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Analysis and Classification Applied to the Methods of Industrial Symbiosis Platform Evaluation

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Abstract
The search for solutions that would help reduce the consumption of non-renewable resources and at the same time limit the emissions of greenhouse gases is a crucial factor for the sustainable economic growth. Industrial symbiosis proved to be that strong ally in the fight for the ecological, economic and social achievements – this bold statement is confirmed by the rapid rise in the number of academic publications on this topic, especially starting from the year 2007. In Europe and Asia, especially in China, the growth of industrial symbiosis has become more evident due to the state policy support. The industrial sector was obviously more active and involved in that trend, specifically because of the produced wastes and higher potential to recycle those waste products and by-products and integrate them into the production cycle. The most common examples come from the chemical, cement, paper and steel industries, as well as oil refineries.
Reuse of production wastes from other industries does not always lead to beneficial results for the companies. These wastes are quite often of low quality in comparison with the initial materials for replacement. In cases when production technology is oversensitive towards low-quality materials, then the problems may arise at the stage of manufacture. In our article, we pay attention to the way the companies can manage wastes quality by integrating their suppliers of wastes into operational business processes of the buying company. Wastes quality control is an important capacity of industrial symbiosis, especially if the companies try to raise their efficiency in that area.

Key-words: Platform, Platform Law, Network, Industrial Symbiosis, Industrial Ecology, Circular Economy, Sustainability, Eco-industrial Park (EIP).

1. Introduction

Apart from improving the quality of life and social well-being level, global industrialization caused an increase in the negative impact on natural environment due to the unbalanced models of production and consumption. Within the model of circular economy and starting from the early 2000-s the intra-industry networks with multiple supply chains came into being. They grew up fast using the patterns of industrial and urban symbiosis.

Industrial symbiosis (IS) – is the domain of industrial ecology research aimed at formation of knowledge network that would include new implemented or perspective patterns for the exchange of resources in the process of enterprise interaction for the sake of industrial ecosystems development. The publications describe new exchange patterns as the search for the new sources of essential resources, acquisition of benefits that cannot be derived directly from the main product. This search leads to the establishment of new business contacts, technical improvements and cultural transformations, all in all improving the ecological perspective [Lombardi and Laybourn 2012].

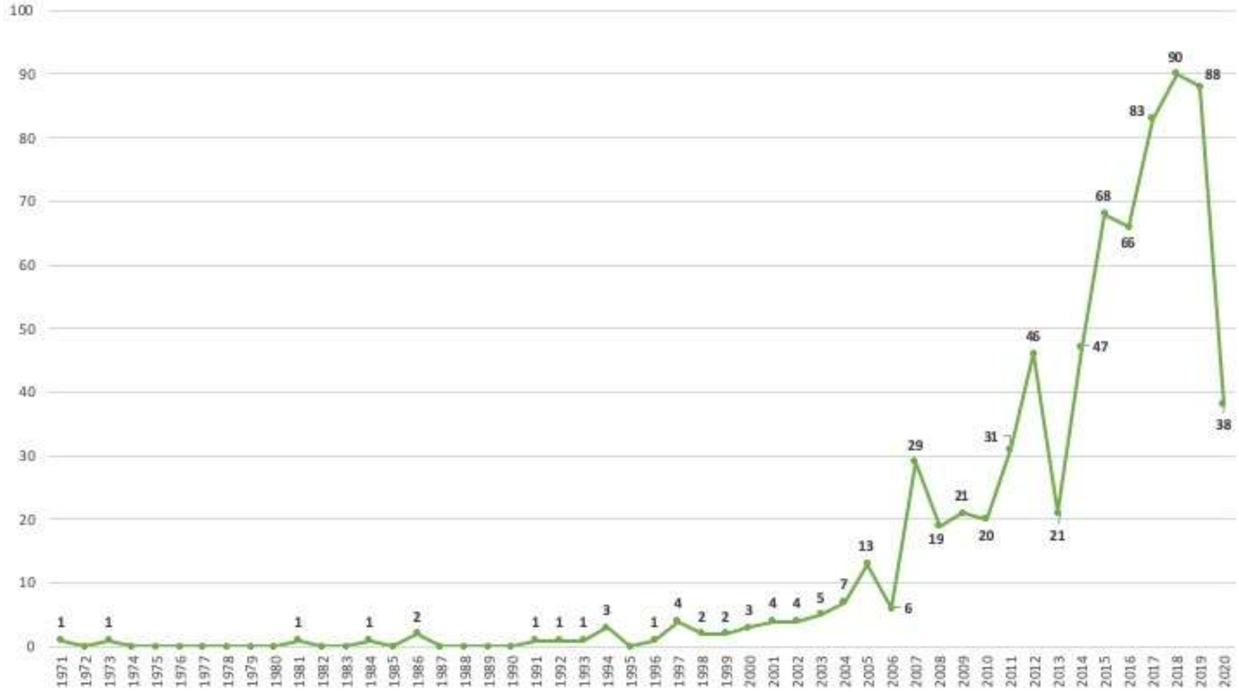
The results of industrial symbiosis combined with the expansion of its benefits might facilitate the implementation of this practice both inside the private sector and state-owned enterprises, stimulating the formation and development of synergy. Industrial symbiosis (IS) has been acknowledged as the most promising strategy for the paradigm shift towards circular economy and stable growth. In other words, privately-owned companies and politicians are all interested in implementation and support of the IS.

A Survey of the Trending Growth of Interest in Industrial Symbiosis

The growth of interest in industrial symbiosis can be traced through the analysis of 752 articles dedicated to the topic of industrial symbiosis. The collected and processed data shows the tendency for progressive increase in the number of publications since 1971 (Fig. 1). The successful example of industrial symbiosis in the Kalundborg city acted as the catalyst of public attention to this issue. Multiple research papers initially published mainly by the people involved in the system of industrial symbiosis inside Kalundborg, confirmed economic, ecological and social benefits for the companies and local community. The development of pan-European, national and regional programs and strategies that stimulate the practice of industrial symbiosis has undoubtedly affected the number of publications [Chertow and Park, 2016].

It is worth noting that the value showed in 2020 is still preliminary, because it only covers the first five months of the year, and nevertheless, judging by the number of already published articles, it is quite probable that their number will multiply and surpass that of the previous year.

Figure 1- The Number of Publications Dedicated to the Topic of Industrial Symbiosis per Year in International Academic Databases

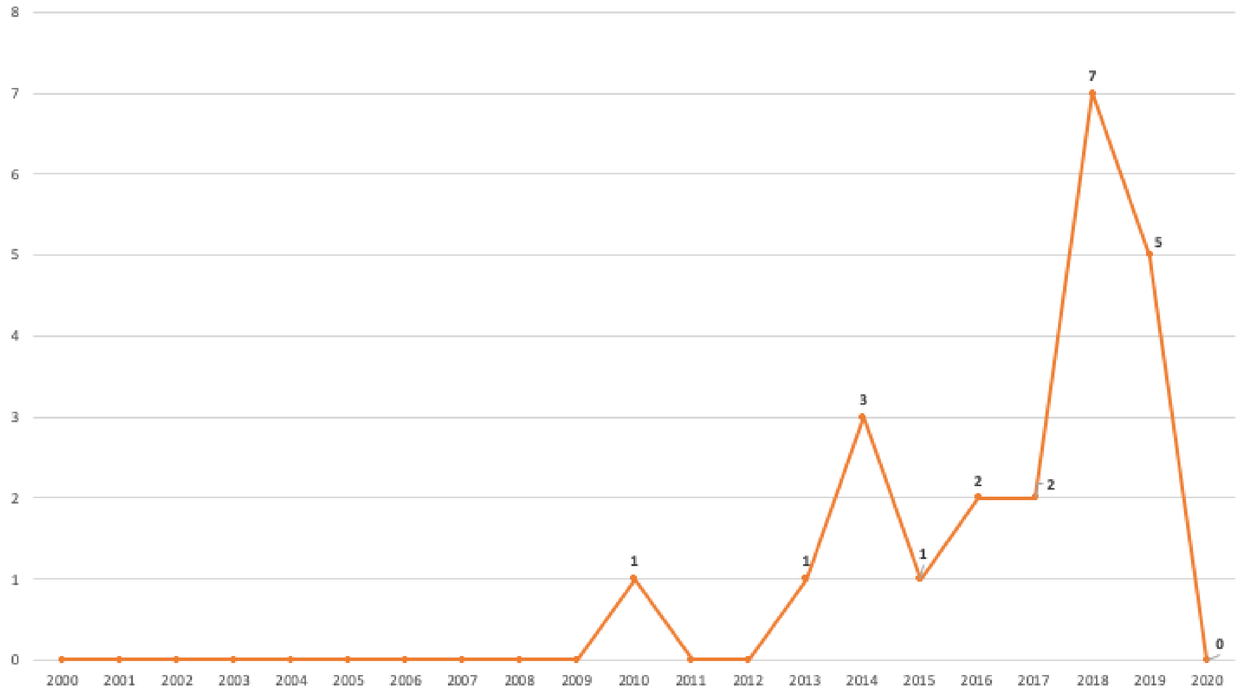


*Compiled by the authors of this article.

To search and analyze the related publications we use a number of academic databases which include the publishers with the most number of articles on the topic, such as Scopus, Wiley Online Library, Springer, ScienceDirect, ResearchGate, and also the eLibrary database for the publications in Russian language.

In order to cover the largest possible number of publications, the chosen key words for the search were “industrial symbiosis” (and the respective Russian translation “промышленный симбиоз”) in every year starting from 1971. Next step, inside each academic database we only selected the publications with the search phrase in their titles, abstracts and key words. After that we analyzed the contents of every single article in order to estimate if they actually deal with the topic of the industrial symbiosis. We excluded all of those articles where industrial symbiosis was just mentioned as one of the examples to explicate another concept or distinguish between several concepts. The articles initially selected were cross-checked and double-checked through the databases to avoid their repetition, the duplicates were eliminated. Thus, a total of 752 articles were selected for further research. It is worth noting that the analysis of the eLibrary database showed the minimum number of publications dedicated to industrial symbiosis in comparison with other sources, the very first publication dates back to 2010 and even now the quantity of published articles remains at a low level (Fig. 2).

Fig. 2- The Number of Publications Dedicated to the Topic of Industrial Symbiosis per Year (eLibrary)



* Compiled by the authors of this article.

The largest number of published articles on the topic of industrial symbiosis belongs to Asia. China, in particular, has the highest quantity of research papers and 36 implemented symbiotic networks of the industrial symbiosis type, which surpasses that of other countries in the world. An explanation to this phenomenon might be the growing concern over greenhouse gases emissions and the necessity for their reduction due to the strong presence of industries with higher energy consumption and carbon dioxide discharge into the atmosphere. The rapid economic growth resulted in increased consumption of energy and material resources, greenhouse gases emissions that significantly exceed international norms of environmental protection [Pao and Chen, 2019]. This pushed China's policy to take action and reduce the amount of emissions. This leads us to the conclusion that the outstanding number of organized projects of industrial symbiosis is to a greater extent justified by the country's state policy. Although European countries have a long-running tradition of sustainability, it was China that took measures for reduction of greenhouse gases emissions, development of programs and strategies, including research and financial stimuli. Despite the fact that industrial symbiosis was the major goal in the developed plans, the implementation of various measures within the circular economy and construction of eco-industrial parks facilitated the development of industrial symbiosis and held back the negative consequences of rapid industrialization and urbanization.

In most cases the emergence of industrial symbiotic relations and especially the organization of successful industrial symbiosis do not directly depend on the existence of a supporting state policy. IS comes into being unplanned and on the company's own initiative. For example, industrial symbiosis in the Danish city of Kalundborg emerged spontaneously in 1960s and united four major industries with the companies outside the industrial park [Zhang and Chai, 2019]. With time a lack of material resources lost its status of the sole purpose for the industrial symbiosis, adding to the list the economic and ecological benefits brought to the enterprises by synergy.

Though some countries of the Southern Europe, Spain and Portugal do not register many cases of industrial symbiosis, they make every possible effort to introduce and develop sustainable methods and programs for the implementation of industrial symbiosis [Ferreira et al., 2019].

Even though industrial symbiosis is currently marching around the globe, in Russia a similar industrial model, known as integrated resource management, was planned in the middle of 1980. That model suggested the distribution of the waste products from the mining industry on the Kola Peninsula when the wastes of one manufacturing enterprise could turn into material resources for another one. The pattern of integrated management promised improvements for the population well-being and reduction of emissions from the mining industry of that region. Collapse of the Soviet Union put an end to that initiative and the integrated resource management was never implemented to the full. Other similar experiments with the integrated management sporadically emerged in the Eastern Europe, but as a rule, they were all gone with the collapse of communist regimes in those countries [Z. Gille, 2000]. Industrial symbiosis can take the leading role in environmentally friendly initiatives of the existing industrial networks and become a part of the current Arctic megaprojects by cutting expenses in raw materials and energy consumption. In addition, IS reduces the negative ecological impact of big business, which is especially important for the fragile environment of the Arctic zone of the Russian Federation.

Evidently, former communist states may become a rich source of information with critical cases of unsuccessful IS implementation. Academic publications dedicated to the topic of industrial symbiosis for the most part describe the "success stories", while lessons that can be learnt from the mistakes are just as much important. We need to understand whether the failures were the result of some external limitations, such as the economic conditions in the region and country as a whole. On the other hand, malfunctions may occur inside the symbiosis network itself, and knowing the true causes may become a rewarding source of information for the understanding and prevention of such cases in future in other networks.

For the Russian Federation and former Soviet Republics, it makes sense to search for the implemented cases or any promising projects of industrial symbiosis and estimate their potential to build new synergies. In other words, we need to evaluate local existing conditions from the point of view of active and operating industries, legislation and other limiting factors, as well as find better solutions for integration of industrial symbiosis in Russia. Further research is necessary for a thorough comparison of the thematic publications in countries with variable levels of industrial symbiosis development; this would help make conclusions on the reasons for such variability in the development, influencing factors, and how they can act as stimuli or barriers of the development.

2. Methods of Industrial Symbiosis Evaluation

Academic publications draw attention to the fact that one of the major gaps in construction, development and implementation of the IS models is the absence of a specific value system, which is required for the estimation of IS. Despite the fact that multiple research publications, dedicated to the study of evaluation methodology for industrial symbiosis, suggest a variety of indicators and methods of calculation, nevertheless an overwhelming, universal and effective system suitable for the analysis of industrial symbiosis is still missing.

There is a stark contrast between the analytical methodologies used in different systems of industrial symbiosis. Within the scope of ecological sustainability calculation for the quantitative evaluation of environmental footprint, the following methods and indicators were employed.

1. Life-cycle assessment for quantitative estimation of potential impact on the environment throughout the cycle, is a common method [Daddi et al., 2017, Martin and Harris, 2018]. Ecological benefits of industrial symbiosis are estimated in comparison with standard scenarios.
2. Material flow analysis [Chance et al., 2018, Guo et al., 2016] and method of exergetic analysis (thermodynamic system analysis method that takes into account the interaction with the environment) [Wu et al., 2018, Wu et al., 2016b] have been among the frequently used methods in thematic publications.
3. Quantitative assessment of greenhouse gases emissions for the most part took place in China, in the country where this is a burning issue, considering the amount of emissions [L. Dong et

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al., 2014b; Fang et al., 2017; Jacobsen, 2006; Wu et al., 2016b; F. Yu et al., 2015a; Liu et al., 2017]. Assessment of carbon emissions relied on the methods proposed by IPCC in 2006, and Guidelines for national greenhouse gas inventories [F. Yu et al., 2015a]. The hybrid model, integrating two types of analytical patterns (expenses/results approach and reserves analysis based on the process approach), was used to analyze the carbon footprint in Qijiang, China [Fang et al., 2017]. In Japanese Kawasaki the reduction of carbon dioxide emissions was estimated by the calculation of annual CO2 emissions. This value depends on a number of indicators, such as CO2 emissions caused by raw materials delivery, industrial and city wastes subjected to recycling and utilization, CO2 emissions in cement production and CO2 emissions caused by wastes production [Hashimoto et al., 2010].

4. The system of indicators designed to evaluate the impact of industrial symbiosis, for example, reduction of resources consumption and limitation of emissions, "ecological benefits" defined as enterprise consumption or emissions, which can be reduced by implementation of industrial symbiosis [Dong et al., 2013b]; additionally, the indicators that include quantitative estimation of energy consumption, and exergy consumption (the amount of thermal energy convertible to work) [Wu et al., 2016b].

Economic effects or consequences of industrial symbiosis are estimated with such indices as cutting expenses from raw materials supply and wastes utilization, revenue from selling wastes [Guo et al., 2016], combination of several indices (reduction of direct expenses, real investments and predicted payback periods) as means of evaluation of the economic aspects of industrial symbiosis [Jacobsen, 2006], and also estimation of economic efficiency by calculation of gross profit and dynamic investment payback period [Cao et al., 2017]. There is an additional index of "economic benefit", which is expressed by either revenues or expenses, avoided by an enterprise with the help of reduction in raw material supply, trimming the amount of produced wastes or their usage in the process of manufacture [Dong et al., 2013b].

Methods employed for the quantitative assessment of industrial symbiosis varied a lot, and those assessments quite often relied on the life cycle evaluation. Environmental analysis was the most frequent type, followed by economic analysis. The predominance of environmental factor can be explained by the growing concern about climate change, urgent necessity to reduce greenhouse gas emissions, save natural resources and expand ecological policy. The increasing attention to economic consequences assessment can be justified by the fact that companies normally try to create synergy to acquire economic benefits. Hence, it is an important effect be considered.

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In comparison with ecological and economic indicators the social indicators are estimated with a certain degree of subjectivity and complexity, the quantitative data is much harder to acquire [Hutchins et al., 2019, Ibáñez-Forés et al., 2019, Kühnen and Hahn, 2018]. Since social domain is the most difficult object for a quantitative assessment, research papers dedicated to industrial symbiosis lack complex analysis of sustainability.

Moreover, another possible issue arising during the estimation of industrial symbiosis social impact is the question of distinction between the direct influence of industrial symbiosis and other measures taken, as well as a social benefit increase. The social domain might be a crucial element in the development of industrial symbiosis, inasmuch as the community and the local governments are informed of the benefits of such synergy and they can even become active participants in the process of industrial symbiosis. This means that further research is necessary to study the effects of industrial symbiosis on the society. For example, indices, such as quality of life (improved social and economic conditions), public healthcare funding, growth in employment rate and income level, transport accessibility, can be referred to in the process of assessment of the industrial symbiosis impact on the neighbouring societies. Besides, researchers should also focus their attention on methodology and means for the distinction of industrial symbiosis effects from other measures, taken to improve sustainability. It is also important to identify those factors which are most valuable for the local population.

3. Industrial Symbiosis Networks

Those enterprises involved in symbiosis should create a reliable network, because the activity of companies, accepting wastes, partially depends on the flow of waste resources from the supply chains, and their shipment in enough quantities and of acceptable quality. Delays in shipment can endanger an enterprise operation or even the complete network of industrial symbiosis [Wang et al., 2018]. At the same time, it is important to understand the network structure of industrial symbiosis and patterns of interaction between its participants because it affects the results of synergy, both economic and ecological aspects. In other words, description of the network and its internal interactions must be optimized to the extent, when both economic and ecological indices of the complete network are improved.

Analysis of the industrial symbiosis networks is rooted in social network analysis [Shi and Chertow, 2017; Song et al., 2018; Velenturf, 2016]. This method defined several interrelated concepts, such as density, degree centrality, degree distribution, centrality, closeness centrality,

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compactness and interconnection degree. The network behaviour in case of certain fluctuations is analyzed to estimate the network's resilience in the face of devastating scenarios and cascade effect initiated by them. The vulnerability of the industrial symbiosis network is estimated with the theory of automated management, mathematical analysis method [Wang et al., 2018], and based on the indicators of the industrial symbiosis network vulnerability and node connection [Li et al. al., 2017]. In addition, the vulnerability of industrial symbiosis network might be affected by economic fluctuations.

Stimuli and effects Produced by Implementation of the Industrial Symbiosis for Enterprises

Economic motives are the most common stimuli for the companies to become the part of industrial symbiosis. The reasons why companies try to achieve symbiotic relations are economic profit, improved competitiveness, potential tax reduction or wastes processing and elimination. Ecological and social reasons are normally defined by the state support of industrial symbiosis. Reduction of wastes and greenhouse gas emissions, employment creation are among the main reasons why governments develop plans and measures engaging the synergy development; additionally, extra taxation is applied to companies that do not implement sustainability, such measures should prevent them from sending their wastes to burial polygons and incineration plants.

There are several tasks for the companies. Whether it be creating a synergy, its operation or expansion, industrial symbiosis is successfully developing, bringing benefits to all involved parties. When organizing new symbiosis, companies should build mutual trust in relationships in order to provide enough quantity and quality of wastes and resources supply required for the operation of accepting companies. Quite often this trust is rooted in the geographical proximity of companies, the way it happened in Kalundborg. Nevertheless, the problem for companies grows in proportion when the symbiosis implies the co-use of utility services, including water and heating, which in addition to the large primary investments in infrastructure represent a greater risk of supply fluctuations affecting enterprise operation. That is why it comes as no surprise that the number of cases of enterprise waste distribution is greater than the number of examples with co-usage of utility services. Additionally, the method of symbiotic network construction can also become the source of problems for the enterprises, especially in case of delays in the supply. The effect is greater if the company where problems occur is the central element of the network with greater synergy responsibilities and greater number of connections. This idea is confirmed by the example of the Kalundborg city. In such cases and in order to minimize the influence of failures, the implementation of new symbiosis might become an excellent opportunity to increase economic benefits and reduce vulnerability of the symbiosis network. For example, the study of Kalundborg example of industrial symbiosis lead the researchers to the conclusion that an increase in synergy of industries also reduces the network vulnerability, because failure of one element could be easily compensated by its replacement with another one, since the network had readily available alternatives [Chopra and Khanna, 2014].

Waste Quality Management in Industrial Symbiosis

After signing the first symbiotic partnership agreement and the successful start of its operation, quite often the enterprises try to expand their network of industrial symbiosis further. Y et, in order to maintain high quality of the final product and keep labour efficiency at the production site, which was designed and optimized for the operation with primary resources in the first place, waste materials should meet strict quality standards. Management of variable waste quality demands from the product manufacturer interaction with the supply chain network, so that the waste quality matches the requirements of industrial manufacture.

Nevertheless, this approach did not manage to bring the results expected from it, since the waste resources suppliers had no clear understanding of how they should adapt the waste quality to the production standards; notwithstanding the fact that academic and research publications on the topic of supply chain networks underline the positive correlation between supplier’s integration and efficiency, estimated by, for example, the quality of supplied materials [Huo et al., 2019].

Assessment criteria for the waste quality and development of suitable stimuli is complicated by the difference of industries involved in industrial symbiosis [Yenipazarli, 2019]. Descriptions of industrial symbiosis cases show that symbiotic relations are quite common for process industries. For example, the MEASTRI [Evans et al., 2017] database, showcasing global symbiotic exchange, indicates that 71% of waste buyers and 75 % of waste suppliers belong to the process industry sector [Prosman 2018].

Process industry is characterized by a higher internal production complexity which is defined as “the level of detail and dynamic complexity of products, processing systems, planning and management of industrial enterprise” [Bozarth et al., 2009]. In the context of industrial symbiosis higher internal complexity of manufacture might lead to complicated relations between waste quality and operational parameters, hence, it can create ambiguity and subsequently waste quality [Pires et al., 2019]. Coordination of waste and side products properties with the production standards might require that suppliers separate certain waste fractions and mix them with other materials.

In order to optimize the strategies that take into account various external factors in their relation to green supply chain, the supplier integration system (SI) aims to provide effective and efficient flow of products, resources, information, services and solutions [Feyissa et al., 2019, Qu et al., 2019]. There is a positive relationship between the SI and supplier effectiveness, the SI is especially effective when supported by internal integration [Zhao et al., 2011].

Transfer of complex information, mandatory for waste management in industrial symbiosis, within the pattern of suppliers' integration, instead of passive requires a faster interactive approach. At the same time, employment of interactive approaches to SI, supported by internal integration, but with the insufficient knowledge of the buyer's processes and products, will not let the suppliers adjust the waste quality according to the buyer's requirements.

Absorptive capacity — is a firm's ability to "recognize the value of new information, assimilate it, and apply it to commercial ends" [Cohen and Levinthal, 1990]. It shows the way SI allows companies to manage waste quality. Hence, absorptive capacity reflects the abilities required of knowledge transfer for waste quality management.

Absorptive capacity can be easily classified into two parts: 1) Potential absorptive ability creates knowledge by means of acquisition and assimilation of respective knowledge; 2) Realized absorptive potential uses potential absorptive ability to transform and use information. Table 1 illustrates the aspects of both potential and realized absorptive capacity of a supplier with respect to SI, which is directed towards the waste quality management.

Table 1- Aspects of the Suppliers' Absorptive Capacity with Respect to the Waste Quality Management through SI.

Direction	Elements [Zahra and George, 2002]	Relation to the waste quality management through integration system SI [Setia and Patel [2013]
Potential absorptive capacity	Receive	The supplier's ability to identify and accumulate respective knowledge through the integration system for the waste quality management.
	Assimilate	The supplier's ability to assimilate and understand acquired knowledge necessary for the waste quality management.
Realized absorptive capacity	Transform	The supplier's ability to integrate existing knowledge into new knowledge in order to estimate better waste quality management.
	Use	The supplier's ability to use the existing competence and create new competence for the waste quality management.

The absorptive capacity of an enterprise might differ from their business partner enterprise; SI will be more effective when it is established between the buyer and waste supplier with the overlapping knowledge databases [Park and Chung, 2019].

The SI alone might be not sufficient for the approval of waste quality according to the production requirements. Other conditions might also affect the integration system, including power imbalance, relationships management and depth of integration [Prosman et al., 2016].

Optimization of the symbiotic operational processes and the value chain allows enterprises to expand the domain and scope of industrial symbiosis. Moreover, the results associated with the concept of absorptive capacity can be used in practically any SI implementation, which are outside the scope of industrial symbiosis.

4. Conclusion

As of today, a number of different indicators have been suggested, whereas a clear and evident roadmap with available tools is still missing [Domenech et al., 2019]. Too many indices without their critical analysis and classification create confusion, which in its turn limit their distribution and implementation. The analyzed thematic publications had one thing in common, that is the obvious imbalance, since the environmental impact, out of all sustainability aspects, was the most frequent topic with a larger number of publications, followed by economic and social indices respectively. In order to overcome this issue, a taxonomic research is required; it would help people responsible for decision-making both in private sector and state institutions choose the right indices for making proper management decisions.

Suggested classifications of the industrial symbiosis indices are designed to answer the three major questions: what, where and how to measure. This brings a better understanding of available indices in terms of the target, context and methodology, respectively.

This research paper allows us to identify perspective trends in future research. Firstly, indices that estimate the social benefits from the IS should be developed. Another future domain of research will be the development of indices and methods pointed in the direction of industrial symbiosis, which would allow quantitative estimation of the three sustainability aspects: ecological, economic and social. Although, there are some publications dedicated to these three domains, they are not focused on the industrial symbiosis. Moreover, inclusion of ecological, economic and social components involved certain complications, such as integration of qualitative and quantitative indices into a single system of assessment [Schoubroeck et al., 2018]; possibility of simultaneous analysis of several target functions in the research optimization and complexity of integration of the social component with other domains, since social component is associated with entire enterprise operation, but not single isolated processes [Petit et al., 2018].

Special attention should also be paid to the development of indices at the levels of the company and its environment. The development of company-level indices which could be used for the quantitative assessment of the IS benefits for the company, are a crucial stimulus for the companies to implement IS. The environmental-level indices will help evaluate the global footprint of the IS. Besides, taking into consideration the growing importance of IS in urban and rural areas [Kim et al., 2018a], additional indices specific for those domains should be developed. As for the methodological perspective, certain tools based on the combination of more than one methodology are required to provide a clear assessment of IS from several point of view. This will also help improve the practical IS planning and design.

To conclude, further research would be necessary to overcome these barriers and assess the specific indices of industrial symbiosis. They will allow quantitative evaluation of the influence of this practice on companies, environment and the society; compare industrial symbiosis in different domains that is different characteristics of the network considering the specifics of the region where it takes place.

References

Bozarth, C.C., Warsing, D.P., Flynn, B.B., & Flynn, E.J. (2009). The impact of supply chain complexity on manufacturing plant performance. *Journal of Operations Management, 27*(1), 78-93.

Chertow, M., & Park, J. (2016). *Scholarship and practice in industrial symbiosis: 1989–2014.* In Taking stock of industrial ecology, Springer, Cham. 87-116.

Chopra, S.S., & Khanna, V. (2014). Understanding resilience in industrial symbiosis networks: Insights from network analysis. *Journal of environmental management, 141,* 86-94.

Cohen, W.M., & Levinthal, D.A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly,* 128-152.

Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, conservation and recycling, 141,* 76-98.

Dong, H., Ohnishi, S., Fujita, T., Geng, Y., Fujii, M., & Dong, L. (2014). Achieving carbon emission reduction through industrial & urban symbiosis: A case of Kawasaki. *Energy, 64,* 277-286.

Evans, S., Benedetti, M., & Holgado Granados, M. (2017). *Library of Industrial Symbiosis case studies and linked exchanges.*

Fang, K., Dong, L., Ren, J., Zhang, Q., Han, L., & Fu, H. (2017). Carbon footprints of urban transition: Tracking circular economy promotions in Guiyang, China. *Ecological Modelling, 365,* 30-44.

Feyissa, T.T., Sharma, R.R.K., & Lai, K.K. (2019). The impact of the core company's strategy on the dimensions of supply chain integration. *The International Journal of Logistics Management.*

Huo, B., Ye, Y., Zhao, X., & Zhu, K. (2019). Supply chain quality integration: A taxonomy perspective. *International Journal of Production Economics*, *207*, 236-246.

Hutchins, M.J., Richter, J.S., Henry, M.L., & Sutherland, J.W. (2019). Development of indicators for the social dimension of sustainability in a US business context. *Journal of Cleaner Production, 212,* 687-697.

Ibáñez-Forés, V., Bovea, M.D., Coutinho-Nóbrega, C., & de Medeiros, H.R. (2019). Assessing the social performance of municipal solid waste management systems in developing countries: Proposal of indicators and a case study. *Ecological indicators, 98,* 164-178.

Jacobsen, N.B. (2006). Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects. *Journal of industrial ecology*, *10*(1-2), 239-255.

Kim, H.W., Dong, L., Choi, A.E.S., Fujii, M., Fujita, T., & Park, H.S. (2018). Co-benefit potential of industrial and urban symbiosis using waste heat from industrial park in Ulsan, Korea. *Resources, Conservation and Recycling, 135,* 225-234.

Kühnen, M., & Hahn, R. (2018). Systemic social performance measurement: Systematic literature review and explanations on the academic status quo from a product life-cycle perspective. *Journal of cleaner production*, *205*, 690-705.

Shi, L., & Chertow, M. (2017). Organizational boundary change in industrial symbiosis: Revisiting the Guitang Group in China. *Sustainability*, *9*(7), 1085.

Li, B., Xiang, P., Hu, M., Zhang, C., & Dong, L. (2017). The vulnerability of industrial symbiosis: a case study of Qijiang Industrial Park, China. *Journal of Cleaner Production*, *157,* 267-277.

Liu, X., & Bae, J. (2018). Urbanization and industrialization impact of CO2 emissions in China. *Journal of cleaner production, 172,* 178-186.

Lombardi, D.R., & Laybourn, P. (2012). Redefining industrial symbiosis: Crossing academic–practitioner boundaries. *Journal of Industrial Ecology, 16*(1), 28-37.

Park, H., & Chung, C.C. (2019). The role of subsidiary learning behavior and absorptive capacity in foreign subsidiary expansion. *International Business Review*, *28*(4), 685-695.

Petit, G., Sablayrolles, C., & Yannou-Le Bris, G. (2018). Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study. *Journal of Cleaner Production, 191,* 135-143.

Pires, A., Martinho, G., Rodrigues, S., & Gomes, M.I. (2019). *Sustainable solid waste collection and management.* Springer International Publishing Switzerland.

Prosman, E.J. (2018). *Supply Chain Capabilities for Industrial Symbiosis in the Process Industry.* Lessons from the Cement Industry. Aalborg University Press.

Prosman, E.J., Scholten, K., & Power, D. (2016). Dealing with defaulting suppliers using behavioral based governance methods: An agency theory perspective. Supply Chain Management: An International Journal, 21.

Qu, S., Zhou, Y., Zhang, Y., Wahab, M.I.M., Zhang, G., & Ye, Y. (2019). Optimal strategy for a green supply chain considering shipping policy and default risk. *Computers & Industrial Engineering, 131,* 172-186.

Van Schoubroeck, S., Van Dael, M., Van Passel, S., & Malina, R. (2018). A review of sustainability indicators for biobased chemicals. *Renewable and Sustainable Energy Reviews, 94,* 115-126.

Song, X., Geng, Y., Dong, H., & Chen, W. (2018). Social network analysis on industrial symbiosis: A case of Gujiao eco-industrial park. *Journal of Cleaner Production, 193,* 414-423.

Velenturf, A.P. (2016). Promoting industrial symbiosis: empirical observations of low-carbon innovations in the Humber region, UK. *Journal of Cleaner Production, 128,* 116-130.

Wang, Q., Tang, H., Yuan, X., Zuo, J., Zhang, J., Gao, Z., & Hong, J. (2018). Investigating vulnerability of ecological industrial symbiosis network based on automatic control theory. *Environmental Science and Pollution Research, 25*(27), 27321-27333.

Yazan, D.M., Fraccascia, L., Mes, M., & Zijm, H. (2018). Cooperation in manure-based biogas production networks: An agent-based modeling approach. *Applied energy, 212,* 820-833.

Yenipazarli, A. (2019). Incentives for environmental research and development: Consumer preferences, competitive pressure and emissions taxation. *European Journal of Operational Research, 276*(2), 757-769.

Yu, F., Han, F., & Cui, Z. (2015). Evolution of industrial symbiosis in an eco-industrial park in China. *Journal of Cleaner Production, 87,* 339-347.

Zhao, X., Huo, B., Selen, W., & Yeung, J.H.Y. (2011). The impact of internal integration and relationship commitment on external integration. *Journal of operations management, 29*(1-2), 17-32.

Wu, J., Qi, H., & Wang, R. (2016). Insight into industrial symbiosis and carbon metabolism from the evolution of iron and steel industrial network. *Journal of Cleaner Production, 135,* 251-262.