

Today PCI is described as an EIP based on the principles of sustainable development [9,10]. The project aimed to address the objectives of global sustainability by accounting for environmental, economic, and social development. The actions were carried out in four fields: i) water (integral management of rainwater within the industrial estate), ii) soil (protection against erosion through ecological processes

that ensure its improvement), iii) energy (design and use of more efficient technology, reducing the carbon footprint and light pollution) and iv) society (collaboration with the different stakeholders involved, from the City Council to local associations, favouring the improvement of corporate responsibility of the companies). The project was developed by a multidisciplinary team that comprised professionals from the public sector, the private sector, and academia (through R+D+i agreements with institutions such as Universidad de Castilla-la Mancha, Universidad Complutense de Madrid and Universidad Politécnica de Madrid).

### *3.3. Nature-based Solutions*

*3.3.1. Blue Infrastructure. Integrated rainwater management*. One of the biggest challenges of an industrial area is the management of the rainwater cycle within the site created by large impervious area of roads, and parking surfaces. Large surfaces of impervious soil compromise the infiltration and natural recharge capacity of local aquifers and increase surface runoff. Thus, given the impervious surface of almost 2 million sqm, and the intense and intermittent rain fall in the rainy season (annual rainfall - 433mm), water management is critical. The proposed solution for PCI is based on two actions. The first is the reduction of the impervious surface with the naturalization of the traffic circles and median systems, "green v-ditch medians" and "permeable pavements", which amount to 150,000 sqm and represent a reduction of 20% of the initial volume to be treated. The final volume of water to be managed is reduced to 34 $Hm^3$/ha, all of which is treated in situ through the second action, an interconnected system of naturalized "rainwater wetlands" (Figure 4). These wetlands with a capacity of 67.2 $Hm^3$ avoid the discharge of large volumes outside the property and reduce the costs of possible infrastructures to manage the discharge such as collectors and pumps. In addition, the proposed water management system generated wetland ecosystems, which previously did not exist in the area, increasing the biodiversity of local flora and fauna.


**Figure 4.** Blue Infrastructure Plans. *Urban Castilla la Mancha and Irati Proyectos, 2021.*

*3.3.2. Green Infrastructure. Use of native plant species*. The other major challenge of large industrial logistic area developments, is to minimize environmental degradation. The ambition was to avoid soil erosion by promoting ecological processes that encourage its redevelopment. The proposed approach was based in four actions. Firstly, "native vegetation" was used, covering the three strata (herbaceous, shrub, and tree) to promote the regeneration of degraded ecosystems due to the secular agricultural use of the territory. Vegetation that does not require irrigation was planted using species adapted to the local climatology and edaphology, through characterization of the land and the preparation of a floristic catalog. Secondly "traditional woody crops" were maintained and replanted -olive groves, vineyards and cereal crops- and local farmers were engaged for their management. Thirdly "insect hotels" and "rest

stops" were installed around green areas creating habitats and shelters to support biodiversity. Fourthly, multifunctional natural open spaces were proposed and integrated within the urban-recreational land use category with programs such as skate parks and climbing parks, green areas such as forest, shrubs and meadows, and bicycle lanes, connecting the industrial logistic park and city center.

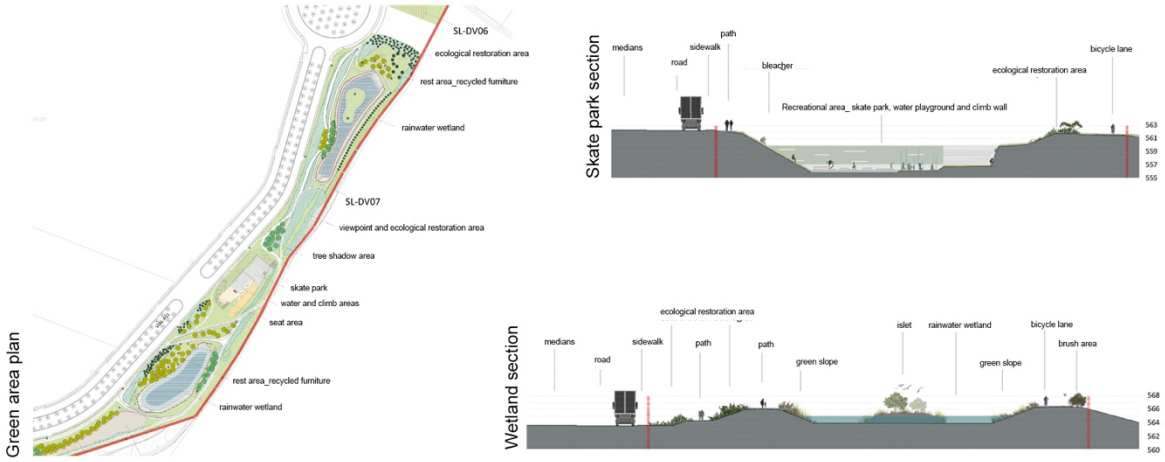



**Figure 5.** Green Infrastructure Plans. *Urban Castilla la Mancha and Irati Proyectos, 2021.*

## 4. Conclusions

The article has highlighted the lack of research and actual initiatives focused on Nature-based Solutions as a strategy to aim the development of Industrial Logistic Parks from urban planning and design fields. On the one hand, the paper has provided a bibliometric analysis, with the terms "Industrial Park", "Eco-Industrial Park" and "Nature-based Solutions", to explore the studies that aimed at contributing to the formulation of industrial land use strategies through an environmental perspective. The results showed the literature establishing connections between these terms is scarce. On the other hand, the paper has also presented a case study - Plataforma Central Iberum-, where industrial urban planning strategies including nature-based solutions were implemented. This Industrial Logistic Park included the design of blue infrastructure such as green v-ditch medians, permeable pavements and interconnected system of rainwater wetlands, and green infrastructure such as native-zero irrigation vegetation, maintained of traditional woody crops, insects hotels and multifunctional natural open space.

## References

[1] United Nations. 2021. Covid-19 and E-commerce. A global review.
[2] International Monetary Funding. 2021. World economic outlook: Managing Divergent Recoveries. Washington, DC, April.
[3] Statista. 2021. Change in e-commerce usage to purchase products normally bought in-store due to coronavirus (COVID-19) worldwide as of March 15, 2020, by country.
[4] Statista. 2021. Global retail e-commerce sales 2014-2025.
[5] Frantzeskaki N. 2019. Seven lessons for planning nature-based solutions in cities. Environmental Science & Policy, 93, 101–111. https://doi.org/10.1016/j.envsci.2018.12.033
[6] Llaguno-Munitxa M, & Bou-Zeid E. 2020. The environmental neighborhoods of cities and their spatial extent. Environmental Research Letters, 15 (7). https://doi.org/10.1088/1748-9326/ab8d7e
[7] Wickenberg B, McCormick K, and Olsson, J. A. 2021. Advancing the implementation of nature-based solutions in cities: A review of frameworks. Environmental Science & Policy, 125, 44–53. https://doi.org/10.1016/j.envsci.2021.08.016

[8] Isabel J, Agudo-Sierra E, Alonso P, Muñoz N, Palain S and S Sardinero. 2018. Aplicación de Soluciones Basadas en la Naturaleza mediante Restauracion Ecologica y Promoción de la Biodiversidad en las Zonas Verde de un Parque Industrial en el Centro de España. Conama 2018. Cong. Nac. del Medio Ambiente.
[9] Universidad de Valladolid and AEICE. 2020. Catálogo de fichas técnicas de Soluciones basadas en la Naturaleza.
[10] Alonso P, Muñoz N and Agudo-Sierra E. 2021. Plataforma Central Iberum. Un caso de estudio de aplicación de Soluciones basadas en la Naturaleza en un desarrollo industrial. Planur-e. Territorio, Urbanismo, Paisaje, Sostenibilidad y Diseño Urbano, 19, 1-14. ISSN-e 2340-8235.
[11] United Nations Industrial Development Organization. 2019. International guidelines for Industrial Parks.
[12] Beers D, Tyrkko K, Flammini, Barahona C and Susan C. 2020 Results and Lessons Learned from Assessing Industrial Parks in Eight Countries against the International Framework for Eco-Industrial Parks. Sustainability 12, no. 24: 10611. https://doi.org/10.3390/su122410611
[13] Côté R and Cohen-Rosenthal E. 1998. Designing eco-industrial parks: a synthesis of some experiences. Cleaner Production, 181-188. https://doi.org/10.1016/S0959-6526(98)00029-8
[14] Roberts B. 2004. The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. Cleaner Production, 12, 997-1010. https://doi.org/10.1016/j.jclepro.2004.02.037
[15] The World Bank, UNIDO, and GIZ. 2021. An International Framework for Eco-Industrial Parks. Version 2.0. https://openknowledge.worldbank.org/handle/10986/35110
[16] Blau M.L, Luz F, Panagopoulos T. 2018. Urban river recovery inspired by nature-based solutions and biophilic design in Albufeira, Portugal. Land, 7 (4). https://doi.org/10.3390/land7040141
[17] European Commission. 2021. Evaluating the impact of nature-based solutions. A handbook for practitioners. https://op.europa.eu/en/publication-detail/-/publication/d7d496b5-ad4e-11eb-9767-01aa75ed71a1
[18] Boix M, Monstratuc L, Azzaro-Pantel C, Domenech S. 2015. Optimization methods applied to the design of eco-industrial parks: A literature review. Cleaner Production, 87, 303-317. https://doi.org/10.1016/j.jclepro.2014.09.032
[19] Fuentes Barrera G.A, Gabarrel X, Rieradevall J and Guerrero J.G. 2021. Trends in global research on industrial parks: A bibliometric analysis from 1996–2019. Heliyon, 7. https://doi.org/10.1016/j.heliyon.2021.e07778
[20] Harzing A and Alakangas S. 2016. Google scholar, Scopus and the web of science: a longitudinal and cross-disciplinary comparison, Scientometrics, 106, 787–804. https://doi.org/10.1007/s11192-015-1798-9
[21] Lozano S, Calzada-Infante L, Adenso-Díaz B and García S. 2019. Complex network analysis of keywords co-occurrence in the recent efficiency analysis literature, Scientometrics, 120, 609–629. https://doi.org/10.1007/s11192-019-03132-w