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ENHANCING ENVIRONMENTAL SUSTAINABILITY OVER FISHERIES INDUSTRY THROUGH PROACTIVE RISK EVALUATION: A CASE OF TOK BALI FISHING PORT

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Abstract: The fisheries industry is a vital industry for Malaysia's economy. There are growth potentials in deep-sea fishing, coastal fishing and aquaculture activities carried out along the Malaysian coast. However, the development of the fisheries industry threatens the sustainability of an environment if it is not managed systematically. The environmental risk of the fisheries industry can result in water and air pollutions, and leading to catastrophic ecosystem damages. As such, a new model is proposed for analysing environmental risks arising from fisheries activities. With this in view, this paper proposes a new analysis model using two methods which are Analytic Hierarchy Process and decision-making rating tool. Environmental risk factors are identified and prioritised by using the Analytic Hierarchy Process method. Mitigation strategies for minimising the risk losses from fisheries activities are suggested and highlighted by using a decision-making rating tool. To demonstrate the applicability of this proactive risk evaluation model, Tok Bali fishing Port is selected as a case study. The result shows that water pollution is a focal environmental risk arising from fisheries activities in Tok Bali Fishing Port. The proposed model is capable of helping related government agencies such as Lembaga Kemajuan Ikan Malaysia and Department of Fisheries Malaysia in conducting a proactive evaluation to enhance the environmental sustainability of the fisheries industry.

Keywords: Environmental sustainability, fisheries industry, risk evaluation, analytic hierarchy process.

Introduction

The fisheries industry is an important sector in Malaysia for the supply of animal protein (Food and Agriculture Organization, 2017). There are more than 10 types of fishing gears used in catching over 100 commercial marine fish species in the Malaysian waters (Samsudin *et al.,* 2015). From these types of fishing gears, the two most efficient are trawlers and purse seines. In 2016, the production of marine fish from Malaysian waters was 1,574,447 metric tons with a value of RM10.176 billion (Department of Fisheries Malaysia, 2017). Since fish is considered as an importance source of protein for majority of the Malaysian population, the necessity to manage the fisheries industry sustainably is becoming crucial. Moreover, the development of the fisheries industry threatens the sustainability of the environment, if, it is not managed systematically. Consequently, the environmental risk from fisheries industry can results in water pollution, air pollution, and ecosystem damages (GESAMP, 1991; Malaysia Fisheries Act, 1985; International Maritime Organization, 2009; 2014). The impact of these pollution and damages from fisheries industry can be worst if no action is taken to manage it systematically. As a result, this paper proposes a new model for analysing the environmental risk arising from fisheries activity and consists of three main areas which are water pollution, air pollution and ecosystem damages.

In order to demonstrate the applicability of this proactive risk evaluation model, Tok Bali Fishing Port is selected as a case study. This model is able to help related government agencies such as Lembaga Kemajuan Ikan Malaysia and the Department of Fisheries Malaysia to conduct a proactive evaluation for enhancing the environmental sustainability of the fisheries industry. Practitioners and academicians will benefit from the proposed methodology for analysing the environmental impact of the fisheries industry in a particular area. This paper presents a basic concept for making decision under uncertainty and explains the risk identification, the prioritisation and the mitigation for the environmental sustainability at Tok Bali Fishing Port. The main objective of this paper is to identify environmental risk factors in the fisheries industry and to prioritise them by using the Analytic Hierarchy Process (AHP) method. Finally, mitigation strategies for minimising the environmental risk in the fisheries industry are suggested and highlighted by using a decision making rating tool.

The Sustainability of Fisheries Industry

Fisheries sector in Malaysia is significant contributor to the Gross Domestic Product (GDP), and fish products are a main source of food and protein for the Malaysia population. This sector contributed around 1% to the Malaysian GDP, underlining its importance in this country (Department of Fisheries Malaysia, 2017). The fish demand is forecasted to increase from 1.57 million metric tons in 2016 to 1.9 million metric tons by the year 2020 (Department of Fisheries Malaysia, 2017). It is noteworthy to mention that the domestic and international demand for fish and fish products are growing year after year, but the captures are stagnant. This negative correlation is caused by several factors such as overfishing, ecosystem damages and pollutions.

The sustainability theory in the fisheries industry refers to the theoretical disciplines involving population dynamics of fisheries and practical fishing strategies (National Geographic, 2016). The purpose of this theory is to avoid overfishing and pollution arising from fishing activities. Several techniques are recommended such as individual fishing quotas, curtailing destructive, illegal fishing enforcement and environmental risk protection (National Geographic, 2016). Crawford Global Technical Services (2016) defined environmental risk as the actual or potential threat of adverse effect on living organisms and the environment by effluents, emissions, wastes and resources depletion. Environmental risk exposures, whether physical, chemical, or biological, can induce a harmful impact and may affect soil, water, air, natural resources or entire ecosystem, as well as on plants and animals (US Environmental Protection Agency, 2017).

Water Pollution, Air Pollution and Ecosystem Damages

The environmental risk is evaluated by considering three main criteria which are water pollution, air pollution and ecosystem damage. Although, these risk criteria have originated from different sources, it is essential to consider them in a single model before proposing mitigation strategies, Moreover, the decision-makers are assisted with a single model that is capable of dealing with multi-elements. The classification of these three criteria follows the recommendations and adaptation of various studies.

Water pollution can be defined in many ways. Usually, it means one or more substances that have built up in water that can cause problems to people, animals and plants. Naturally, oceans, lakes, rivers and other inland waters can clean up a certain amount of pollution by dispersing it harmlessly. However, water pollution caused by oil spill from vessels (e.g. fishing and merchant), waste garbage and from waste from agriculture is difficult to be cleaned and almost impossible to be dispersed naturally. In fishing sector, cleaning boats and oil disposal are some of activities that caused water pollution. From these activities, sea water surface is covered and polluted with discharged oil. In addition, poor disposal facilities at fishing port also contribute to low awareness among fishermen. Sea pollution is the problem faced by coastal communities, marine animals and plants. This pollution was introduced by human, whether directly or indirectly into the marine environment resulting in deleterious effects, such as harms to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities (GESAMP, 1991).

Air pollution can result from human and natural actions. However, pollution from natural occurrences is not frequent compared to human actions. For example, an emission from vessels are a significant source of air pollution and it is estimated that carbon dioxide emission from various types of ships (i.e. currently were equal to 2.2% of the global human-made emission in 2012) will arise by as much as two to three times by 2050 if no action is taken (International Maritime Organization, 2009; 2014). Although, there is a perception that fishing vessel contributes a lower amount of air pollution, it still needs to be evaluated. Based on expert consultation, the use of chlorofluorocarbon (CFC) and jetty extension area by burning mangrove and *'nipah'* trees are considered as the causes of air pollution instigated by fishing activities.

Fisheries industry can cause ecosystem damages if this sector is poorly controlled. Excessive fishing capacity, overfishing and oil discharge are some instigators of ecosystem damages. Oil spill is harmful especially for animals like sea birds when it swims on the surface of the water. Malaysia Fisheries Act (1985) argued that ecosystem damages are intended when harvesting extreme amount of fish, using prohibited or banned fishing gears, smuggling and intrusion of foreign fishermen, and damaging coral reef ecosystems or interfere with the natural life. As a result, it is worth mentioning that ecosystem damages in the fishery activities can be instigated by oil spill from fishing vessels, overfishing and fishery sewages.

Analytic Hierarchy Process (AHP)

AHP is a theory of measurement through pair-wise comparisons and relies on the judgments of experts to derive priority scales (Mohd Salleh *et al.,* 2015). The comparisons are made using a scale of absolute judgments that represents the relative importance of one element to another element in a given attribute. The fundamental scale has been shown to be the one that captures individual preferences with respect to quantitative and qualitative attributes as well as, or better than, other scales (Saaty, 1980). In addition, the AHP approach is a well-structured approach for organizing and analysing complex decisions such as multilevel criteria or attributes. It has been developed based on precise mathematical structures of consistent matrices and their associated right-eigenvector's ability to generate weights (Saaty, 1980). The AHP approach also has the capability of measuring inconsistencies and improving judgments (Saaty, 2008).

Several researchers have conducted risk assessment in the fisheries industry (Fletcher, 2005; Kolar *et al.,* 2007; Ellis *et al.,* 2009; Copping *et al.,* 2015; Huchim-Lara *et al.,* 2016). None of them however, deal with the assessment of environmental risks arising from fisheries industry, which highlights a significant research gap to be fulfilled. In addition, the application of the AHP approach in this risk assessment model is a new attempt since no studies have been found that employ this method.

Methodology

For the evaluation of the environmental risk in the fisheries industry, two methods are employed. Firstly, environmental risk factors are identified and prioritised by using the AHP method. Secondly, the mitigation strategies for minimising the risk losses from the fisheries industry are suggested and highlighted by using a decision-making rating tool. To develop the calculation process for prioritising the environmental risk factors in the fisheries industry, a flow chart of proposed methodology in sequential order is illustrated in Figure 1.

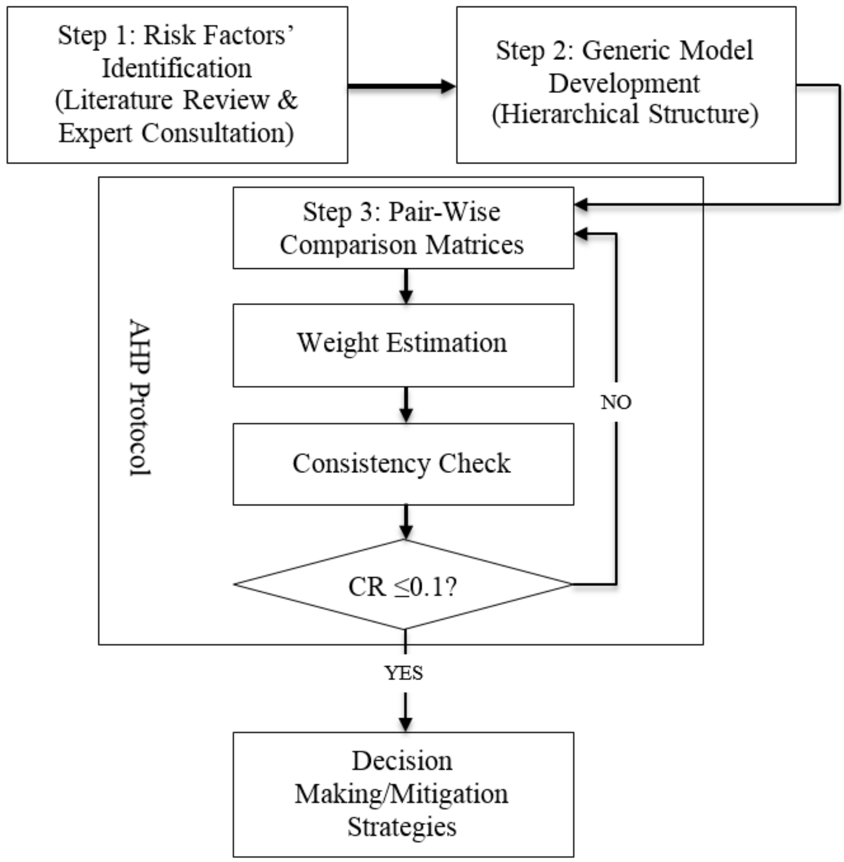

Figure 1: Methodological framework for analysing the environmental risk in the fisheries industry

Identification of the Environmental Risk Factors in the Fisheries Industry (Step 1)

As shown in Table 1, the risk factors are identified through literature and further consulted with an expert.

Table 1: The summary of identified environmental risk criteria

Main Criteria	Sub-criteria
Water Pollution	Trash Dumping Fishery Sewage Dumping Oil Spill/Disposal
Air Pollution	Emissions from the Use of Fossil Fuel Burning Activities for Extension Area (Jetty Opening) The Use of Chlorofluorocarbon
Ecosystem Damage	Oil Spill/Disposal Overfishing Fishery Sewages Discharging

Development of a Generic Model for the Proactive Risk Factors in the Fisheries Industry on Environmental (Step 2)

The kernel of developing a generic model is that it can be modified or adjusted to be used for a particular firm or industry (Mohd Salleh *et al.,* 2015). The risk factors, as shown in Table 1, are used for developing a generic model in a hierarchical structure form. In step 2, the decision hierarchy from the top with the goal of the decision, followed by the intermediate level to the lowest level, is structured. As shown in the Figure 2, the environmental risk instigated by fishery industry are classified into three main categories (i.e. as discussed in step 1), which are water pollution, air pollution, and ecosystem damages. The water pollution is caused by oil spill/ disposal, trash dumping and fishery sewage dumping. The second category is air pollution, instigated from burning activities for extension area, emissions from the use of fossil fuel, and the use of chlorofluorocarbon (CFC). The third category is ecosystem damages, triggered by fishery sewages discharging, oil spill/ discharge, and overfishing.

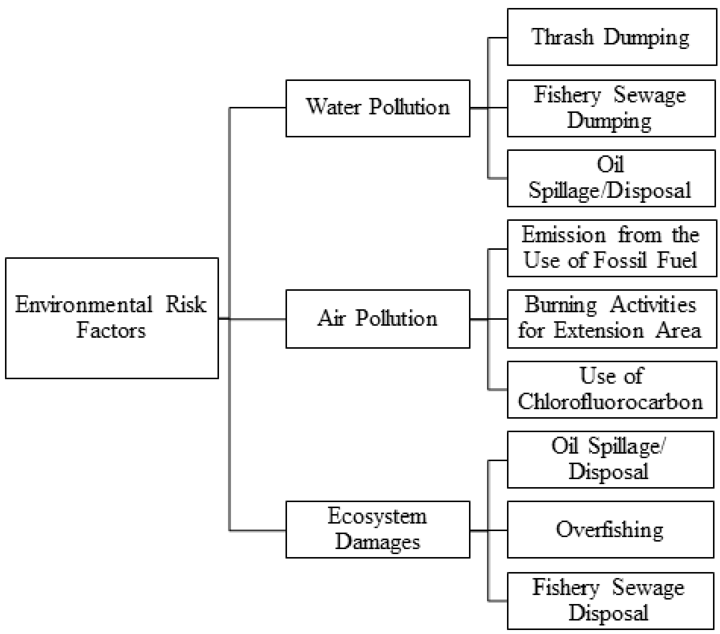

Figure 2: The generic environmental risk model in the fisheries industry

Establishment of Criteria Weight (Step 3)

A weight can be assigned to each criterion using established methods such as simple rating method or more elaborate methods based on pair-wise comparisons (Mohd Salleh *et al.,* 2014). To compare the criteria or alternatives in a nature pair-wise comparisons mode, a fundamental scale of absolute number is used. Table 2 shows a fundamental scale of the ratio scale of pair-wise comparisons which consist of linguistic meaning and numerical assessment. From this Table 2, expert should understand the ratio scale of the pair-wise comparisons before the assessment has been taken to avoid misjudgement. Qualitative data collections are used in this study and all necessary data are obtained from expert judgment and mathematical algorithms. All experts contributed their ideas and opinions in developing a scientific model, answering a set of pair-wise comparison as well as determining the parameters.

Table 2: The ratio scale of pair-wise comparisons (Mohd Salleh *et al.,* 2015)

Numerical Assessment (Scale)	Linguistic Meaning
1	Equally Important (EQ)
3	Weakly Important (WE)
5	Strongly Important (ST)
7	Very Strongly Important (VS)
9	Extremely Important (EX)
2, 4, 6, 8	Intermediate Values Between The Two Adjacent Judgements

To determine the consideration pair of attributes A_i and A_j is presented by an *n x n* matrix d. The entries a_{ij} that are determined by rules of entry as follows (Saaty, 1980):

I. Rule 1: If $a_{ij} = \alpha$, then $a_{ii} = 1/\alpha$, $\alpha \neq 0$.

II. Rule 2: If A_i is judged to be of equal relative importance as A_j, then $aij = a_{ji} = 1$.

According to above rules the matrix *D* is shown in Equation 1 as follows:

$$D = a_{ij} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ . & . & \cdots & . \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

The calculated judgment of comparison on pair (A_i, A_j) is renowned as aij in the matrix *D*; next step is to allocate the weight vector for each criterion or alternative, as it indicates the prioritisation of the criteria (Mohd Salleh *et al.,* 2015). A weight value wk can be calculated by using Equation 2 as follows:

$$w_k = \frac{1}{n} \sum_{j=1}^{n} \left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} \right) (k = 1, 2, 3, \ldots, n) \quad (2)$$

The decision may be inconsistent due to different views and beliefs with regard to criteria. By using a Consistency Ratio (CR), inconsistency of the pair-wise comparisons can be calculated. If *CR* value is 0.10 or less, the consistency of the pair-wise comparison is considered acceptable, and the AHP can continue with the computations of weight vectors (Andersen *et al.* 2011; Riahi *et al.* 2012; Mohd Salleh *et al.,* 2015). In contrast, a *CR* with a greater value than 0.10 indicates an inconsistency in the pair-wise judgements. To check the consistency of the judgements, a *CR* is computed by using Equations 3-5 (Andersen *et al.* 2011):

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

$$\lambda_{max} = \frac{\sum_{j=1}^{n} \left[\frac{\sum_{k=1}^{n} w_k a_{jk}}{w_j} \right]}{n} \quad (5)$$

where CI is the consistency index, RI is the average random index (Table 3), n is the number of items being compared, and is the maximum weight value of the n x n comparison matrix D.

Table 3: Value of average random index (RI) versus matrix order

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.141	1.45	1.49

Case Study

To test the applicability of this evaluation model, Tok Bali Fishing Port has been selected as a case study. Tok Bali, which is located at Pasir Puteh, Kelantan, is intended to provide convenience to deep-sea fishermen in Kelantan and the surrounding area such as Terengganu and Pahang. Tok Bali is the most important fishing port to the State of Kelantan. The fisheries industry at Tok Bali has a potential prospect and become a vital industry for Malaysia's economy in the future. This growth refers to the development of deep-sea fishing, coastal fishing and aquaculture activities carried out along the Malaysian coast.

To deal with qualitative data, 10 domain experts were approached to perform the pair-wise comparisons and to assign the appropriate grade for every environmental risk instigated by fishery activities. However, only five experts were able to commit during the interview session. Under the AHP approach, five experts are acceptable for further evaluation as there are studies that only used three experts (Mokhtari *et al.,* 2012; Mohd Salleh *et al.,* 2015). Selection of domain experts for subjective judgments was based on their qualifications and experiences of more than 15 years in the fisheries industry. The five domain experts are managers from Lembaga Kemajuan Ikan Malaysia (LKIM) at Tok Bali, fishing companies located at Tok Bali and Fisherman's Association of Semerak Area. The methods of evaluation were conducted through interviews between the researcher and the domain experts, who are guided with an evaluation form which was given to them during the interviews session. The average time taken during the interview session is 70 minutes.

Due to difficulties in assigning weight for experts and to avoid prejudgement, they are assigned with equal weight. To obtain the aggregated comparisons matrices, geometric mean is used in this study to aggregate the judgement of experts (Equation 6).

$$\text{Geometric Mean}_{ij} = \left[e_{ij}^{1} \cdot e_{ij}^{2} \cdot e_{ij}^{3} \cdots e_{ij}^{k}\right]^{\frac{1}{k}} \tag{6}$$

where k is the number of experts and e_{ij}^{k} stands for the k^{th} expert opinion for relative importance of the i^{th} criterion to the j^{th} criterion.

To demonstrate the aggregation process by using the GM, based on data obtained, a judgment (i.e. from five experts) of the importance of the criterion "Water Pollution" to the criterion "Ecosystem Damage" is calculated as $(1/3 \times 3 \times 1/3 \times 3 \times 3)^{1/5} = 1.241$. "Water Pollution" to the "Air Pollution" is aggregated as $(5 \times 7 \times 7 \times 7 \times 5)^{1/5} = 6.119$. Lastly, the importance of the criterion "Ecosystem Damage" to the "Air Pollution" is aggregated as $(7 \times 1/3 \times 5 \times 5 \times 3)^{1/5} = 2.804$. As a result, the matrix *D* for main criteria (i.e. water pollution, ecosystem damage and air pollution) is shown in Table 4.

Table 4: Matrix *D* for the pair-wise comparisons of main criteria

	Water Pollution	Ecosystem Damage	Air Pollution
Water Pollution	1	1.241	6.119
Ecosystem Damage	0.806	1	2.804
Air Pollution	0.162	0.357	1

Based on Equation 2, weight calculations for main criteria are demonstrated as follows:

$$w_W = \frac{1}{3}\left(\frac{1}{1+0.806+0.162}\right)+\left(\frac{1.241}{1.241+1+0.357}\right)+\left(\frac{6.119}{6.119+2.804+1}\right)=0.534$$

$$w_E = \frac{1}{3}\left(\frac{0.806}{1+0.806+0.162}\right)+\left(\frac{1}{1.241+1+0.357}\right)+\left(\frac{2.804}{6.119+2.804+1}\right)=0.359$$

$$w_A = \frac{1}{3}\left(\frac{0.162}{1+0.806+0.162}\right)+\left(\frac{0.357}{1.241+1+0.357}\right)+\left(\frac{1}{6.119+2.804+1}\right)=0.107$$

where w_w is the weight for water pollution, w_E and w_A are the weights for ecosystem damage and air pollution. As a result, water pollution, ecosystem damage and air pollution are calculated as 0.534, 0.359, and 0.107. A further step is to calculate and check the *CR* of the pair-wise comparisons. Firstly, λ_{max} is calculated as to lead the *RI* and *CR*. Based on Equations 3-5, the *CR* is calculated as follows:

$$W=(1\times0.534)+(1.241\times0.359)+(6.119\times0.107)=1.634$$

$$E=(0.806\times0.534)+(1\times0.359)+(2.804\times0.107)=1.089$$

$$A=(0.163\times0.534)+(0.357\times0.359)+(1\times0.107)=0.322$$

$$\lambda_{max} = \frac{\left(\frac{1.634}{0.534}\right)+\left(\frac{1.089}{0.359}\right)+\left(\frac{0.322}{0.107}\right)}{3}=3.034$$

$$CI = \frac{\lambda_{max}-n}{n-1}=\frac{3.034-3}{3-1}=0.017$$

Based on Table 3, *RI* for three criteria is 0.580. As a result, the *CR* is computed as follows:

$$CR = \frac{CI}{RI}=\frac{0.017}{0.58}=0.029$$

The CR value for main criteria is 0.029. Saaty (1980) stated that a CR $\geq$ 0.1 indicates that the judgment is acceptable. As a result, the consistency of the pair-wise comparisons for main criteria is acceptable. The same calculation procedure is applied to rank the sub-criteria in the environmental risk evaluation model. The weight values and consistency ratio values for sub-criteria are shown in Table 5.

Results and Discussion

Based on Table 5, the result has shown that water pollution is the main environmental risk from fisheries activities in Tok Bali, followed by ecosystem damage and air pollution. Based on the AHP calculation, the weight for water pollution is calculated as 0.534, followed by ecosystem damage (0.359), and air pollution (0.107). It is noteworthy to mention that the weight for water pollution is closely associated with the perspective of experts' judgment (questionnaires). They believed that fisheries activities and water pollution are directly proportional and are mostly directly linked.

Table 5: Result of weight values and consistency ratios for all main and sub-criteria

Main Criteria	Weight	Sub-criteria	Local Weights	Global Weights
Water Pollution	0.534	Oil Spill	0.546	0.292
		Trash	0.137	0.073
		Fishery Sewage	0.121	0.065
			CR = 0.058	
Ecosystem Damage	0.359	Oil Spill	0.705	0.253
		Fishery Sewage	0.151	0.054
		Over Fishing	0.145	0.052
			CR = 0.029	
Air Pollution	0.107	Using Fossil Fuel	0.705	0.075
		Extension Area	0.169	0.018
		Using Chlorofluorocarbon	0.126	0.013
			CR = 0.0009	

Based on global weights as shown in Table 6, the most significant lowest level criteria are found to the water pollution instigated by oil spill or discharged (0.292), followed by the ecosystem instigated by oil spill/discharged (0.253) and air pollution due to the emissions from the use of fossil fuel (0.075). The ranking orders of all other lowest-level criteria are also shown in Table 6.

Table 6: Ranking orders of the lowest-level criteria

Lowest-level Criteria	Global Weight	Rank
Water Pollution Instigated by Oil Spill	0.292	1
Ecosystem Instigated by Oil Spill	0.253	2
Air Pollution Instigated by Using Fossil Fuel	0.075	3
Water Pollution Instigated by Trash	0.073	4
Water Pollution Instigated by Sewage	0.065	5
Ecosystem Damage Instigated by Fishery Sewage	0.054	6
Ecosystem Damage Instigated by Over Fishing	0.052	7
Air Pollution Instigated by Extension Area	0.018	8
Air Pollution Instigated by Using Chlorofluorocarbon	0.013	9

The AHP results have shown that oil spill or discharge from fishing vessel are the main cause of environmental risk in Tok Bali Fishing Port. It is noteworthy to mention that the impact of oil spills from the fishery sector ranging from sea water pollution to the contamination of marine catches. These negative impacts lead to substantial losses if no proper practices are taken in fishing routines. Several useful practices that can be applied to minimise the risk of polluting the water are to avoid overfill the tank when refuelling, ensure the portable tanks are properly capped and locate them away from water. Fishermen should also use proper oil disposal facilities at fishing port, avoid pumping the polluted water into the sea, cover the engine and gearbox with a dip tray to ensure oil entering into the bilge and empty it regularly. Finally, avoid overuse detergent as it can cause water pollution too. In addition, effective contingency plans can be arranged to address oil spill response measures, prompt action can be taken to reduce the impact of oil spills, if water pollution occurs. Fishermen should be informed and trained on how to react when water pollution occurs.

To minimise the losses from overall risk causes, long term strategies are suggested. Based on interviews with the domain experts, three general strategies are recommended. As shown in Figure 3, the strategies are law enforcement, strategic fisheries management practices and environmental education to the fishermen. These strategies are discussed as follows:

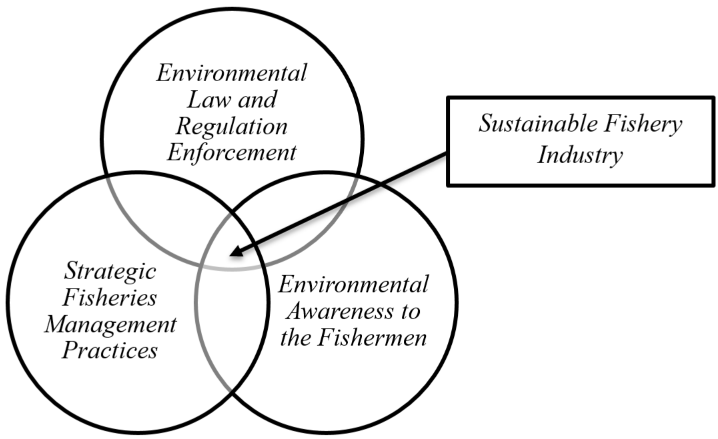

Figure 3: The long-term strategies for enhancing environmental sustainability over fisheries industry

Environmental Law and Regulation Enforcement

Among the strategies to solve the environmental pollution is to enforce environmental laws and regulations that have been allocated. In the fisheries industry, the Fisheries Act No. 317 (1985) should be implemented and enforced. Authorities such as the Department of Fisheries, Royal Malaysia Police, and the Department of Environment need to act decisively against any negative impact to the environment especially oil spills and discharge from jetty or fishing vessels. Frequent monitoring at fishing port should also been conducted.

Strategic Fisheries Management Practices

Strategic fisheries management practices are ongoing practices to address environmental pollution and reducing a large scale of mangrove deforestation for rearing aquaculture areas. These practices can be designed by related agencies such as LKIM and further collaboration with local fishermen's associations. These practices involves research and development (R&D) related to sustainable fishing activities. For example, a research on how community-based fisheries management (CBFM) can be implemented for enhancing the sustainability and reducing pollution in fishing activities in Malaysia.

Environmental Awareness to the Fishermen

Environmental education among fishermen should be intensified. This campaign will educate the fishermen on the importance of the environment. In addition, an effort to improve understanding and awareness among the fishermen through distribution of flyers, forums, seminars, joint dialogue involving government agencies, private sector, and non-governmental organizations (NGOs), should be conducted actively and effectively. Moreover, activities such as informal education between related agencies and fishermen can help them become more responsible for the care of the environment.

Questions have been raised on the best strategy to solve these issues. To answer this question, decision making rating tool is used to prioritise the best strategy that can suit with the problem. Therefore, experts are again provided the judgments by assessing the effective scale (i.e. as shown in Figure 4). Based on Figure 4, the effective scale is described as "1 i.e. very weak", "3 i.e. weakly effective", "5 i.e. medium effective", "7 i.e. very strongly effective", "10 i.e. extremely effective" and "2, 4, 6, 8 and 9 are intermediate values of effectiveness".

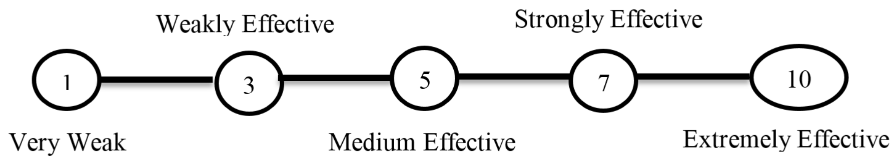

Figure 4: The effective scales for suggested strategies

Based on the assessment by using decision making-rating tool, Table 7 shows environmental law and regulation enforcement is the best strategy to minimise the environmental pollution in the fishing activities at Tok Bali Fishing Port. Based on decision making rating tool, the implementation of "Environmental Law and Regulation Enforcement" is assessed as 5.069, indicates that this strategy is the best option compared to "Strategic Fisheries Management Practices" (4.041) and "Environmental Awareness to the Fishermen" (3.543). However, since the result values of these three strategies are not different from each other, it is suggested that these strategies can be implemented together for better impact.

Table 7: The calculation process for selecting the best strategy

Strategy / Pollution	Water pollution	Ecosystem damage	Air pollution	Effectiveness Value
Environmental Law and Regulation Enforcement	3.097	1.651	0.321	5.069
Strategic Fisheries Management Practices	2.456	1.221	0.364	4.041
Environmental Awareness to the Fishermen	1.816	1.149	0.578	3.543

Conclusions

It is noteworthy to mention that fisheries industry and marine environment provide the important source (i.e. protein) for the majority of Malaysians. As a result, Malaysia fisheries industry aims to increase its production by one third from the current performance. However, since the fishing industry is one of the pollution contributors to the surrounding areas, the environmental risk and impact from this industry need to be proactively analysed and assessed by using an appropriate approach, thus enabling informed decisions to be made regarding mitigation strategies. In this paper, the proactive environmental risk model and decision support framework for prioritising the environmental risk criteria are proposed. The proposed proactive risk evaluation model is tested at Tok Bali Fishing Port as a case study. The result has shown that water pollution is the key environmental risk from fisheries activities at Tok Bali. In addition the most effective strategies to enhance the sustainability of fishery industry at Tok Bali is found to be environmental law and regulation enforcement, followed by strategic fisheries management practices and environmental awareness to the fishermen. The proposed model can help related government agencies such as LKIM and Department of Fisheries Malaysia to conduct a proactive evaluation in order to enhance the environmental sustainability of the fisheries industry. For future research, a quantitative risk evaluation for assessing the targeted or whole criteria in the environmental risk model can be implemented. Several mathematical methods such as Fuzzy Rule-Based and Evidential Reasoning for the assessment can be employed.

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