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https://doi.org/10.5109/4794183

出版情報：Evergreen. 9 (2), pp.524-530, 2022-06. 九州大学グリーンテクノロジー研究教育センター
バージョン：

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(Received February 11, 2022; Revised June 20, 2022; accepted June 20, 2022).

Abstract: The Indonesian ships fleet are dominated by old ships, which quickly to be sent for recycling. Ship recycling is the main source of scrap steel to the steel industry, and ship components replacement to ship repair yards in Indonesia. But the recycling activities usually create negative impacts on the environment. The study aims to recommend a strategy for developing a sustainable and environmentally friendly ship recycling industrial park, using literature study and the Analytical Hierarchy Process method. The development phase, the parties involved, and the management model are included in the conclusion.

Keywords: development; eco-industrial park; environmentally friendly; green and sustainable; ship recycling

1. Introduction

The International Maritime Organization (IMO) defines ship recycling as the activity of dismantling of a ship at a intended facility to reuse and recycle the compenents and materials, and paying attention on the hazardous substances associated with it, but does not involve in the further processing and disposal of the wastes created. Gwin[5)] suggested that ship recycling activity is not similar to ship scrapping; ship scrapping only focuses on dismantling the ship without considering their effects on the safety of the workers, environment, and health of the community, while ship recycling is also considering the reuse of the ship components and equipment, and recycling the ship materials, and the effects of the activity to the safety of the workers, community health, and the environment.

In Indonesia the ship-breaking activity was started in the early 1990s, as stated by Fariya et al[4)] (2016), particularly in the southern part of Madura Island in East Java, the industry has been growing due to the significant increase of old ships, as the impact of the implementation of cabotage principle in 2005, and the government's incentive to waive the importation tax to the shipping companies that purchase used ships from abroad. Besides Madura, the main ship-breaking activities in Indonesia can also be found in Cilincing, North Jakarta, and Tanjung Uncang, in Batam Island. As mentioned by Sunaryo et al[22)] (2021), those ship breaking centers become the main source of steel scraps as raw material for most steel industry in Indonesia, and for replacement of ship components and equipment by ship repair yards. All of the ship-breaking activities are still using conventional methods and manual workforce, and do not put any consideration on the effects to the environment, the safety and health of the workers. The pollution created by ship-breaking activities is almost the same as those of heavy industry, such as heavy metals and toxic materials, which dissolve in the seawater and sediment as mentioned by Masaki[11)] (2016).

Shipbreaking is categorized as dangerous and environmentally unfriendly occupational activities. The hazardous materials conceived in the ships being dismantled include electric and electronic wastes from ship's equipment, as stated by Mostafa and Sarhan [14)] (2018), as well as structural wastes, include asbestos, anti-fouling paint, heavy metals, etc., which are listed in Resolution MEPC 269 (68)[19)]. Therefore national and international regulations were drawn to restrict and to monitor the ship breaking activities, which include the International Maritime Organization's (IMO) Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships 2009[6)], which is known as the Hong Kong Convention, the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal 1989[1)] published by the United Nations Environment Programme (UNEP), the Ship-recycling Regulation of the European Union (EU SRR) 2013[24)], and the International Labour Organization's (ILO) Safety and Health in Ship-breaking: Guidelines for Asian Countries and Turkey[7)]. While the national regulations that govern ship-recycling activities are: National Law No. 17 - 2008 on Shipping[12)], Government Regulation No. 21 - 2010 on the Protection of Maritime Environment[15)], Regulation of the Ministry of Transport Republic of Indonesia No. PM 29 - 2014 on the Prevention of Maritime Environmental Pollution[13)], and Government Regulation No. 101 - 2014 on the Treatment of Dangerous and Poisonous Waste[16)].

Refer to the characteristics of the industry, as defined by IMO, ship recycling is not a standalone industry, but it is connected directly or indirectly to many industries and institutions, such as ship owners and shipbrokers, consumable materials distributors, waste treatment facilities, ship repair yards, steel mills, hospital, training center, workers' housing, used components, and equipment market, etc.

Besides the national market, Indonesia's geographical location as the world maritime fulcrum opens a great opportunity to the international ship recycling market as well, since many developed countries as stated by Kundu[9] (2020), have applied high restrictions on ship recycling activities in their territories, such as China, and European Union. Unfortunately, as mentioned by Sunaryo et al[22] (2021), in Indonesia there is no ship recycling yard complies with the national as well as international regulations, or possesses Hong Kong Convention Certificate, and none of ship recycling facilities is officially registered as a ship recycling yard. To elevate the image of Indonesian ship recycling facilities into environmentally friendly and sustainable industry, and to increase its supply chain efficiency, a concept of eco ship recycling industrial park or estate has been proposed to be established in Madura, Cilegon in Banten, Tanggamus in Lampung, and Batam. Refer to the requirements of several international regulations, the industrial park should be at least composed of: a number ship recycling yards with various capacities, waste treatment facility, hospital, workers accommodation flats, training center, steel mills, consumable materials distributors, electricity power plant, freshwater plant, and estate management office. As a complementary to the proposed concept, a study has been conducted to simulate the optimum development strategy of the eco-industrial park, to identify the most applicable development phase, party's involvement priority, and the management model of the industrial park.

2. Method

The study was conducted by reviewing available regulations and literature related to the eco-industrial park, and ship recycling, to be used as references for the proposed concept and development strategy of the eco industrial park. To identify the importance level of the strategy, Analytical Hierarchy Process (AHP) method was applied, and expert opinions through interview and questionnaire distribution were carried out for supporting the method.

2.1 Ship Recycling Regulations

Any hazardous pollution created by industry is tightly regulated by both international and national regulations, as Dwiki[3] (2018) stated. These international and national regulations are explained as follows:

Hong Kong Convention

Hong Kong Convention controls the ship from design to its end of life, including its inventory of hazardous materials (IHM), and when the ship is sent for recycling. Concerning ship recycling, the convention controls and authorizes wide aspects of the ship-recycling activities, such as its management system, health risk control, worker safety training, and the removal of any hazardous material.

Basel Convention

Basel convention regulates trans-boundary movement of hazardous waste, and ships subject to be recycled are considered as hazardous waste. The convention provides guidelines for the environmentally sound management of the full and partial dismantling of ships, environmental management plan of the ship to be dismantled, and the ship-recycling facility.

European Union's Ship-recycling Regulation

The objective of EU SRR is to reduce the negative effects of ship-recycling activities. The regulation mainly controls the ships that fly the flag of EU member states. It adopts wholy the Hong Kong Convention, and regulates the downstream toxic waste management, and the wefare of the workers.

ILO's Safety and Health in Ship-breaking Guidelines

The guidelines give directions on the activity planning, general procedures on the preventive, protective, and management of the hazardous substances; monitor of the physical, biological, ergonomic, and psychosocial hazards; safety in using tools and equipment; requirements to wear personal protective equipment; implementing contingency plans and emergency procedures.

National Regulations

Out of four regulations only two that have rather comprehensive requirements for ship recycling activities. As stated by Sunaryo et al[22] (2021), Regulation of the Ministry of Transport No. PM 29 – 2014 includes most of the requirements covered in Hong Kong Convention, with some addition for ships above 100 GT, but it does not include the disposal and treatment of waste from ship-recycling facilities. The Government Regulation No. 101–2014 covers various aspects of the treatment of hazardous and toxic wastes, including wastes from ship-recycling activities, but it does not govern the handling and treatment of hazardous and toxic wastes from ship-recycling activities.

2.2 Eco-Industrial Park

Suemy[21] (2012) defines industrial estate as a center of industrial activities in which, its infrastructure is built and managed by an estate enterprise that is authorized by the government, while Kodrat[8] (2011) defines it as an infrastructure that supports the successful economic development in the industrial sector, and Tungjiratthitikan[23] (2018) stated that industrial estate is the area where the industrial plants are systematically allocated together with basic facilities for workers such as residences, telephone and other necessary services including post offices, banks, shopping centers, and gas stations. Caroline[2] (2009) suggests that the benefit of an industrial estate is to reduce the transportation and transaction costs, reduce social costs, create collective assets, and increase efficiency and innovation. With the demand in industrial ecology, the concept of the industrial park is also developed toward more environmentally and economically friendly, which is widely known as the eco-industrial park. According to Lowe et al[10] (2001), an eco-industrial park is consisted of a group of manufacturing and service industries that agree to achieve high environmental and economic scale through collaboration in managing the environment and resources, including energy, water, and materials. The same idea is also suggested by Putri et al[18] (2021) as a green manufacturing concept, where industry puts more emphases on niminizing its negative effects on the safety and environment. The community develops a collective benefit that is greater than the sum of all individual companies would have realized. United Nations Industrial Development Organization (UNIDO)[26] (2017) emphasizes that an eco-industrial park should comply with the existing environmental and social regulations.

In Indonesia, the establishment of an industrial estate is regulated by Government Regulation No. 142 – 2015 on Industrial Estate[17]. In the chapter 10 of the regulation, it requires that an integrated industrial estate should provide supporting infrastructure, which is usually consisted of energy and electrical power plant, freshwater plant, telecommunication network, sanitation system, and transportation network, while for the supporting infrastructure is consisted of: workers' housing, worker's training center, research, and development center, public health facility, fire fighting station, waste disposal, and treatment facility.

Benefits of an eco-industrial park

UNIDO suggests that the benefits of an eco-industrial park are not just commercial, but also strategic; reduce unnecessary risks, increase productivity and competitiveness of the industries, increase supply chain efficiency, and collaboration between the member industries, and the stakeholders. There are at least three benefits of an eco-industrial park i.e. economic benefits, environmental benefits and, social benefits. Economy benefits include costs reduction in production system due to sharing of facilities and infrastructure, the shorter supply chain that will reduce transportation costs, pooling of resources that will increase efficiency. Environmental benefits include more efficient use of natural resources such as energy, water, and raw materials, proper treatment and reuse of wastes, and better management of hazardous materials. Social benefits include: create direct and indirect employment, increasing welfare and health of the community due to the availability of social infrastructure and community services.

Eco-industrial park management models

The management of Eco-industrial park is very important in ensuring the effective operation of the park in order to achieve its vision. Tessitore et al[25] (2015) mentioned that the main function of the management in an eco-industrial park are: to manage the environmental services for the tenants, develop the industrial park, provide services to the tenant companies, including environmental and socio-economic services, and promote the eco-industrial park. UNIDO identified that there are four types of eco-industrial park management models:

- Associative management model, an association is established by the tenants and an organization structure is formed to manage the industrial park.
- Government management model, the government assigns special team from national, regional, or municipal authority to manage the park, and regularly give an account of the progress of the park to the government, such as in the case of special economic zones, where high investment has been put in by the government.
- Mixed public-private management model, government contracts a private company to assist government employees in managing the industrial park; the partnership can be permanent or temporary.
- Private or individual management model, the management is run by a private company or the real estate agent.

2.3 Analytical Hierarchy Process

Vargas[27] (2010) defined the analytical hierarchy process (AHP) as a technique for making decision of a complex environment, where many variables or criteria are considered for priorities or alternatives. A problem is analyzed and compared independently by decomposing it into a logical hierarchy of criteria, and then the alternatives are assessed systematically for each criterion through pair-wise comparisons. The comparison may use real data or human expert judgments. AHP converts the comparisons into numerical values for further processes and comparisons. The elements in the hierarchy are assessed by weighing each factor. Then the numerical probability of each alternative is calculated, to determine the likelihood of the fulfillment of the expected goal. To generate priorities, the decision is decomposed into the following steps:

- Define the problem and determine the goal of the problem.

- Construct the decision hierarchy including the goal of the decision, the objectives, criteria of subsequent elements, and alternatives.
- Construct pair-wise comparison matrices.
- Weigh the priorities for every element and obtain overall priority.

Relative importance scale was introduced by Saaty[20] (2008) to make the comparison between elements of the AHP, which is consisted of varying values from 1 to 9 as shown in table1. It is noted that even numbers are only being used when a consensus cannot be reached.

Table 1. The scale of relative importance.

Scale	Numerical Rating	Reciprocal
Extremely preferred	9	1/9
Very strong to extremely	8	1/8
Very strong preferred	7	1/7
Strongly to very strong	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally proffered	1	1

Following the establishment of the hierarchy, the criteria are then evaluated in pairs to determine the relative importance of them and the goal. The priority vector (or Eigenvector) is used to determine the contribution of each criterion to the goal. The mathematical average of all criteria are calculated to obtain the relative weights between each criterion, and the sum of all values from the vector is always equal to one.

The next step is to check for the data consistencies. The consistency index is obtained from summing the product of each element in the Eigenvector by the respective column of the original comparison matrix.

$$CR = \frac{\mathrm{CI}}{\mathrm{RI}} \qquad (1)$$

Where CR is Consistency Ratio, CI is consistency index, and RI is Random Consistency index. The value of consistency index CI is obtained from:

$$CI = \frac{(\lambda\, max - n)}{(n - 1)} \qquad (2)$$

Where λmax is the maximum Eigenvalue and n is the number of evaluated criteria. The matrix is considered consistent if the ratio is less than 10%. Saaty[20] (2008) stated that the value of RI is fixed and is based on the number of evaluated criteria as shown in table 2.

Table 2. Random consistency indexes.

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0,58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

3. Results and Discussion

Referring to the requirements of the available regulations and the goal of the study, the hierarchy elements for the analytical hierarchy process were arranged, which were consisted of: feasibility analysis, land acquisition and development, infrastructure construction, and permanent operation, as shown in figure 1. The weighing level of each element was obtained through distributing questionnaires to the experts in ship recycling, such as ship recycling yard owners, researchers, officials from government institutions, etc. The collected data are used for constructing pair-wise comparison and criteria comparison matrix as shown in table 3.

Table 3. Criteria comparison matrix.

	Feasibility analysis	**Land Acquisition And Development**	**Infrastructure Construction**	**Permanent Operation**
feasibility analysis	1	0.63	0.69	0.79
Land Acquisition And Development	1.59	1	0.55	0.70
Infrastructure Construction	1.45	1.82	1	0,86
Permanent Operation	1.26	1.43	1.17	1
Total	5.30	4.88	3.41	3.35

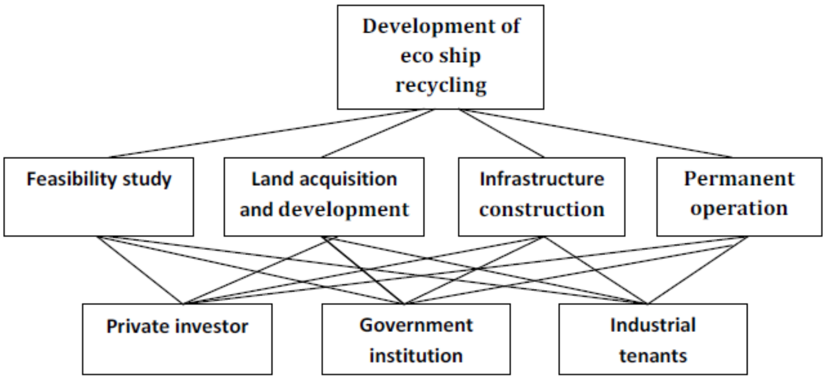

Fig 1. The hierarchy elements of AHP.

To obtain the priority level, the comparison matrix was normalized by dividing the value of each element by the total value of each column. The normalized matrix of priority criteria is shown in table 4, and then the values of each row are averaged, as shown in table 5.

Table 4. Normalized matrix of priority criteria.

	Feasibility analysis	Land Acquisition And Development	Infrastructure Construction	Permanent Operation
Feasibility analysis	0.19	0.13	0.20	0.24
Land Acquisition And Development	0.30	0.20	0.16	0.21
Infrastructure Construction	0.27	0.37	0.29	0.26
Permanent Operation	0,24	0.29	0.34	0.30
Total	1	1	1	1

Table 5. Priority criteria.

Criterion	Priority
feasibility analysis	19%
Land Acquisition And Development	22%
Infrastructure Construction	30%
Permanent Operation	29%

The weighing validity was checked by investigating the consistency ratio. For this purpose, it was obtained that the maximum Eigenvalue λmax is 4.07, and the consistency index CI is 0.02, and thus the consistency ratio CR is 0.0259 or 2.3%, which is much less than 10%.

The same approach was conducted to obtain the priority hierarchy of the parties that should carry out the strategy, and the results are presented in tables 6, 7, 8, and 9 respectively for feasibility analysis, land acquisition and development, infrastructure construction, and permanent operation. For the global alternative hierarchy, the priority sequence is presented in table 10.

Table 6. Strategy priority for the feasibility study.

Party	Priority
Government institution	50%
Private investor(s)	36%
Industrial tenants	15%

Table 7. Strategy priority for land acquisition and development.

Party	Priority
Government institution	38%
Private investor(s)	42%
Industrial tenants	20%

Table 8. Strategy priority for infrastructure construction.

Party	Priority
Government institution	27%
Private investor(s)	39%
Industrial tenants	34%

Table 9. Strategy.

Party	Priority
Government institution	31%
Private investor(s)	30%
Industrial tenants	40%

Table 10. Priority for the global alternative hierarchy.

Party	Priority
Government institution	35%
Private investor(s)	36%
Industrial tenants	29%

Based on the priority analysis, it can be concluded that the priority hierarchy is the infrastructure construction, permanent operation, land acquisition and development, and feasibility analysis, but since the difference between infrastructure construction and permanent operation priorities are only 1%, therefore it is up to the decision-maker to consider the development strategy of the eco ship recycling industrial park. The authors suggest that infrastructure construction should be put as the priority because the arrangement of the industrial park is very much dependent on it. For the management model, the most suitable model for feasibility analysis is the government management model; for land acquisition and development the most suitable is the mixed public-private management model; for infrastructure construction, the most suitable is the individual management model; and for permanent operation, the most suitable is mixed public-private management model. For the overall proposed eco ship recycling industrial park, the mixed public-private management model is suggested. The results of the analytical process are very much influenced by the input from the experts, therefore wider perspectives of information should be included when the definite location and capacity of the proposed eco ship recycling industrial park has been decided.

4. Conclusion

Refer to the results of the analytical hierarchy analysis for the development strategy of an eco ship recycling industrial park, it is concluded that the development phase would consist of feasibility analysis, land acquisition and development, infrastructure construction, and permanent operation; the parties development priority are infrastructure construction, permanent operation, land acquisition and development, and feasibility analysis; and the proposed management model is mixed public-private management model.

Acknowledgments

The authors would express their thanks to all parties who have contributed to the successful activities of the study, in particular to the Ministry of Research and Technology/National Research and Innovation Agency Republic Indonesia, and the Directorate of Research and Development Universitas Indonesia, who have provided the research fund with contract No. NKB-037/UN2.RST/HKP.05.00/2021.

Nomenclature

CR	Consistency Ratio
CI	consistency index
RI	Random Consistency index
λmax	maximum Eigenvalue
n	number of evaluated criteria

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