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COASTAL EROSION INDEX USING AHP AND ANN FOR COASTAL MANAGER

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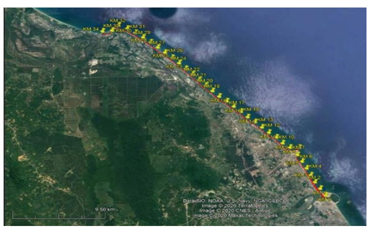


Abstract

Coastal erosion can be found on almost all of Malaysia's beaches, but it is particularly prevalent on the country's east coast. The problem of coastal erosion has been resolved through the use of a variety of methods and treatments that are tailored to the severity of the erosion. It is critical for coastal managers and responsible agencies to have an index of erosion that can be used as a guide in determining the level of erosion in a given area in order to design the appropriate mitigation and treatment measures. It is necessary to identify and categorize the factors contributing to coastal erosion. This study employed a literature review and expert feedback questionnaires to identify the primary factors contributing to coastal erosion. This paper put forward the combining method of the AHP and neural network for evaluating the weights of each influential parameter to coastal erosion. As a result of the analysis, AHP discovered that coastal structure was the most influential factor influencing coastal erosion, followed by human activity, waves, and wind with weights of 0.5333, 0.2404, 0.1804, and 0.0459, respectively, whereas ANN analysis also discovered that coastal structure was the most influential factor influencing erosion, followed by human activity, wind, and waves with weights of 0.612, 0.232, 0.082, and 0.074, respectively. Despite the fact that the results of the two analyses were quite different in terms of weights values, the results of both analyses allowed us to determine which factors are the most important in terms of erosion. The weighted application of these factors will be an additional guide to existing guidelines such as NCES and ISMP in evaluating appropriate coastal mitigation and planning strategies. The outcome of this study also able to enhance the coastal management in terms of being the early reference of coastal manager and stakeholders in developing or managing coastal areas.

Keywords: Coastal Erosion, Coastal Erosion Causes, Coastal Erosion in Terengganu, AHP Analysis, ANN Analysis

1.0 INTRODUCTION

In the preceding few decades, urbanisation and the rapid expansion of coastal cities have been a notable population trend, culminating in the formation of several large cities in all coastal regions around the world. With numerous projects, developments, infrastructure, and ecosystems, the coastal zone is one of the most developed locations on the country (Koks et al., 2019; Temmerman et al., 2013). Since 1985, the coastal areas, like Malaysia, have experienced substantial economic expansion. Economic growth and increased human activity along the shore have resulted in ongoing coastal erosion and high land loss rates along the Malaysian coast (Ghazali, 2006). Based on National Coastal Erosion Study (NCES) 2015, about

1,324 km of Malaysia's coastline was found to be eroding. (DID, 2015)

The most severe coastal erosion occurs in fast developing areas, such as the northern estuary of the Terengganu River, particularly the Kuala Nerus coastal area, as case example of Terengganu today. This erosion is caused by morphological changes (Northeast Monsoon effect) on the Kuala Terengganu coast, which are triggered by wave energy variations and associated seasonal changes in the direction of coastal drift, as well as the extension of Terengganu airport (Yee Ling et al., 2019). Terengganu coastal changes were also documented in NCES 2015, which found that 20 places along the Terengganu coast are eroding at a rate of 2 to 4 metres per year and had been degraded by nearly 148 kilometres (until 2015). Since then, the government has implemented a number of mitigation projects in Terengganu to counteract erosion. Furthermore, the government has conducted many studies on the phenomenon of coastal erosion, including a details study of coastal areas in Malaysia. An Integrated Coastal Management Plan (ISMP), and a guideline known as "DID Circular 97," to determine the best solutions for coastal erosion rehabilitation and to aid in future coastal planning and management has been introduced.

In addition, many previous studies in technical and management have been conducted to assess the factors that influence coastal conditions and the causes of severe erosion on both short and long term temporal and geographical scale, such as; (Asmawi & Ibrahim, 2013; Mentaschi et al., 2018; Prasad & Kumar, 2014; Rangel-Buitrago et al., 2018; Williams et al., 2018). Erosion is often caused by a combination of numerous nature causes interacting with anthropogenic factors along the shoreline and they may be classified into two primary types; natural and human-induced factors (Goldenberg et al., 2014; Jonah et al., 2016; Williams et al., 2018).

Due to the factors of natural and man-made, the current coast areas have received unmanageable magnitudes and impacts due to increasing exploitation along coastal zones such as the example of Terengganu coast as mentioned above. Thus, identifying the extent to which each parameter influences coastal erosion is particularly important for coastal management. When it comes to coastal disaster risk reduction management and coastal planning for sustainable development, identifying the most important factors that will influence the current state of the coast in the face of disasters is critical (Rangel-Buitrago *et al*., 2020; Rudiastuti et al., 2020; Sheik Mujabar & Chandrasekar, 2013). In order to mitigate such consequences, as well as the resulting economic and human losses, coastal managers must understand the sensitivity of natural coastal sectors, which is related to wave energy, beach characteristics/evolution, sediment pathway, and sea level trend, among other factors (Coelho et al.,2006).

Thus, the purpose of this papers is to develop a methodology which may comprehensively assess the most influential factors in order to provide a basic and quick guide in measuring the speed of erosion that occurs. The index developed in this study is intended for beaches in Malaysia only, therefore, the most influential factors and factor ratings are adequately determined by local experts only. Local experts can differentiate genuine variability on a finer scale, particularly on NCES Category I beaches, where eroded beaches are caused by more than just sea levels, waves, and wind.

2.0 METHODOLOGY

2.1 Test Area: Telipot Beach, Kuala Nerus

Kuala Nerus is a Terengganu district located at 5º20'N 103º00'E. Gong Badak, Seberang Takir, Batu Rakit, and Batu Enam are among the important towns and villages in Kuala Nerus, which has a land area of 388km2. The study area is located at Telipot beach which is between the mouth of the northern Kuala Terengganu River and Batu Rakit. Beach (Figure 1). The beach is severely eroded, affecting several settlements including Kg. Pengkalan Maras, Kg. Tanjung, and Batu Rakit. The National Coastal Erosion Study (NCES) 2015 has determined that the erosion rate at Kuala Nerus is between 2 – 11 m/year. However, the erosion rate at Mengabang Telipot and Mengabang Telung, Kuala Nerus, has grown to 20 m/year since 2016. The erosion rate in areas adjacent to these portions has also increased significantly. A relevant case study was chosen for the deployment of an index-based technique.

Figure 1 Erosion site at the test area

2.2 Method and Materials

The main parameters influencing coastal erosion are discussed in this paper, and an index-based method for coastal erosion is proposed. The goal is to evaluate key factors that are significant in determining the extent of coastal erosion.

2.2.1 The Analytic Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP), the decision analysis tool utilised in this study, is a mathematical method created by the University of California at Berkeley for assessing complicated choice issues with numerous criteria. The AHP method is a measuring theory that derives priority scales from pairwise comparisons. The development of priority scales is based on the expert judgements (Al-harbi, 1990; Saaty, 2002). This method isn't new; the AHP has been the most extensively used method to represent the subjective decision-making process based on multiple attributes for about two decades (Dong et al., 2008). Since then, it's been frequently utilised in corporate planning, portfolio selection, benefit/cost analysis by government agencies for resource allocation, and the establishment of multinational logistics centres, among other applications (Chou & Yu, 2013).

The AHP procedure can be divided into four steps, which are as follows.

- Step 1: Create the hierarchy system by decomposing the problem into a hierarchy of interconnected elements.
- Step 2: Create input data consisting of a pairwise comparison matrix to determine the comparative weight of the decision elements' attributes.
- Step 3: Summarize the decision and estimate the relative weight.
- Step 4. Determine the combined relative weights of the choice elements in order to reach a set of ratings for the alternatives/strategies of decision.

The typical form of Analytic Hierarchy Process (AHP) as illustrates in Figure 2.

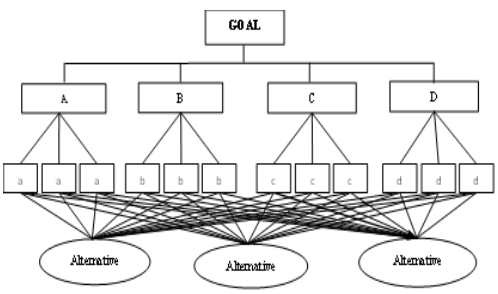


Figure 2 Typical model of AHP analysis

Goal represents an Index erosion

- A, B, C, and N represent the parameter dimension of coastal erosion
- a, b, c, d and n represent the parameters or factors (have represents the weightage of each dimension and sub-dimensions)
- Alternative is present the final result of problem analysis, that is, weight values in relation to the set objective

2.2.2 Artificial Neural Network *(ANN)*

The second method was employed in this study is Artificial neural Network (ANN). An ANN is an information system with certain features in common with biological neural networks (Hendriyono et al., 2015; Kabir & Hasin, 2013; Vagropoulos et al., 2016). On the basis of some assumptions, ANN have been constructed as expansions of human cognition mathematical models or neural biology. Neurons, a mechanism for weight determination also known as neuronal training and neuronal activity, characterise ANN.

The data gathering, training, testing, and prediction processes are all part of the neural network mentioned above (Chen et al., 2019; Dongare et al., 2012; Lecun et al., 2015; Özcan et al., 2020). Input, weighting, aggregation, activation, and output elements make up the fundamental neural network structure used in this study. (Figure 3).

Wave heights in metres, wind speed in m/s, coastal structures, and human activities within the coastal area in terms of range between 1-10 are all included in the input layer. Data will be collected through official databanks, reports, and site observations from 2016 to 2019. Output data known as dependent variable also should be provided for analysis, and the output data for this study is a record of erosion from 2016 to 2019 at Telipot beach that will be used as training data for ANN.

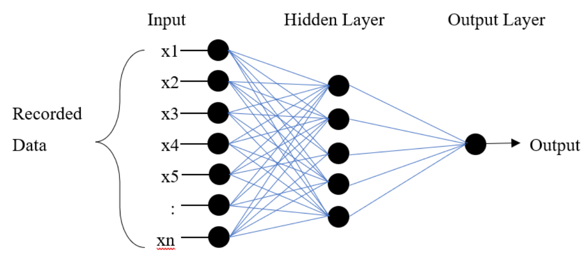


Figure 3 Typical of neural network architecture.

2.3 Parameters Identification

The identification of criteria (parameters) that are provided in this paper is the first stage in the AHP flowchart. The early parameters for this study were only discovered after a thorough review of the literature for the general coastal area. This step is critical for determining the major variables that have been documented by multiple researchers in relation to the worldwide incidence of coastal erosion. The literature was examined for reliable data on purpose by looking at (a) specific sorts of journals, such as the Scopus database, and (b) keywords that might refine the results.

Scopus was chosen as the database since it is one of the largest abstracts and citation databases for peer-reviewed literature, including scientific journals, books, and conference proceedings, all of which are covered by the study (Nobre & Tavares, 2017). Following that, the list was examined using the process shown in Figure 4.

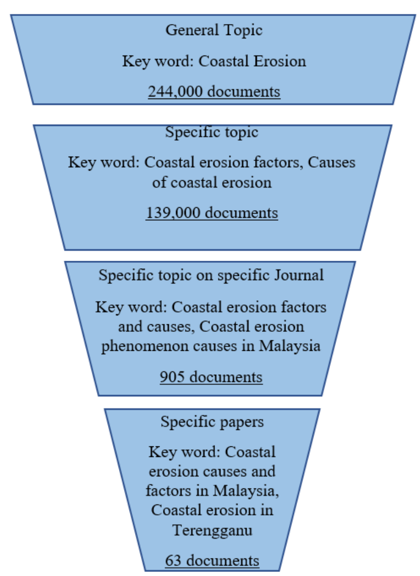


Figure 4 Literature review key word searching mapping process

Based on Figure 3, the findings of a complete examination of the literature on numerous studies and research on the factors contributing to coastal erosion, as described in Table 1.

Table 1 Summary of coastal erosion factors identified through literature review

Dimensions	Factors
Natural Factors	Wave Wind Sea Level Rise Storm Tides Water Temperature
Man-made Factors	Human activities Ecosystem Destruction
Socio-Economic Factors	Coastal Structure

2.4 Parameters Selection

The details of the factors identified as contributing to erosion will be examined to pick the factors that significantly cause erosion, which will be used as input for both AHP and ANN analyses. This study employed a literature review and surveys of coastal experts to determine the most significant factors affecting erosion.

Based on Literature

The findings of a comprehensive literature review, as mentioned in the topic 'parameter identification,' guide the first step in the selection of criteria. Using the keywords "erosion causes", "coastal erosion factors," and "coastal erosion in Terengganu," the abstracts of the retrieved papers were analysed to see if they could be used as analysis criteria. The aim of this process is to determine which probable parameter could cause coastal erosion, based on extensive and adequate data and explanation from prior research or studies.

The current investigation uses 63 articles related to coastal erosion and all of them have the common factors in causal the coastal erosion. The articles have been carefully chosen from valid, well-respected scholarly resources (e.g., ScienceDirect), from high Impact Factor journals, as stated by Journal Citation Reports, and from prestigious international conferences. As a result, criteria will be established based on an assessment of the factors that are usually recognised as the principal cause of erosion in the literature. In the form of a table, all identified parameters will be summarised and expressed as percentages.

All factors identified will be grouped into three categories of dimension: natural, man-made, and socioeconomic. Only the highest percentage parameters for all three dimensions factors will be considered as sub-criteria for AHP analysis. The criteria identified during the literature review were listed in Table 2. Calculating the frequency of a factor listed in the study that contributes to erosion gives the percentage number.

Table 2 Summary of parameters in the literature

Dimensions	Factors	Percentage
Nature Factors	Wave	15
	Wind	10
	Sea Level Rise	2
	Storm	3
	Tides	2
	Water Temperature	1
Man-Made Factors	Human activities	25
	Ecosystem Destruction	1
Socio-Economic Factors	Coastal Structure	41
	TOTAL	**100**

Based on Questionnaire

The second approach for selecting parameter is to interview a group of experts, which includes DID officers, consultants, and academics with considerable expertise and experience in the field of coastal. Selected experts will be asked to respond to a questionnaire provided through email based on current situation of the country. Select experts will be given a specific period of two weeks to complete the questionnaire in order to achieve an accurate response rate for this study.

The number of experts for the AHP method is between 10 to 50 experts are required. Confirmation of the number of experts required for this method is also consistent with earlier research, which suggests that the number of experts authorised should be between 10 and 15, with great regularity (Adler & Ziglio, 1996). The experts chosen for this study have between 8 and 26 years of expertise with Malaysia's coastline erosion problem.

Because the index being developed is only designed for use in Malaysian coastal areas, information from local specialists will suffice in its creation. As a result, a panel of ten experts in coastal engineering was assembled for this study. The panel has been careful selected based on experiences, services, and projects involved. As overall, these experts have between five and twenty-six years of experience dealing with the problem of coastal erosion. Candidates were chosen based on their knowledge and experience with coastal issues and management projects as shown in Table 3. A series of questionnaires (as in Table 4) were sent to the respondents via mail. In the first phase of questionnaires, respondents were asked to prioritize eight influencing parameters for coastal erosion. The respondents were given the opportunity to add any parameters they believed should be included in the erosion index formulation to the list. Additionally, respondents were assigned to rate specific parameters. The rating scale ranged from "1" (least relative significance) to "5". (Highest relative significance) as illustrated in Table 5.

Table 3 The list of experts participated in the Survey

Respondent	Respondent Experience Information
Ahmad Azimi bin Kamaluddin Engineer Dr. Nik & Associates Sdn. Bhd.	• Working as a senior engineer in Coastal & Hydraulics Department/Project Management Department for coastal experienced consultant. • Working experience in coastal field and projects for over 8years. Master in Civil Engineering (Hydraulic Engineering) from Delft University of Techonology
Khairulizam Bin Md. Yasin Jurutera, J44 Bahagian Pengurusan Zon Pantai- JPS Malaysia	• Working as a senior engineer in Coastal Division at DID Malaysia. • Working experience in coastal field and projects for over 8years. • Master in Coastal Engineering from Universiti Teknologi Malaysia
Dr. Effi Helmy Bin Ariffin Lecture Faculty of Geoscience Marine, Universiti Malaysia Terengganu (UMT), 21030 Kuala Terengganu	• Has extensive experience in the field of coastal engineering and lecturer in the Faculty of Geoscience Marine in UMT for over 10 years • Has published lots of writings in the field of coastal engineering such as; - Evaluating the Effects of Beach Nourishment on Littoral Morpho-dynamics at Kuala Nerus - Beach Morpho-dynamics and Evolution of Monsoon-dominated Coasts- in Kuala Terengganu, Malaysia: Perspectives for integrated management,
Mad Sor Bin Abdullah Pengarah, Jusa C Jabatan Pengairan dan Saliran Negeri Terengganu	• Former Director at Coastal Division in DID Malaysia. • Experience in coastal field and coastal projects for over 25years.
Ir. Mahran Bin Mahamud Jurutera, J44 Bahagian Pengurusan Zon Pantai- JPS Malaysia	• Working as a senior engineer in Coastal Division at DID Malaysia. • Working experience in coastal field and projects for over 15years.
Ahmad Ikhwan Bin Abdual Wahid Jurutera, J44 Bahagian Pengurusan Zon Pantai- JPS Malaysia	• Working as a senior engineer in Coastal Division at DID Malaysia. • Working experience in coastal field and projects for over 13years. • Master in Engineering in the Coastal Environment from University of Southampton
Wong Koh Yin Jurutera, J44 Bahagian Saliran Mesra Alam - JPS Malaysia	• Former senior engineer in Coastal Division at DID Malaysia. • Working experience in coastal field and projects for over 8years. • Master in Civil Engineering (Specialised in Marine Structures) from Technical University of Denmark.
Ir. Iwan Tan Sofian Tan Senior Engineer Dr. Nik & Associates Sdn. Bhd.	• Working as a senior engineer in Coastal & Hydraulics Department/Project Management Department for coastal experienced consultant. • Working experience in coastal field and projects for over 15years.

Table 4 Questionnaire: Erosion Considerations on Coastal Erosion

Scope	Questionnaire
Description of Coastal Erosion	• Describe the Malaysia coastline. • The current state of Malaysia due to coastal erosion. • Identify/listed the main factor(s) that usually caused coastal erosion in Malaysia
Coastal Erosion related to the nature factors. ▪ Scoring parameter of Wind/wave ▪ Scoring parameter of Sediment Pathway ▪ Scoring parameter of Sea Level Rise ▪ Scoring parameter of Water Temperature ▪ Scoring parameter of Tides Castal Erosion related to the man-made factors. ▪ Scoring parameter of structure ▪ Scoring parameter of Human activities ▪ Scoring parameter of Ecosystem destruction.	• In this part, each parameter identified during the literature search will be categorised based on the dimension, i.e., natural effects and man-made effects. • Participants will be asked various questions about the level of effect for each parameter in order to determine the score points for the AHP analysis.

Table 5 Likert Scale

Least relative significance	1
Have relative significance	2
Neutral	3
High relative significance	4
Highest relative significance	5

Three dimensions and four parameters were chosen as criteria for AHP analysis for evaluating the weighted influence of parameters, as indicated in Table 6, based on literature, expert questionnaire results, and experience.

Table 6 The dimensions and factors of coastal erosion.

Dimensions	Factors
Nature Factors	Wave Wind
Man-made Factors	Human activities
Socio-Economic Factors	Coastal Structure

Wave

Monsoon-generated waves have the greatest impact on the Terengganu coastal area (Saadon et al., 2020). The DID databank was used to gather wave records for this study. They will usually hire consultants to perform data collecting for a monitoring programme or to prepare for future projects. Wave data/roses are based on annual and monthly plots from the Wavewatch III (WW3) historical model retrieved from point 6°N, 103.2°E in Terengganu waters. The monthly wave rise diagram for 2019 in Kuala Terengganu is shown in Figure 7a) and Figure 7(b). It appears that most of the predominant wave energy is coming from 55°N.

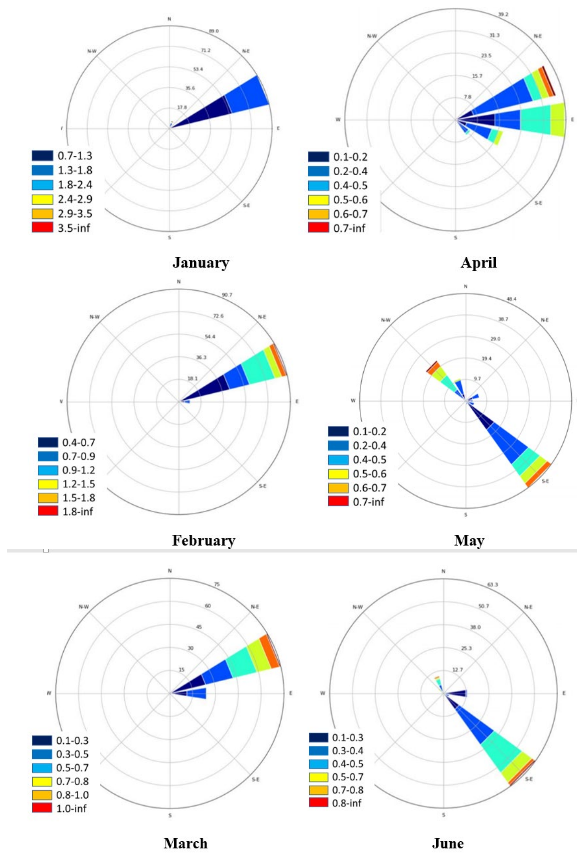
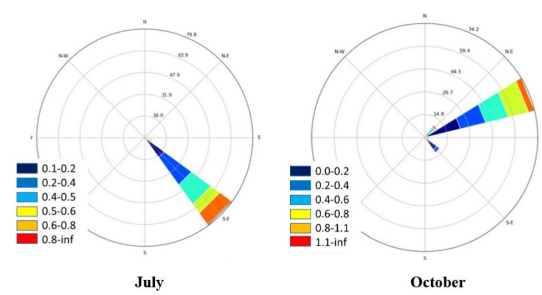


Figure 7(a)



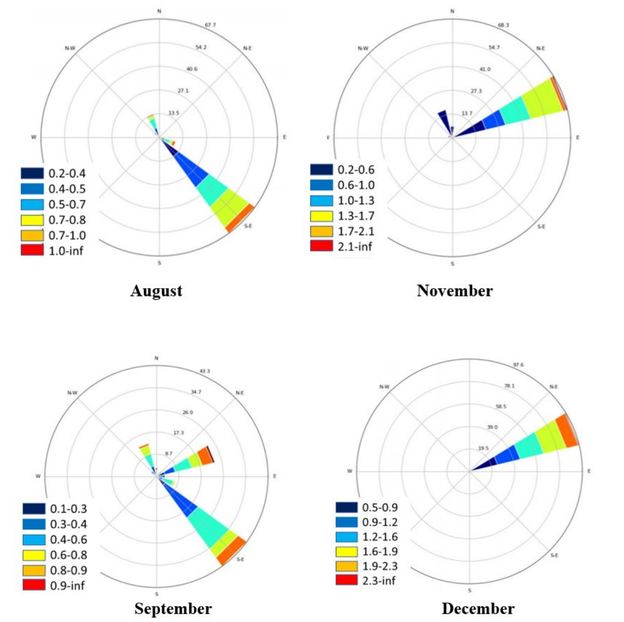


Figure 7(b)

Wind

The study site faces the South China Sea and is exposed to monsoon winds during and between monsoons. For the majority of the year, the Northeast monsoon and trade winds dominate the study region. The wind data was given by the Malaysian Meteorological Services Department (MET). For the purposes of this study, wind data from Kuala Terengganu was used. Wind velocity and direction statistics were collected between 1985 and 2019, with the Kuala Terengganu station located at roughly 5° 23' N, 103° 6' E. Figures 8 shows the yearly wind rise diagram for Kuala Terengganu. According to the yearly wind rise summary data, speeds of less than 5 m/s account for almost 80% of the observation period, with 7.7% of the time being quiet. Winds from the northeast, east, south, and southwest are also prevalent, coinciding with the northeast and southwest monsoon seasons. The time of quiet varies by month and monsoon, with the proportion of calm ranging from 6.6 percent (November to March) to 9.9 percent (October)

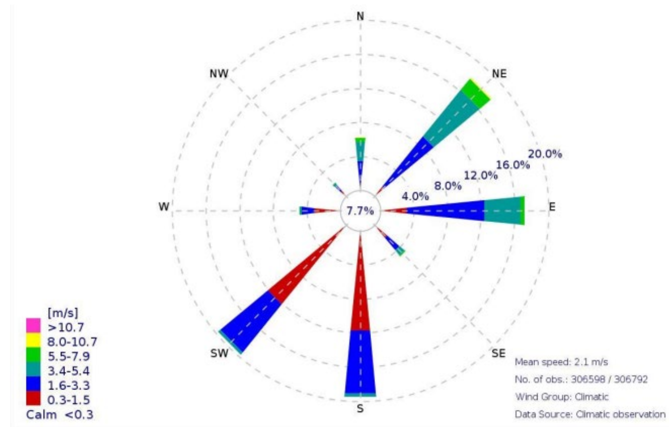


Figure 8 Annual Wind Rose for Kuala Terengganu (1985-2019)

Coastal Structure

Due to a lack of understanding and integrated management, the majority of coastal erosion is caused by improperly designed and constructed coastal protection measures (Prasetya, 2001). When countermeasures (hard or soft structural solutions) are applied incorrectly or not maintained effectively, and the consequences on surrounding coastlines are not thoroughly examined, the erosion problem develops. The detrimental influence of coastal structures has been identified as a critical issue along a number of the world's coastlines (Ndour et al., 2018). These structures have the potential to disrupt longshore sediment transport or alter the dynamics of the nearshore current system (Hsu et al., 2007).

In the research area, which runs from Sultan Mahmud Airport to Telipot Beach and is densely populated, changes in coastal dynamics were also detected (Yee Ling et al., 2019). The placement of the structure from the airport to the research area is depicted in Figure 9 and Table 7. (Red circle). A set of questionnaires with questions relating to the coastal structure in the study area was distributed to the villagers in the study area to get a better understanding on the influence of structure along the coast on the study area. To help villagers answer the questionnaires, a Likert Scale was employed in the survey study with primary and secondary data to measure respondents' attitudes by evaluating their level of agreement or disagreement with a particular issue.

Table 7 Existing conditions summary in study area

Location	Location (Village name)	Structure Remarks
KM1	Seberang Takir	Revetment
KM2	Seberang Takir	Revetment
KM6	Teluk Ketapang	Airport
KM8	Tok Jembal	Breakwater
KM9	Tok Jembal	Breakwater
KM10	Banggol Tok Lib	Breakwater
KM13	Telipot	Erosion occurring

Figure 9 Locations of structures along the stretch of study area.

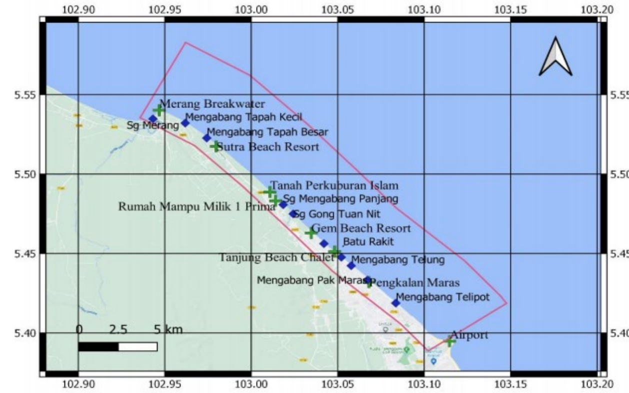


Figure 10 Extent of study area for human activities consideration

Human Activities

Human actions, on par with natural forces, are a significant element in shaping the shape and function of our coastlines and coastal landforms in many places. (Sheik Mujabar & Chandrasekar, 2013). This is related to rising demand factors such as industry, trade and commerce, tourism, human population increase, and migration along the coast, all of which are adding to global pressures in the coastal zone (Zhang et al., 2000).

Coastal development encompasses engineering projects such as land reclamation for urban expansion and airport expansion, channel dredging, and the construction of ports, harbors, and jetties. Such coastal development frequently has an impact on the environment, leading to the destruction of natural dynamic ecosystems and alterations to coasts (Awang et al., 2019). In other words, these developments have the potential to disrupt the long supply of coastal sediments, leading to erosion and coastal erosion.

The activities occurring within the study area and those occurring outside the study area that have an effect on neighbouring coastal processes are depicted in Figure 10 and Table 8. Even if the activity is not directly related to the study area and takes place outside, it should be evaluated if it has an impact on the region being examined. To ascertain the extent of the impact of human activities on the study area, a questionnaire similar to the factors of human activity was developed and distributed to the study area's villagers. The Likert Scale will also be used to assist residents in answering questions for this purpose.

Table 8 Existing activities summary in study area

Location	Remarks/Activities
Mengabang Telipot	Study area. Erosion occurring
Pengkalan Maras	Erosion occurring. No revetment or protection measures. Scarp formation.
Mengabang Telung	Eroding. A small stream flowing at the location
Batu Rakit	Submerged rock 640m from shore. Erosion occurring. Scarp formation
Gem Beach Resort	Slow erosion starting to occurring. Casuarina trees along the beach. No new growth in front of the trees
Sg. Mengabang Panjang	Small sand mining from year 2017-2018.
Mengabang Tapah Besar	Small sand mining from year 2018-2019.
Mengabang Tapah Kecil	Small sand mining from year 2018-2019.

3.0 RESULTS AND DISCUSSION

This section will explain the analysis of data acquired from three sources: expert feedbacks from questionnaires, digital data for waves and winds, and observational data from coastal structures and human activities. Two methods, AHP and ANN, were utilised to conduct the analysis utilising the data acquired to determine the extent of the impact of all of these factors on coastal erosion.

3.1 AHP Pairwise Comparison

The AHP method was used to determine the weighting of each criterion, namely natural, human activities, and socio-economic factors. By judging the relative importance of indexes in pairs, the indexes of a level are compared to other indexes of the same level and their relative importance is calculated, as illustrated in Table 9. For the purposes of comparison, a scale ranging from "1" to "9" will be used, with "1" indicating the least significant effect and "9" indicating the most significant effect on coastal erosion. The significance value of the pair-wise comparison is represented on a scale of 1-9 as shown in Table 10 according to (Saaty, 2002).

Table 9 Pair-wise Comparison Matrix for the criteria

Criteria	Wave b_1	Win b_2	Coastal Structures b_3	Human Activities b_4
Wave, b_1	1	5	1/5	1
Wind, b_2	1/5	1	1/7	1/7
Coastal Structures, b_3	5	7	1	2
Human Activities, b_4	1	7	1/2	1
TOTAL	**36/5**	**20**	**129/70**	**29/7**

Table 10 The fundamental scale of absolute numbers

Numerical Rating	Verbal judgments of preferences
9	Extremely Importance
8	Very strongly to extremely
7	Very strongly Importance
6	Strongly to very strongly
5	Strongly Importance
4	Moderately to strongly
3	Moderately Importance
2	Weak or slight
1	Equally Importance

3.2 AHP Weighting

Next, for each factor included in this study, the priority weightage vector, also known as the eigenvector, is determined. The priority weightage is generally preferred as a reasonable approach to evaluate the relationship between these aspects, hence leading to the situation of intransitivity (Morais & De Almeida, 2012).

The following are some examples of weighted computations for each factor;

$$\text{For the first cell, } b_{11} = a_{11} / (a_{11} + a_{21} + a_{31})$$

After all the values have been computed using the equation as shown above, the normalised eigenvector (W) is calculated by averaging all the values across the rows as presented below;

$$W = 1/4 \begin{bmatrix} 5/36 + 5/20 + 14/129 + 7/29 \\ 1/36 + 1/20 + 10/129 + 1/29 \\ 25/36 + 7/20 + 70/129 + 14/29 \\ 5/36 + 5/20 + 35/129 + 7/29 \end{bmatrix} = \begin{bmatrix} 0.1804 \\ 0.0459 \\ 0.5333 \\ 0.2404 \end{bmatrix}$$

The normalised eigenvector is also called as the priority vector which is shows the relative weightage among the factors. The fractional values in each row were transformed into decimals after the normalised eigenvector for all factors was determined. The overall average obtained for the 'criteria' must equal 1 to guarantee that the computation is correct. Table 11 shows the preferred findings for the four factors in terms of the cause criterion.

Table 11 The Normalized Matrix with Row Averages between Criteria

Criteria	Wave	Wind	Coastal Structures	Human Activities	Weightage
Wave	0.0347	0.0625	0.0795	0.0603	0.1804
Wind	0.0069	0.0125	0.0193	0.0086	0.0459
Coastal Structures	0.1736	0.0875	0.1356	0.1207	0.5333
Human Activities	0.0347	0.0875	0.0678	0.0603	0.2404
				TOTAL	**1.000**

It is assumed that the weights can be expressed as a continuous function with values between 0 and 1 based on the outcomes of weightage values obtained above. Higher weights, which is closer to 1, represent factor more significant to coastal erosion. Similarly, when the factor has less of an impact on coastal erosion, the lower weights will approach zero. Table 12 shows the final weights obtained for all aspects.

Table 12 The Final Weightage for Each Criteria

Criteria	Weightage
Wave	0.1804
Wind	0.0459
Coastal Structures	0.5333
Human Activities	0.2404

3.3 ANN Results

ANN analysis also can provide weighting values for each factor against erosion in addition to AHP. These figures can be derived through ANN results analysis (Dongare and colleagues, 2012). An ANN is a sort of processor that has a natural tendency to put previously learned knowledge into practise. The goal of this step is to use ANNs to offer an alternate solution for the MCDM's basic weighting process such AHP. The network proposed in this study is a feed forward network with one hidden layer. The input layer is composed of five neurons (wave, wind, human activities, coastal structures, and recorded erosion rate for data training namely as "bias"). Whereas, each hidden layer is composed of four neurons, and the output layer is composed of one neuron (predicted erosion rate). For the purpose of ANN method analysis, SPSS software was used to submit the data as described above.

Data sets in numerical form for the aforementioned parameters are provided for 2016 to 2019 as data input for ANN analysis. For factors "Coastal structures" and "Human activities", a basic inspection process at study area was utilised to generate results in numerical form for use as input data in the SPSS programme. Inspections are carried out by examining current beach conditions as well as previous records (2016-2019). When there are no coastal structures or human activities in the study area, a value of "0" will be assigned, while a value of "5" will be assigned when there are dense coastal structures and considerable human activity. Data on wind, wave, and coastal erosion will be obtained from government databanks as well as consultant reports for the period 2016-2019.

ANN analysis was performed after the data was successfully uploaded into the system. As a result, Figure 9 depicts the outcomes of this study's neural network topology. The connections between nodes are defined by the network topology (lines). A thick blue line shows a strong relationship between inputs and outputs, and these connections dictate how nodes interact. The strength of the connection between the input and the neuron is indicated by the weight values.

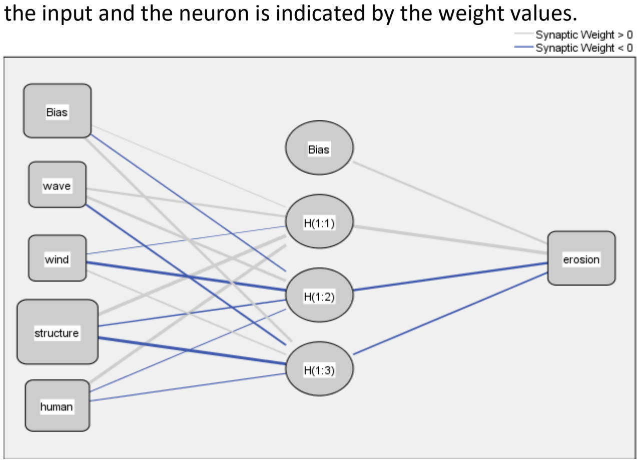


Figure 9 ANN Topology Result.

The significant computational weightage and normalized importance for each parameter that can be obtained using ANN models is shown in Table 13. The ANN model was used to determine the relative importance of coastal erosion causes, and it was discovered that factor coastal structures had the greatest impact on erosion (61.2%), followed by human activities (23.2%), wind (8.2%), and wave (7.4%). Because the test results varied according to the application and data groupings, it was observed that the test results differed from the AHP results. However, both applications demonstrated a strong correlation in terms of their significance across all parameters. The amount of data used and familiarity with software applications are both important factors in the success of artificial neural network applications.

Table 12 Independent Variable Importance

Factors	Importance	Normalized Importance
Wave	.074	12.1%
Wind	.082	13.4%
Coastal structures	.612	100.0%
Human activities	.232	37.8%

Based on AHP and ANN analysis, the weights in Table 14 show the relationship between the influential parameters on coastal erosion.

Table 13 The Final Weightage for Each Criteria from AHP and ANN

Criteria	**Weightage (AHP)**	**Weightage (ANN)**
Wave	0.1840	0.074
Wind	0.0459	0.082
Coastal Structures	0.5333	0.612
Human Activities	0.2404	0.232

The findings of the study show that the degree of influence of factors on coastal erosion varies. The study's findings are outlined below;

i. The coastline structure has the greatest influence on coastal erosion, according to the results of the AHP and ANN analyses performed on the data collected in this study. The presence of coastal structures in the study area, such as offshore breakwaters, revetments, and groynes, has several effects, including trapped sand at the structure's top, which consumes sediment budgets and causes coastal erosion along adjacent shorelines. According to various prior studies conducted on the Kuala Nerus/Kuala Terengganu coastline, most of the coastlines in the two districts are classified as critical. This severe erosion is caused by physical processes such as sea level changes and human activity, as well as the construction of erosion defense structures that affects adjacent beaches. (Muslim et al., 2011; Zulfakar et al., 2020, 2020).

ii. According to the findings, human activities have the second highest impact on the problem of coastal erosion. A significant human activity on the coast of Kuala Nerus is the construction of the Sultan Mahmud airport, which projects 500 metres into the sea. After construction was completed in 2008, erosion on the beach next to the airport (north side) became visible, causing erosion along 290 to 360 metres in some area (Muslim et al., 2011). Because of the impact of the airport extension construction, the government had to spend a large amount of cost in 2011 to solve the problem of critical erosion on the beach of Tok Jembal, which is the beach closest to the airport. To this day, the airport's construction has had a substantial impact on erosion in the surrounding coastal area.

iii. The area of study faces the South China Sea. Wind conditions in the South China Sea and the Gulf of Thailand are primary wave generating mechanism for wave's incident to the study area. It can be seen that winds coming from the east and north east coincides with the north-eastern monsoon period. The waves and wind are the most extreme during this season, with wave heights reaching 3 to 4 metres. During this season, when the direction of the waves is perpendicular the coast (cross-shore), a large amount of sediment will be carried by the waves and cause erosion.

4.0 CONCLUSION

It is quite clear that the causes of coastal erosion include a variety of factors, each of which has a significant effect. The AHP and ANN methods were found to be quite capable and computationally easy to compute the level of contribution of each factor to coastal erosion with the available data. The AHP method employs measurements considered criteria with relative importance in order to rank each factor in relation to other factors. For AHP methods, subjective assessment, the experience, and intuition of experts on the evaluation of selected categories and levels of risk are used. The test results are encouraging, implying that this approach could be used in real-world situations. When there is a lack of statistical data for every possible parameter, the AHP method provides a fairly good and reliable assessment. But, by using the ANN method, with complete data it thus reduces the process of human error assessment in assessing the level of contribution of each factor to coastal erosion. However, the results show that the AHP and ANN-based models produce reliable results, the fault tolerance capacity is small, and the weighting result show no significant differences between the two methods. As a future scope, an index-based erosion rate determination method can be developed through weighted analysis for each influential factor to assist decision makers in assessing the extent to which each factor affects erosion when a coastline is to be developed.

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