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DEVELOPING DIVE SITE RISK ASSESSMENT MODEL (DSRAM) TO ENHANCE TOURISM SAFETY AND SUSTAINABILITY IN PERHENTIAN ISLAND

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Abstract: Recreational scuba diving sport in marine tourism industry has grown rapidly every year. Scuba diving is one of the primary attractions for tourist to visit Perhentian Island. It is worth mentioning that scuba diving is not just a recreational activity, but it is also a survival skill. Divers are exposed to many risks which ultimately depend on many factors such as diver condition, equipment and dive site. Statistically, the accident rate at dive site is notably increasing every year around the world. So far, no mathematical model has been developed for assessing the dive site risk dealing with multiple criteria. As a result, this paper aims to develop a Dive Site Risk Assessment Model (DSRAM) with the objectives to identify, prioritize, assess and map the dive sites' risk level in Perhentian Island. A hybrid method called Fuzzy Evidential Reasoning (FER) is utilised in this proposed model. The results have shown that the most influential risk factors at dive site are found to be boat traffic, followed by current, hazard, wave, visibility, marine life threat and depth. It is expected that dive site risk levels produced by DSRAM can be used as safety guidance for commercial scuba divers and tourism operators (e.g. dive centre) in their diving routines. In addition, the DSRAM model will also contribute significant benefits to a sustainable tourism industry by enhancing the safety of recreational scuba diving sport.

Keywords: Scuba diving, dive site risk assessment model, tourism safety and sustainability, analytical hierarchy process, evidential reasoning.

Introduction

Today, recreational coastal water activities such as snorkelling, scuba diving and fishing are popular among tourists. With good accessibility such as modern diving and snorkelling equipment, it creates more leisure time for tourist to be involved in these activities. The development of recreational scuba diving sport has contributed a multi-billion dollar to the tourism industry, and it is rapidly increasing (Ong *et al*., 2012). In Malaysia, recreational scuba diving sport has contributed over RM1.5 billion involving diving centre services, basic facilities, equipment and accommodation for the divers (Rahman, 2017). Malaysia Scuba Diving Association (MSDA) aims a turnover of RM5 billion through this industry by 2020 (Rahman, 2017). As a result, it is noteworthy to mention that this scuba diving sport is able to generate revenue for Malaysia's economy.

Currently, the certified scuba divers are rapidly increasing due to safer and affordable diving equipment (Davis and Tisdell, 1996). Despite this increasing figure, scuba diving accident is also notably increasing every year around the world (Buzzacott *et al.,* 2016). According to Trout *et al.* 2015, the global scuba diving accident has increased from 117 cases in 2010 to 161 in 2012. As a result, it is worth mentioning that scuba diving is not just a recreational activity, but it is also a survival skill. Divers are exposed to many risks, which ultimately depend on many factors such as diver condition, equipment and dive site.

Table 1 shows the primary disabling agent that causes the scuba diving fatalities. According to Buzzacott *et al.* (2016), the causes of death are determined by the medical examiners assigned to fatality cases. Several disabling agents related to dive site are water movement, excessive depth, poor visibility, cold, marine animals, caves, entanglement, exit and entry problems, boats, diving under a ledge or boat and night diving. So far, no model has been developed for assessing the dive site risk dealing with multiple criteria, making the current research is essential.

Therefore, the primary aim of this paper is to develop a Dive Site Risk Assessment Model (DSRAM) for identifying, prioritizing, assessing and mapping the risk level at dive site. The Analytic Hierarchy Process (AHP) is being performed for factors pair wise comparison based on expert consideration to get most influence factors (Saaty, 2008). Furthermore, Fuzzy and Evidential Reasoning (FER) is being employed to formalizing the human reasoning that faces conflicts in multi-criteria decision-making (Wang *et al*., 2006). As a result, this model can assist divers to identity which dive sites are suitable based on their interest and capability. The remainder of this paper is organized as follows. Section 2 discussed the literature review followed by research methodology in Section 3. Section 4 presents the dive site risk assessment in Perhentian Island. Results are discussed in Section 5 and finally, the conclusion is given in Section 6.

Table 1: Primary Disabling Agent Ascribed to 2014 Breath-hold Incidents

Disabling Agent	Count	Percentage
Medical health	27	48
Procedure/Behavior	11	20
Environmental conditions	7	13
Boat strike	4	7
Animal involved injury	4	7
Poor physical fitness	3	5
Total	56	100

Source: Divers Alert Network Annual Report (2016)

Literature Review on Risk Assessment in Scube Diving

In general, the acronym for scuba diving is 'self-contained underwater breathing apparatus'. Since 1990 until 2016, several studies have been conducted by the researchers in the particular area of scuba diving risks such as Edmonds *et al*. (1990), Wilks *et al*. (2000), Ihama *et al*. (2008), Denoble *et al*. (2008), Denoble *et al*. (2011) and Divers Alert Network (2016). The details of

Table 2: The summary of existing research in scuba diving risk

Authors	Research Information
Denoble *et al.* (2011)	This paper assessed the risks of dying while diving, reviewed measures of recreational diving facility rates, explored fatality rates and safety criteria from other fields and the fatality rates based according to estimation methods, demographics and diving practices.
Denoble *et al.* (2008)	This paper is focused on disabling injuries that are more relevant to diving safety than the subsequent cause of death and drowning. This paper found the most common disabling injuries are drowning and cardiac incidents.
Wilks & Davis (2000)	This paper focused on risk management for scuba diving operator in Australia Great Barriers in order to choose the most appropriate methods to reduce diving risk.
Ihama *et al.* (2008)	This paper investigated the causes of scuba diver death from 1982-2007 and discussed the qualified age and sex for scuba diving, experience and unexpected accident during scuba diving.
Edmonds & Walker (1990)	This paper discussed the environment factors that influence the scuba diving fatalities, the study cases demonstrated that although diving is safe but when other factors combined, the person cannot handle the complexity of equipment and environment.
Buzzacott et al. (2016)	This report shown scuba diving fatalities causes, incident report, incident analysis, etc.

these studies are summarized in Table 2. So far, there is no research been carried out on dive site risk assessment and there is no mathematical model has been developed to assess dive site risk in the literatures.

In order to assess dive site risk, seven factors have been identified from the review of several literatures, which are water depth, visibility, current, wave, hazard, boat traffic and marine life threat. Water depth is one of the identified risk factors in DSRAM model. Each dive site has a different water depth level. When a diver dive in a deeper parameter, the total pressure of oxygen that is inhaled will be drastically boosted (Martin, 1997). The deeper the diver dive, there will be more pressure on diver body. Under the sea level around 14.5 square inch of air pressure to diver body, the pressure is unnoticeable because diver body's fluid is pushing outward with the same force. When diver ascend, there will be more pressure on the diver body because there is more water above him and exerts to the diver body. Recreational diver may go deeper than 130 feet; the diver will face the risk of the bends, running out of air and nitrogen narcosis increases when the diver goes deeper (Martin, 1997). The deeper they go, the higher the risk that they will be exposed. The understanding of air pressure effect and decompression illness can help the diver to be more cautious when the diver dive more than 130 feet. The minimum of water depth to determine of diving injuries is not been ascertained conclusively for the safe diving (Bartram & Rees, 1999).

Visibility is very important during the diving activities in the ocean. However, if the visibility of the diver is poor, it influenced and affected diver dive significantly. Divers will have a hard time to stay with their buddy, keep track where they are and where they are going (PADI Open Water Diver Manual, 2016). While diving, the visibility under the water will depend on sunlight that travels to the water depth. When the diver descending, water begins to absorb the spectrum of colours immediately and colour will be gradually disappeared in each level of depth and finally at a certain depth, colour will be vanished (Alan, 2008). In each dive site, there will be a different sight of level due to the depth of dive site and geographical condition. For example, the more depth of dive site location, the less light absorption at the location. Recreational diver who dives in tropical water obviously has a lower risk compared to diver who dives in cold, dark waters with little visibility (Germonpré, 2006).

Ocean surface current movement is generated by wind direction, earth rotation or the position of landforms that interact with the current. Current may happen due to differences of density in water mass caused from temperature and salinity changes (Wunsch, 2002). This phenomenon can endanger diver who are in trap in the current circulation. Some currents are relatively permanent and some of them are temporary. These differences caused by wind blowing over the surface, unequal heating and cooling and wave (PADI Open Water Diving Manual, 2016). Therefore, there are places that have a permanent current and some are not. Current is an obstacle that a diver can encounter, even experienced divers sometimes unable to estimate accurately the speed and impact of a current (Mike, 2010).

The cause of waves is from wind or bad weather whereby the friction between wind and water surface instigates the growth of waves. When the wind starts to blow, waves will appear depend on the strength of the wind (Salmon, 2008). The wind blow in the ocean surface forms waves, a wave travel to a direction until loses its energy and flatten (PADI Open Water Diver Manual, 2016). The chances to be affected by seasickness is greater when a big wave occurs on the way to the dive site, gearing up will be more tired and influences the diving activity. Strong wave in shallow or deep water increased the risk of the diver to go against rock. The highest ocean waves are because the blow of strong wind, high wave is generated by passing or near storm wavelength (Segar, 2012). The wave turbulence will affect diver physically. To those whom has a motion sickness, it will cause depression to them and this will affect diver condition and contribute the after affect to diver. Therefore, when the diver health condition is not good, it is a clear indication that diver is not suitable to be involved in the diving activity.

Hazard is a potential source of adverse health effect or harm on a person (CCOHS, 2017). Each dive site has a different existence of hazard such as narrow channel, death coral reef and shipwreck. According to BSAC (1999; 2009), diver will be trapped inside a shipwreck and drowned due to the extreme fatigue. Other than that, narrow part of wreck has become additional reason for diver's death (Kingsbury *et al.,* 2011).

According to Oxford Living Dictionary (2017), a boat is a vessel traveling by water while traffic is the movement of a vessel. In this paper, boat traffic is the boat coming through at the dive site zone. Boat traffic can be dangerous to diver if the diver is not following the procedures when ascending to the surface (Pollock *et al.,* 2008). Notably, boat driver who does not careful enough while propel through at the dive site zone also can be dangerous to the diver.

Marine life animal such as barracuda, giant octopus, shark and giant eel also attacking diver because of reaction of self-defence or it feel threatened. Diver must be cautious and aware on the presence of the fish or other marine life animal to ensure safety while diving. Animal behaviour is unpredicted; it is recommended to give a special attention especially to venomous and poisonous marine animals. Most accident which caused by marine animal are caused due to the self-defence (Fernandez *et al*., 2011). Dangerous animal of the sea known to be poisonous are better to be avoided by the divers to ensure their safety during diving activity (Alparslan *et al.,* 2010). The main reasons that caused divers attacked by marine animals are because of starvation and incorrect assumptions of human as their primary pray, inquisitive, attraction to sound, bright colour, confused, self-defences, human invade its space, *etc.* (Somers, 1988). This behaviour is hard for diver to predicted, so the safer measure is to be cautious and make sure they do not disturb the marine animal.

For assessing the dive site risk in this DSRAM model, two methods are used including Analytical Hierarchical Process (AHP) and Fuzzy and Evidential Reasoning (FER). AHP method is used to establish the weight for each factor in the DSRAM model. An AHP theory is a pair wise comparison based on expert consideration to get most influence factor (Saaty, 2008). AHP framework in multiple criteria intuitive is involved in rational quantitative and qualitative aspect (Mohd Salleh *et al*., 2015). After the weight for each factor is established, the FER method is employed to formalize the human reasoning that handles conflicts in multi-criteria decision-making (Wang *et al*., 2006).

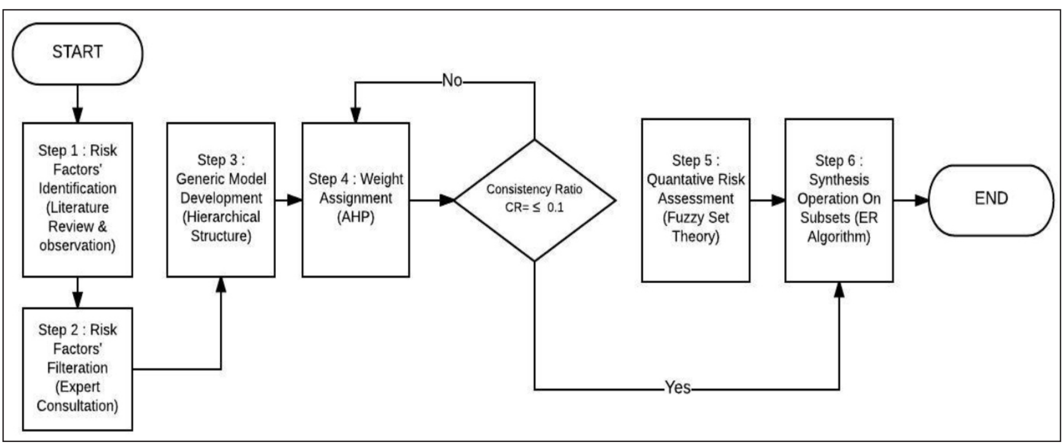

Figure 1: The Procedures in DSRAM

Methodology

In order to assess dive site risk by using the DSRAM, the combination of different decision-making methods which are AHP and ER (i.e. called Fuzzy Evidential Reasoning) is used. To develop the calculation process in the DSRAM, a flow chart of proposed methodology in sequential order is illustrated in Figure 1 and explained in sub-sections below.

Risk Factors' Identification and Filtration (Steps 1, 2 and 3)

The identification process of risk factors in this paper is based on the literature review (see Table 3) and further discussed with the support of the consultation with the experts. Filtration process has been conducted after consultation with the experienced scuba divers. As a result, seven risk factors have been considered in the DSRAM.

After the risk factors have been identified, revised and further filtered, a hierarchical model is developed as shown in Figure 2.

AHP Weight Assessment (Step 4)

The AHP method is used to perform weight assignment for each risk factor in the DSRAM. This method consists of five key formulas which need to be calculated. Table 4 shows a preferable scale from 1 to 9, where a preferable scale 1 shows the equivalent between factors while a

Table 3: DSRAM main criteria

Main Criteria	Literature Review
Water Depth	Martin (1997), Bartram & Rees (1999)
Visibility	Germonpré (2006), Alan (2008)
Current	Wunsch & Ferrari (2004), Mike (2010)
Wave	Salmon (2008), Segar (2012), Open Water Diver Manual (2016)
Hazard	Martin (1997), CCOHS (2017)
Boat Traffic	Pollock *et al.* (2008)
Marine Life Threat	Somers (1988), Alparslan *et al.* (2010), Fernandez *et al.* (2011)

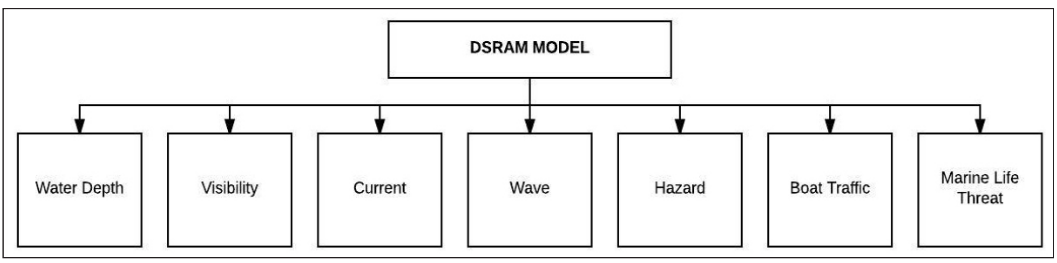

Figure 2: Dive Site Risk Assessment Model (DSRAM)

Table 4: Comparison scale

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.

preferable scale of 9 shows one criterion is very important than the other factors when they are compared (Saaty, 2008).

To quantify judgements of criteria A_i and A_j are presented by n x n matrix D. The a_{ij} entries are defined by entry rules as follows:

- Rule 1: if $a_{ij} = \alpha$, $1/\alpha$, $\alpha \neq 0$
- Rule 2: if A_i is judged to be of equal number of equal relative number as A_j, then $a_{ij} = a_{ji} = 1$.

According to above rules, matrix D is shown as follows:

$$D = a_{ij} = \begin{bmatrix} 1 & a_n & \cdots & a_{1n} \\ 1/a_n & 1 & \cdots & a_{2n} \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}$$

Equation (1)

where $i, j = 1, 2…., n$ and each a_{ij} is the relative importance of criterion A_i to criterion A_j.

The quantified judgement of comparison of pair (A_i, A_j) is noted as a_{ij} in the matrix D; a further step is to allocate the weight vector for each criterion or alternative as it shows the prioritization of the criterion or alternatives (Riahi *et al*., 2012). A weight value w_k can be calculated as follows:

$$wk = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{akj}{\sum_{j=1}^{n} a_{ij}}\right) k = 1,2,3, \ldots, n$$

Equation (2)

where a_{ij} stands for the entry row i and column j in a comparison matrix of order n.

By using the Consistency Ratio (CR), inconsistency of the pair wise comparison can be measured. If CR value is 0.10 or less, the consistency of the pair wise comparison can be accepted as reasonable and the AHP can continue with computations of weight vectors (Mohd Salleh *et al*., 2015). In contrast, a CR with greater value than 0.10 indicates an inconsistency in the pair wise judgements. Thus, decision maker should review the pair wise judgements before proceeding. To check the consistency of the judgements, a CR is computed by using Equations 3-5 (Mohd Salleh *et al*., 2015).

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

Equation (3)

$$CI = \frac{\lambda\, max - n}{n - 1}$$

Equation (4)

$$\lambda\, \text{max} = \frac{\sum_{j=1}^{n}\left(\frac{\sum_{k=1}^{n} wk\, ajk}{wj}\right)}{n}$$

Equation (5)

where CI is the inconsistency index, RI is the average random index (Table 5), n is the number of items being compared and λ_{max} is the minimum weight value of the n x n comparison matrix D (Mohd Salleh *et al*., 2015).

Quantitative Risk Assessment (Step 5)

Risk assessment can be done by using quantitative data. A quantitative analysis uses numerical values rather than the descriptive scales that are used in analysing the qualitative and semi quantitative methods. In this paper, the numerical values are obtained by interviewing diving instructors who have more than ten years' experience in scuba diving. The transformation of quantitative factor to qualitative factor is conducted by using Fuzzy Set Theory (FST). By using the value from expert consultations, the membership function transformation can be constructed as shown in Figure 3. The degree of membership function is often point out on the vertical axis ranging over to the real interval [0 1] (Riahi *et al.,* 2012). For example, for assessing the marine life threat in diving site is demonstrated as follows.

Based on the opinion from the experts, if a dive site has 0 to 2 marine life threat, then the dive site is considered to be very low risk. If the dive site has marine life threats for 3-4, 5-6, 7-8

Table 5: Value of average random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	058	0.9	1.12	1.24	1.32	1.41	1.45	1.49

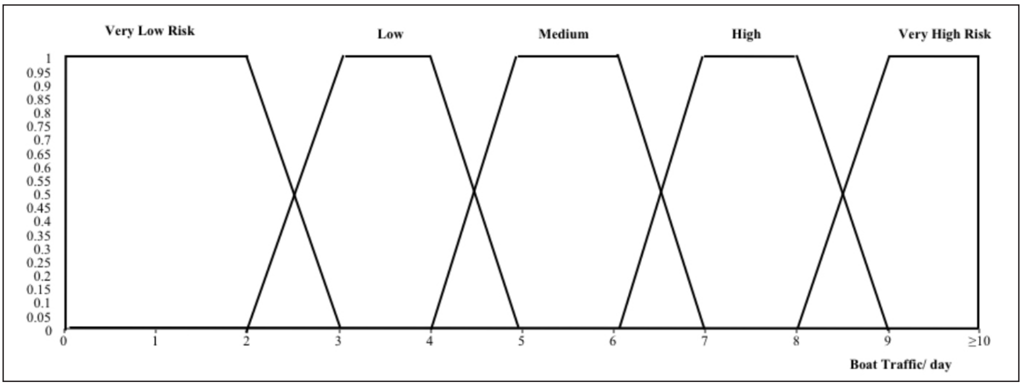

Figure 3: Membership Function of Marine Life Threat

and 9 or more marine life threats respectively, then the dive site is considered as low risk, medium, high and very high risk.

Based on the above technique, all risk criteria are designed with membership function and their risk scales are shown in Table 6.

Synthesis Operations on Subsets by Using ER Algorithms (Step 6)

The kernel of the ER approach is an ER algorithm developed based on of a multi-attribute assessment framework and the evidence combination of the D-S theory (Wang *et al*., 2006). By using the ER algorithm, aggregation of multi-attributes in a hierarchical structure can be implemented. In a hierarchical structure, an upper level is assessed through associated lower level attributes. For example, water depth, visibility, current, wave, hazard, boat traffic and marine life threat are the subsets of the dive site risk. If all these subsets are assessed to be exactly low risk, then the dive site risk should also be low risk. The details of ER algorithms can be found in Wang *et al.,* (2006) and Mokhtari *et al.* (2012). In this paper, with the assistance of the IDS software package, a process of aggregation in the hierarchical structure can be implemented. Consequently, the IDS software package will be employed in the case study to synthesize the dive site risk criteria.

Case Study: 21 Dive Sites in Perhentian Island

In order to test the applicability of this DSRAM, diving sites in Perhentian Island are selected as a case study. Perhentian Island is located 21km of northeast coast of Terengganu in Peninsular Malaysia. In 2013, 134,000 of tourist visit Perhentian Island, 62,000 tourists from foreign country and 72,000 tourists are from within Malaysia itself (Tourism Planning Research Group, 2015). The number of visitors

Table 6: Risk scales for each risk factor in DSRAM

Risk Factor	Risk Scales				
	Very Low Risk	**Low Risk**	**Medium Risk**	**High Risk**	**Very High Risk**
Water Depth (meter)	0-10	11-15	16-20	21-25	26 more
Visibility (meter)	21-25	16-20	11-15	6-10	5 or less
Current (kph)	0.5	1.5	2.5	3.5	4.5 more
Ocean Waves (feet)	0.0-1.0	1.5-2.0	2.5-3.0	3.5-4.0	4.5 more
Hazard (object amount)	0-2	3-4	5-6	7-8	9 more
Boat Traffic (number of boat per day)	0-2	3-4	5-6	7-8	9 more
Marine Life Threat (species amount)	0-2	3-4	5-6	7-8	9 or more

keep accelerating because of the attraction of Perhentian Island by providing scuba diving learning course especially in east coast Malaysia. Low cost of fees and charges for scuba courses and activity is the main factor that inviting more divers to Perhentian Island (Malaysia Tourism Research, 2015). Dive site risk assessment is a new angle of study in the field of scuba diving. As a result, dive site risk assessment has been proposed in this paper to enhance the scuba diving activities as well as reducing the rate of fatalities in this island. There are about 30 dive sites in Perhentian Island, however, only 21 out of 30 dive sites have been assessed by using this DSRAM due to difficulties in obtaining data for nine inaccessible dive sites. 20 experts have been approached to participate in this paper, however, only 17 experts are able to commit. Based on these expert's judgement, the assessment results are shown as follows.

Based on Step 4, the identified risk factors are prioritized in order to identify the significant factor in the DSRAM. Table 7 shows the weight for each risk factor, where the most important risk factor is found to be boat traffic with the weight of 0.3246 and followed by current (0.1742), wave (0.1045), hazard (0.0956), visibility (0.0891) and water depth (0.0745).

Table 7: Established weight for each risk factor in DSRAM

Main Factor	Weight of the Main Factors	Rank
Water Depth	0.0745	7
Visibility	0.0891	6
Current	0.1742	2
Wave	0.1045	3
Hazard	0.0956	4
Boat Traffic	0.3246	1
Marine Life Threat	0.0939	5

In step 5, all criteria have been assessed quantitatively (i.e. Figure 3) and further transformed into risk levels under fuzzy environments. For example, based on Table 8, the risk of marine life threat for 21 dive sites are assessed by using membership function (i.e. Figure 3) and further transformed into fuzzy sets.

Once all the risk criteria are assessed and transformed into fuzzy sets, these values are then synthesized to represent the overall risk values (utility values) at each dive sites. By using IDS software, the overall risk values for all 21 dive sites are shown as follows:

Results and Discussion

Based on the AHP calculation, the most three significant factors have been identified which are boat traffic, followed by current and wave. Boat traffic is the total number of boats coming through on the dive site zone in a day. Based on the experts' opinion, boat traffic is the higher risk factor for divers due to its severity. Current is the second significant risk factor at the dive site which can distract the divers while diving and the accident can happen due to entrapped in the current flow. Wave is the friction of wind that causes the surface of the sea going up and down, this phenomenon can affect diver condition when going down from their boats or while floating on the surface. On the other hand, based on experts' view, water depth is considered as the insignificant risk factor among these seven risk factors because they believed that water depth exposes only minimal risk to diver if they follow the proper procedures.

Based on Figure 4, from the 21 assessed dive sites, Sugar Wreck (i.e. 55%) is the dive site with highest risk values at Perhentian Island, followed by Vietnamese Wreck (44%) and Shark Point (44%). Sugar Wreck's geographical condition is located at the middle path area of passing boat coming from various angles. Risk value is contributed from the boat traffic that are coming through the dive site zone, total hazard that existed around the dive site are more than six, total marine life threat that can be found is around five to six type of species, current and wave condition risk is quite high due to its geographical area and lastly, water depth is measured as a medium risk. Vietnamese Wreck is the second highest risk dive site among 21 dive sites at Perhentian Island as it is located near to the Sugar Wreck dive site. Vietnamese Wreck risk has contributed most from the depth

Table 8: Fuzzy sets for marine life threat in all dive sites

Dive Site	Fuzzy Set (Marine Life Threat)
Sugar Wreck	{(Very Low, 0), (Low, 0.3713), (Medium, 0.2054), (High, 0.2511), (Very High, 0.1722)}
Vietnamese Wreck	{(Very Low, 0.0462), (Low, 0.4707), (Medium, 0.0738), (High, 0.4092), (Very High,0)}
Shark Point	{(Very Low, 0.4130), (Low, 0.1535), (Medium,0.0721), (High, 0), (Very High, 0.3614)}
Tokong Laut	{(Very Low, 0.0944), (Low, 0.3918), (Medium, 0.2646), (High, 0.2491), (Very High,0)}
Karang Selat	{(Very Low, 0.3664), (Low, 0.1430), (Medium, 0.3515), High, 0), (Very High, 0.1391)}
Batu Nisan	{(Very Low, 0.5733), (Low, 0.3599), (Medium, 0.), (High, 0.0668), (Very High,0)}
Sea Bell	{(Very Low, 0.2866), (Low, 0.2536), (Medium, 0.4598), (High, 0), (Very High,0)}
Terumbu Tiga	{(Very Low, 0.0636), (Low, 0.8231), (Medium, 0.),(High, 0.1134), (Very High, 0)}
Panglima Abu	{(Very Low, 0.1641), (Low, 0.7131), (Medium, 0.1228) ,(High, 0), (Very High, 0)}
D'Lagoon	{(Very Low, 0.1641), (Low, 0.7131), (Medium, 0.1228), (High, 0), (Very High, 0)}
Kerma Laut	{(Very Low, 0.4925), (Low, 0), (Medium, 0.5075), (High, 0), (Very High, 0)}
Maritime Wreck	{(Very Low, 0.3471), (Low, 0.5267), (Medium, 0), (High, 0.057), (Very High, 0.0692)}
Tanjung Basi	{(Very Low, 0.1641), (Low, 0.7131), (Medium, 0.1228), (High, 0), (Very High, 0)}
Police Wreck	{(Very Low, 0.3841), (Low, 0.4843), (Medium, 0.1317), (High, 0), (Very High, 0)}
Tanjung Batu Caping	{(Very Low, 0.5989), (Low, 0.2769), (Medium, 0.0561), (High, 0.0681), (Very High, 0)}
Tanjung Tukas Darat	{(Very Low, 0.5989), (Low, 0.2769), (Medium, 0.0561), (High, 0.0681), (Very High,0)}
Romantic Beach	{(Very Low, 0.5733), (Low, 0.3599), (Medium, 0), (High, 0.0668), (Very High, 0)}
Batu Layar	{(Very Low, 0.5125), (Low, 0.4201), (Medium, 0.0674), (High, 0), (Very High, 0)}
Tiga Ruang	{(Very Low, 0.5125), (Low, 0.4201), (Medium, 0.0674), (High, 0), (Very High, 0)}
Kerma Darat	{(Very Low, 0.4130), (Low, 0.1535), (Medium, 0), (High, 0.0721), (Very High, 0.3614)}
Teluk KK	{(Very Low, 0.8995), (Low, 0.0454), (Medium, 0.0551), (High, 0), (Very High, 0)}

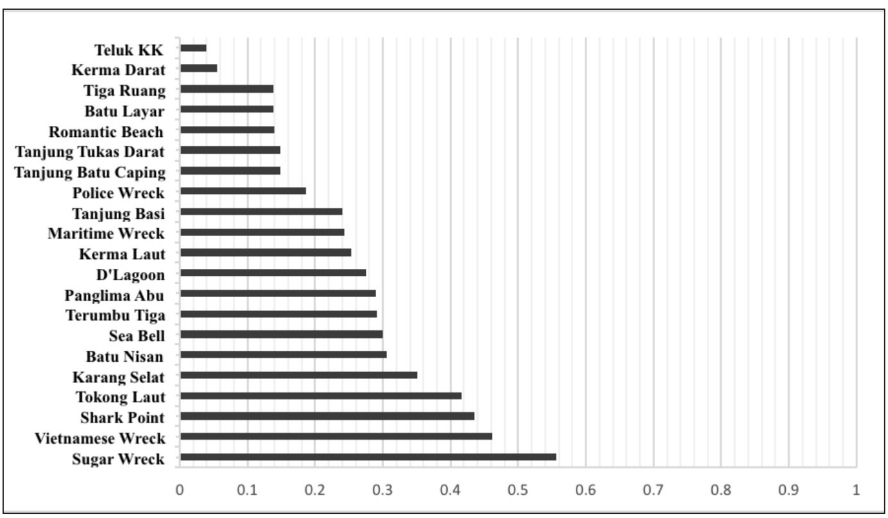

Figure 4: Risk values for all 21 dive sites at Perhentian Island

level, total existed hazard, total marine life threat and total boat that coming through the dive site. Shark Point is assessed as the third highest risk dive site at Perhentian Island due to the boat traffic coming through at the dive site zone. The shark Point dive site is famous not only for diving but also for snorkelling activity. Meanwhile, the lowest risk dive site is Teluk KK that also known as artificial reef diving site.

Based on the overall result, it is noteworthy to mention that the risk levels of all 21 dive sites in Perhentian Island are ranged from 3% (i.e. very low risk) to 56% (i.e. medium risk). Consequently, these results are concluded that these dive sites are not reach a high-risk level and considered as safe dive sites for diving activities as long as the procedures are followed.

Conclusion

Dive site risk assessment is a new angle of study in marine tourism industry. In this paper, the DSRAM has been proposed in order to provide a decision-making tool for assessing risk level at dive sites. Firstly, the risk factors are identified through literatures, consulted with experts and further filtered in the second step. As a result, seven main factors for assessing dive sites are identified which are water depth, visibility, current, wave, hazard, boat traffic and marine life threat. Thirdly, a generic hierarchical structure is developed to provide a visual structure for DSRAM. It is noteworthy to mention that this model is generic where it can be modified and adjusted based on decision makers' preferences. Fourthly, the AHP method is employed for prioritizing the dive site risk factors. The most significant factors are found to be boat traffic, followed by current, wave, hazard, marine life threat, visibility and water depth. Fifthly, all risk factors are assessed quantitatively by using the designed membership functions under fuzzy environments. Finally, synthesis operations are conducted in order to obtain overall risk values for each dive site. Consequently, the top three highest risk dive sites in Perhentian Island are Sugar Wreck, Vietnamese Wreck and Shark Point. It is expected that dive site risk levels produced by DSRAM can be used as safety guidance for commercial scuba divers and tourism operators (e.g. dive centres) in their diving routines. In addition, the DSRAM model will also bring obvious benefits to a sustainable tourism industry by enhancing the safety of recreational scuba diving sport. In the future, the visual graphic map will be produced based on the produced results and it can be used at every dive centre for their guidance. Moreover, this DSRAM model can be used to assess a new potential dive site before it can open for commercial diving sites.

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