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Assessment of Industrial Symbiosis Implementation Opportunities: A Study in a Selected Industrial Zone, Sri Lanka

E. A. C. P. Karunarathne[1*] and W. A. P. Madhushan[1]

[1]Department of Industrial Management, Wayamba University of Sri Lanka, Kuliyapitiya-60200, Sri Lanka.

Authors' contributions

This work was carried out in collaboration between both authors. Authors EACPK and WAPM conceived the study and were responsible for the design. Author WAPM was responsible for data collection. Both authors were engaged in the development of the data analysis and data interpretation. Author EACPK did the writing of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Most Sri Lankan Industries discharge or dispose of many waste materials in large quantities in solid, liquid, and gaseous forms. Due to the high cost of treatment, many industries dispose of wastes either to dumpsites or lowlands through third-party contractors. The haphazard disposal of untreated waste is growing into a significant problem in the country. As a result, this study was conducted to identify the application options to treat or reuse the valuable waste generated by some selected industries by implementing the industrial symbiosis process in an industrial zone. Personal interviews and questionnaires were used as the methodological tools of the study to collect firm-related waste. Material properties and feasibility facts were mainly considered concerning industrial symbiosis application potential with respect to the waste receivers' and doners' perspectives. Through the study, potential secondary usage of waste was identified, avoiding direct discharge into the environment. The result from the evaluation indicates some support to the theories that industrial symbiosis can have benefits both from an economic and environmental point of view.

**Corresponding author: E-mail: chami@wyb.ac.lk;*

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1. INTRODUCTION

Improving resource efficiency is increasingly required from products to industry-wide systems since decreasing total natural resource input is critical for sustainability [1]. As a result, sustainability has become a widely discussed topic worldwide with significant concern for the environment. As per Hauschild et al., natural resource usage has to be brought down to a certain level to achieve environmental sustainability [2]. Implementing a highly resource-efficient manufacturing industry based on concepts is one possible way of achieving this [1,3]. Industrial Symbiosis (IS) is one of such potential concepts considered part of industrial ecology. IS is a form of collaborative supply chain management aiming to make the industry more sustainable and achieve collective benefits based on the utilization of waste, byproducts, and excess utilities between economically independent industries [4]. Mainly IS assumes that the sector can increase its product value while decreasing resource usage and production of waste material by effectively integrating related material and energy flows into a more extensive system. By implementing such a strategy, industries focus on increasing profit by complying with legal regulations and taking advantage of physical proximity [5]. In other words, the critical factors considered in IS are collaboration and the synergistic possibilities through geographic relationships concerning the physical exchange of materials, energy, water, and byproducts, which can be identified as a collective approach to gain competitive advantage among conventionally separate industries. By implementing such policies, some firms expect recognition as an environmentally concerned entity by the social environment [6-8].

On the other hand, Industrial ecology is a relatively new discipline that focuses on optimizing material and energy flows in industrial systems (generally considered as all systems intervened by anthropogenic activities). By applying underlying principles to industrial systems, valuable knowledge and advantage can be derived from analyzing the cycles in natural ecosystems. This study aims to use the framework of IS to the selected industrial zone in Sri Lanka. IS incorporates initiatives in which two or more industrial entities develop mutually beneficial relationships. Most communal is when one entity makes productive use of a material that is regarded as waste by another entity. Thus, good environmental performance often reduces the consumption of resources and reduces amounts of waste and emissions.

Industrial ecology attempts to provide a new conceptual framework for understanding the impacts of industrial systems on the environment [9]. Further, it provides a fundamental understanding of the value of modeling the industrial system on ecosystems to achieve sustainable environmental performance [10]. In other words, through the applications of these concepts, industries ultimately target to gain sustainable environmental development to their firms by implementing identified strategies to reduce the environmental impacts of products and processes associated with industrial systems. Answering ecological issues through a systematic approach is the main idea of industrial ecology. For that, a proper understanding of the industrial practices carried out by industry employees and ecological processes is highly required. This is a systematic process in which one should optimize the total materials cycle from virgin material to finished material, component, product, obsolete product, and ultimate disposal. Factors to be optimized include resources, energy, and capital. On the other hand, by increased recycling, the systems could be more effective and decrease resource use and the discharge of pollutants [11]. As per Chertow, industrial ecology can occur at three different levels, namely; Industrial symbiosis, product life cycles and industrial sector initiatives [3].

The term Industrial symbiosis (IS) describes a network of diverse organizations that use different byproducts to improve their ability to achieve common goals, improve environmental conditions, and/or improve business and technical processes [12]. Also, in present industrial world, the IS is considered as a key practice for the transition towards the circular economy [13,14]. By adopting IS strategies, firms target to gain economic benefits while offering environmental and social benefits for society [15,16]. IS applications are usually visible within industrial zones where they can gain advantage from geographical locations by realizing environmental benefits with each other. In some studies, IS has been identified as a social actor since this process allows to use of discarded resources from one industry as a new source of material for another firm [17]. The same has been noted by Yeo et al. and identified the support generated through the IS tools for the corresponding firms to manage the compatibility of inputs and outputs [18].

The product life cycle can be identified as the flow of a product from its launch into the market to its' declines. In other words, till the product go far away from the market. The lifecycle mainly comprises four stages, namely, introduction, growth, maturity, and decline. Most of the time, the life cycle is considered in IS as a specific method to monitor the environment concerning the material flows throughout the product life cycle. Therefore, the evaluation process is commonly known as life cycle assessment, and as per the International Standard Organization (ISO), Life cycle assessment is a standardized methodology used to address the potential environmental impacts throughout a life cycle extending from raw material extraction through production, use, end-of-life treatment, recycling, and final disposal [19].

A significant amount of researches has been conducted in the emerging field of industrial ecology and its subfield, IS. The sustainability of industrial regions and industrial networks at different levels are addressed by these researchers using different approaches. The localized industrial systems can be sustained using IS combining the regional scale applications toward developing sustainable regions. The social aspects of IS were discussed by analyzing the potential applications of social network theory to the IS field. Cultural and institutional factors impact the development of IS networks and are crucial for understanding the dynamics of IS. The significance of social factors is usually spontaneous in IS development [20]. The concept of "uncovering" IS was brought up, and it showed the potential of discovery and utilization of the number of environmentally and economically profitable symbiotic exchanges of utilized and non-utilized byproducts. Attention was paid to the quantitative analysis of IS in general and the environmental and economic benefits of implementing IS in particular [3]. A few research studies have been made of the facilitation of IS by considering the organizational and human dimension of IS, techno-business models for waste management, waste management policies, and using Information and Communication Technology (ICT) tools. The facilitation of IS development by waste management policies in a European context was investigated by Costa et al. in one of their studies [7]. Furthermore, the majority of instances of facilitation of IS development have been performed by considering social network, human and organizational dimensions of IS, and less effort on facilitation by using IS analytical and planning tools which are mainly dependent on availability, sharing, handling and developing of data and information amongst participating actors and stakeholders in a symbiotic network [3].

Key drivers of IS development can be grouped into five categories namely; economic, social, technological, information-related and policy-related. Implementing IS is also considered a way to obtain an aggressive advantage as IS strengthens the environmental profile of the organizations and will increase possibilities for innovation and get admission to new markets. Financial incentives, economic tools, and access to financial help tackle economic barriers and support the planning and implementation of eco-innovation [21]. Social factors also play a vital role in enabling the execution of IS. Many authors refer to social concepts of embeddedness and trust when studying IS network stability, evolution, and resilience [3].

Sri Lanka does not have proper management systems to control the volumes of waste generated by an urban population. Thus, these have caused to create environmental and public health issues. On the other hand, from an Industry perspective, most industries use more packaged products, resulting in higher volumes of plastics, paper, glass, metals, and textiles. Though some firms have taken necessary waste prevention actions to reduce the waste generated from their processes, a higher level of waste can still be identified. IS is a platform to bring companies together in innovative collaborations, finding ways to use the waste from one as raw materials for another [22].

Based on the waste generation in 2019, the total waste generation in the selected zone was around 12,000 MT. According to the collected data, around 6000 MT were compiled by the cement manufacturing company for incineration. The amount of material collected by contractors was approximately 4000 MT. However, out of the above 4000 MT considerable amount of waste again collected by the scavengers and the rest of the waste collected from the cement manufacturing company for incineration.

As a result, this study was conducted to identify the application options to treat or reuse the valuable waste generated by some selected industries by implementing the IS process in the selected industrial zone. As secondary objectives, major waste types generated from selected industrial sectors are to be identified, and the most considerable material properties and factors in implementing IS concepts are to be identified. For this evaluation, the application potential of IS and the development of an IS model for selected industries in the industrial zone were considered.

2. METHODOLOGY

This research focused on the industries which are generating waste from their operations. The study mainly focused on a selected industrial processing zone in Western Province in Sri Lanka since most industrial establishments (31.2%) are located there [23]. For this study, both primary and secondary data were considered. Preliminary data were gathered by following direct methods, such as personal interviews and questionnaires. Secondary data were mainly collected from published sources to identify industrial waste and related information. The data collection criteria were developed focused on the factors which affect decision-making when implementing IS for industries. The elements have been studied based on material properties and feasibility analysis. From the waste properties' perspective waste size, waste material, hazardous/ toxic level, and moisture content of the waste were considered. Since this study mainly focuses on environmental impact, waste generating firms' perception of waste disposal and their expecting benefits were identified through the analysis. Information was gathered with respect to the economic, environmental, social, and technological aspects. Sametime, their perception of using another firms' waste for their production process was identified with respect to the material properties. For this study, all the industries in the selected zone were categorized into five industrial sectors; i.e. Rubber & rubber-based products, Metal & metal extrusion, Ceramic industry, Food & Beverages, and Textiles & apparel. Considering industry proportionate in the zone, 70% of industries from each sector were covered for data collection. Finally, based on collected information, data analysis was completed, and the conclusions were drawn along with developing a IS model for the selected industrial zone.

According to this study, an experimental approach was conducted by selecting the most considerable material properties, and most important factors for implementing IS concepts for the designated industrial zone. The maximum mean values were identified for two decision-making factors by analyzing the collected data. Those factors were the most considerable factors when implementing IS. As a result, the possible IS models can be developed using the collected waste data to minimize waste disposal in the zone. On the other hand, through the developed IS model, the selected industries can exchange waste as input material and open new opportunities to establish new processing firms in the zone.

3. RESULTS AND DISCUSSION

As an initial step, perceptions of the waste receiver were obtained with respect to the feasibility aspects considered in this study. The summary of mean value in feasibility analysis was shown in below Fig. 1. This was mainly used to identify the most considerable factor for implement IS according to the waste receiver.

Most companies highly consider economic benefits when implementing the waste exchange process since those industries' main target is to minimize their production cost, which ultimately increases firm's profit. Firms receive these kinds of waste as the input of their product or any other beneficial point. The same perception has been identified in several studies [5,6] and noted economic benefits with replacing waste as a raw material taking advantage of physical proximity when the price is lower than that of a raw material. When a company is focusing on sustainability, firms used to consider highly on the environmental factor. Through the implementation of waste exchange procedures both parties can gain benefits. Here, a byproduct of one company can use as a raw material for another company. The waste-generating firm does not require to follow waste management techniques since another firm is ready to buy them, which ultimately helps the originated firm discard them easily.

On the other hand, most companies are now considering social benefits and trying to minimize the negative impact on society. By following these types of procedures, firms can rectify their concerns about the community. Furthermore, analysis implies the firms' less perception over technology though many industrial-technological methods are available in today's world to reuse byproducts of the industries. As a result, with IS implementation, firms can further enhance the economic value and social and environmental performance [5].

Further, waste generating firms' (waste donor) perception of waste also gathered regarding feasibility factors considered in this study. According to the waste donor, a summary of mean value for implement industrial symbiosis was also graphed to identify the most considerable factor from their perspective. The summary result has shown in Fig. 2.

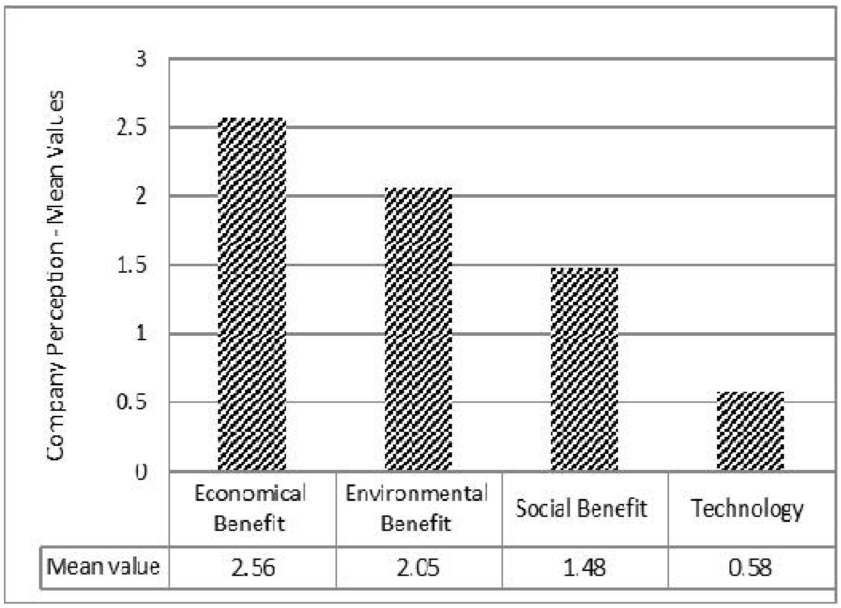

Fig. 1. Waste receiving company perception of waste

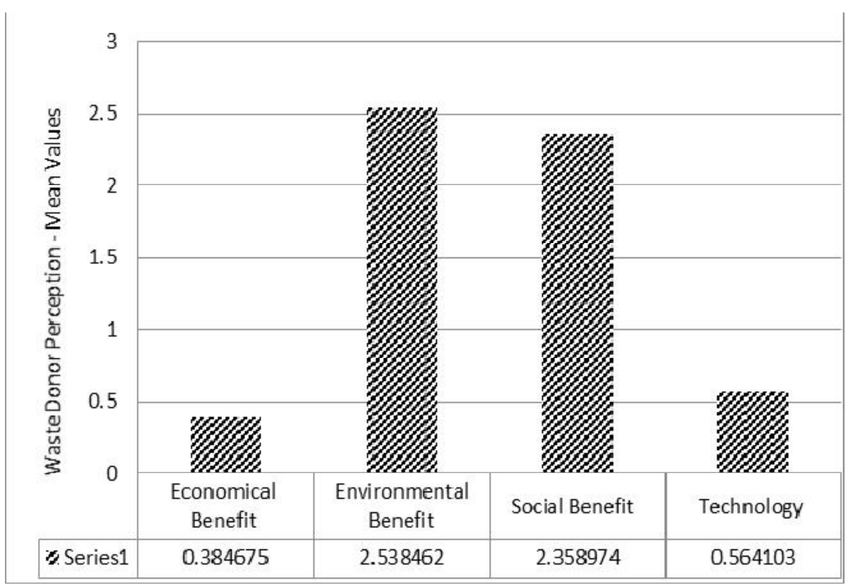

Fig. 2. Waste donor's perception of waste

According to Fig. 2, most of the donor firms are having higher consideration for the economic benefits. Many industries have paid greater attention to the waste management process since they can benefit from the proper waste management process. From a waste-disposal perspective, many rules and regulations are there for industries to follow. Reduce, reuse and recycle (R3) concept is one of the most popular among industries, but it is required a higher level of financial allocation on the implementation. On the other hand, some byproducts such as chemicals, wastewater, etc. can't be categorized under the R3 concept. As a result, industries have to treat them under the toxic waste before releasing it to the environment. It's also costly to the company. Due to these reasons, it is worthy for those industries to donate those waste to another firm to process them to use as a raw material for their production process. Moreover, through the exchange, firms can bring value to the waste by increasing the useful life of them without following early disposal procedures [24]. Further, from an environmental perspective, the utilization of recycled materials helps to reduce the usage of natural resource preserves [5,25]. Such shifting will enhance the firm's corporate image since the continuous deterioration of the environment is a challenging issue discussed in today's world. As a result, these industrial firms' lowest focus was on economic benefit, though it is possible for waste generators to receive subsidies for the waste [26]. As a result, these firms can make their goodwill and bring a higher economic value for the firm. And firms can claim that "No damage to society, society reacts happily". Interestingly, from firms' perspective, though the IS typically depends on financial results besides materials optimization [5], the perception of environmental benefits among waste doners is a highly encouraging factor.

In this study, solid waste receivers' response over the waste characteristics were gathered. From the waste properties' perspective, waste size, waste material, hazardous/ toxic level and moisture content of the waste were considered. A Summary of the solid waste receivers' preferences over waste characteristics has been given in below Fig. 3.

As per the analysis, solid waste receiving firms are concerned about the hazardous levels of solid waste as the highest waste charateristic, implying a 2.65 mean value. The second-largest mean value obtained in the waste amount, and the lowest mean value was recorded in moisture. As a result, zero hazardous characteristics can be identified as the most considerable property when implementing IS concept. Thus, the material risk factor can be identified as a barrier for the IS implementation, as noted in several studies [5,27]. In addition to that, firms required to concern with the size of the waste since that characteristic is also concerned by waste receivers. This might be caused due to the imbalance between the availability and demand of the waste [5]. Though there are perceived receivers, the firms may not generate the required level of waste through their continuous process.

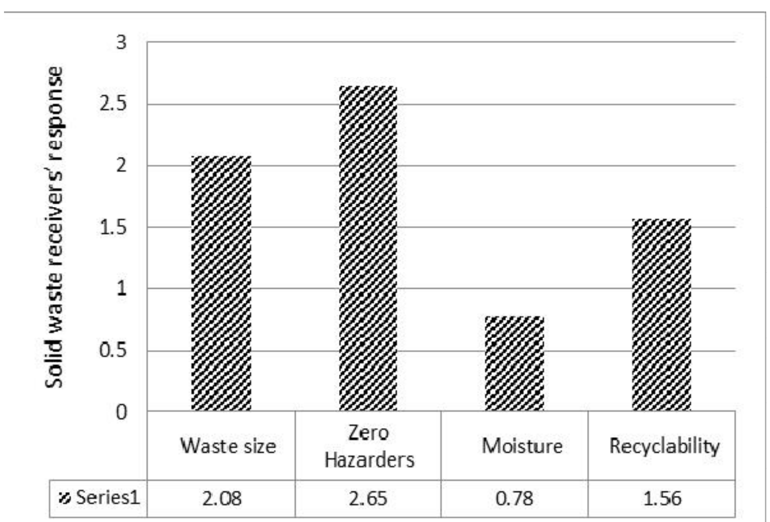

Fig. 3. Solid waste receivers' response over the waste characteristics

As per the information gathered through this study, the following potential IS application prospects were identified as feasible option to implement IS procedures. Though the proximity to partner industries is a barrier in implementation [28], networking will not be an issue since this application focuses on the industrial zone. Concerning the wastewater, it is recommended to use wastewater (pH 2-3) which discharges from metal fabrication plants to adjust pH level 9-7 under the wastewater exchange model. This model aims to reduce acidity level (usually HCl/ H2SO4 consumption), which can be implemented easily in industrial zones to make it available for another process/firm to use. On the other hand, sludge generated with wastewater usually contains many organic compounds even after treatment. Hence, there is a possibility to use this sludge to make organic fertilizer. Fabric off-cuts exchange model with the IS implementation opinion, it can be used as an alternative raw material for sectors of shoe, toy or mattress manufacturing plants. Model of toy manufacturing can use the textile off-cuts as a filling material for toy manufacturing plants. The rubber manufacturing industry generates a large number of rubber scraps and rubber-related compounds as waste. It also generates damaged tires as waste. However, there is a potential to use these wastes to manufacture the garden rubber tile and play pine in the carpet. By these applications, firms can utilize the waste, and greenhouse gas (GHG) emissions can be reduced.

4. CONCLUSION

The haphazard disposal of untreated waste is growing into a significant problem in the country due to several reasons. Lack of infrastructure, lack of monitoring mechanism of environmental regulations, and lack of understanding among the industries are significant reasons. On the other hand, the companies have not fully adopted waste prevention activities or concepts inside the factory to reduce the waste generated from processes. Therefore, finding new pathways to utilize the generated waste will bring more significant advantages for the firms, the environment, and society.

In the IS concept, two major parties are involved in the process: waste receiver and waste donor. This study facilitated the identification of industries' preferences to receive waste due to its economic benefit. It leads to improve industrial efficiency and pave a path to manage firms' resources cost-effectively. From the waste donors' perspective, firms prefer to supply the waste mainly to gain environmental benefits. While minimizing environmental impact, firms' focus on the environment is vital to promote their company image in society since most customers value it in today's marketplace. Further, such practices have been encouraged by different awarding agencies by including those into sustainability criteria. On the other hand, it minimizes the cost allocation for discard by eliminating the disposal incineration process requirements. Moreover, such a practice enables both parties to increase firms' competitiveness which indirectly leads to job creation. Waste receivers consider several properties of solid and liquid waste in IS. First, most of the industries considered the zero hazardous property in both solid and liquid waste. And secondly, waste size in solid waste and pH value in liquid waste when collecting waste to IS application. Industries think about fulfilling zero hazardous because it is challenging to handle hazardous waste due to the lack of available technology with them and in Sri Lanka. Another factor is, the variation of pH value in liquid waste causes to increase in the treatment cost before using it as a raw material. But, industries can implement several methodologies and systems to treat waste before disposed to the outdoors. On the other hand, it was identified that most of the industries in the selected industrial zone transfer their hazardous waste for incineration. Though another manufacturing firm uses it to generate heat, it dramatically affects the environment. As an example, waste generated by the textile industry consists of chemically contaminated cotton. Thus, it may lead to emitting different types of toxic gasses during incineration. But, there is a possibility of using most waste as a raw material for another sector to implement the IS concept.

In summary, through the IS survey findings, the implementation possibility of the IS concept was identified. Through efficient implementation, it may bring lots of benefits to a selected individual zone and all over the country. Industrial proximity in the zone is an advantage for implementing effective networks that create a win-win situation for both participants. Also, IS may benefit from enhancing economic value and the social and environmental performance of the firms in the zone. As a result, IS can be identified as one of the best ways to link the industries to improve the waste management process in Sri Lanka. Therefore, making aware the firms of the advantages of IS applications is essential, and for the smooth functioning, initiation of a platform to network those industries with respect to the waste can be recommended. Further, facilitating agencies should enable all networking parties to receive sufficient economic benefits to encourage those firms towards cooperation. Thus, implementing this highly resource-efficient concept, the role and involvement of local government bodies, including policy developing institutes, will be vital.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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