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Electric Transmission Tower Corrosion Assessment Using Analytic Hierarchy Process and Health Index

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ABSTRACT

A transmission tower is one of the components in power infrastructure supporting overhead power lines (OHL). Electrical components, structural, and environmental factors are classified as the primary concern as they can cause catastrophic failure in transmission lines. Transmission towers are in various environments, such as coastal and industrial areas, with different atmospheric corrosion levels due to various corrosive pollutants. For maintenance planning, it is essential to consider the effects of corrosion on towers by physical evaluation influenced by atmospheric corrosion. The physical evaluation of each element uses a scoring or rating method ranging from one to five. The Analytic Hierarchy Process (AHP) and Health Index (HI) are used to evaluate the overall condition of the towers. The study discovered that soil corrosivity in coastal areas is high, and atmospheric corrosion is due to chloride content. Although the pollutants in those areas are high and corrosive, the physical evaluation found that most industrial, coastal, and road towers are in good condition at a rating of 4 and 5. The HI result is the dominance of 71% to 85%, which indicates that the towers are in good health.

Keywords: Analytical hierarchy process, corrosion assessment, energy, health index, transmission tower

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INTRODUCTION

A transmission tower is one of the components in power infrastructure that supports overhead power lines (OHL). Tenaga Nasional Berhad (TNB) owns more than 723,134 km of power lines to provide electricity for Peninsular Malaysia

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(https://www.tnb.com.my/assets/annual_report/TNB_IAR_2021.pdf). Malaysia Energy Commission 2018 annual report stated that the largest electricity consumer is from the industrial sector, which consumes around 46% of electricity, followed by the commercial sector at 30.8%. The residential sector at 20.5% (https://www.st.gov.my/ms/contents/files/download/99/Performance_Statistical_Information_on_the_Malaysian_Electricity_Supply_Industry_20181.pdf). A study by Hashim et al. (2019) found that electricity supply interruptions are mainly due to conductor issues, about 40%, and environmental factors, about 31%. Another factor was due to structural failures with 17% and disturbances by the third party with 12%.

In order to avoid disruption to the transmission tower system, assessment and evaluation of the transmission tower condition are essential because it will deteriorate over time due to many factors, one of which is corrosion. The identification process can be done by assessing the current condition of the tower. One way to determine the condition of transmission towers is by evaluating their physical condition, including visual and corrosion assessment. Cardenas et al. (2019), Tsimberg et al. (2014), Velásquez and Lara (2018) and Wuller and Pharmatrisanti (2012) mentioned in their research that the physical evaluation is based on the common condition of the components through visual inspection and non-destructive tests using simple tools and equipment.

However, a physical evaluation is insufficient to fulfil the required conditions for the transmission tower. Moreover, the environmental effect is essential, as environmental changes significantly influence atmospheric corrosion. In their research, Usman and Khalid (2021) mentioned condition assessment studies that consider environmental elements using atmospheric corrosion levels. The effect of corrosion on the integrity of the tower structure is necessary for the maintenance plan to identify the service level of the tower.

The reason for considering atmospheric corrosion conditions is that based on studies by Krishnasamy et al. (2020) and Usman et al. (2021) stated that transmission towers in coastal areas are influenced by marine salt particles such as chloride (Cl^-). Additionally, Corvo et al. (2008) mentioned that coastal areas are prominent for high corrosion rates. On the other hand, Usman and Rediansyah (2008) found that industrial areas emit high concentrations of sulphates (SO_4) while nearby roads increase the emission of nitrogen dioxides (NO_2) through vehicle combustion. Based on a study by Arroyave and Morcillo (1995), the highest corrosive effects in atmospheric corrosion are chloride (Cl^-) and Sulphates (SO_4), while nitrogen oxides (NO_2) increase depending on the amount of the fuel combustions, mainly from the vehicles.

A study by Usman and Rediansyah (2008) classified atmospheric areas into six categories: urban, rural, island, highlands, industrial, and coastal. However, this study considers the area by the distance from industrial, coastal, and road areas, considering the vehicle's exhaust emission to the transmission towers due to the corrosive pollutant agents emitted in those areas. The condition assessment of the elements in this study allows the energy infrastructure authorities to study and compare to determine the reliability and the remaining life of a transmission tower (Van-Der-Wal et al., 2004).

This study, therefore, attempts to highlight the assessment of transmission towers by applying physical evaluation methods and considering the influence of atmospheric corrosion on the deterioration of transmission towers. It is also recommended to plan for mitigation and adapting strategies. Based on the European Environment Agency (https://www.eea.europa.eu/publications/adaptation-in-energy-system), the long-term services of transmission towers can be improved by implementing the possible consequences of climate changes, such as the severity of extreme weather conditions, changes in temperature patterns, rising sea levels, as well as applying climate-resilient measures, such as considering temperature differentials, and corrosion damage control.

METHODOLOGY

The Peninsular of Malaysia is located at a latitude of 4º0’0” N and a longitude of 102°30’0”E. The country has an equatorial climate characterised by hot and humid weather throughout the year. Southwest and northeast monsoons play a significant role in determining climate variability. Southwest monsoons occur between April and September, while northeast monsoons occur between October and March. The weather during the southwest monsoon is drier, and there is less rainfall than during the northeast monsoon (Kwan et al., 2013; Tang, 2019).

In Peninsular Malaysia, the most industrialised areas are primarily located in the western region, in the states of Selangor and Johor. Malaysia’s heavy industries, such as electronics, textiles, and chemicals, are primarily concentrated in Selangor. Johor is another major industrial centre in Peninsular Malaysia, known for its port, electric and electronics, oil and gas, and shipbuilding industries (Frost & Sullivan, 2018). Meanwhile, the state of Penang strongly focuses on high-tech industries, such as semiconductors, medical devices, and aerospace (https://www.oecd.org/education/imhe/47505889.pdf). This study collected data onsite for condition assessment across the north, south, east, and west. Figure 1 shows 434 tower locations in different transmission lines collected.

Condition Assessment of Transmission Tower

The structure of lattice transmission towers is divided into three main parts: overhead line, body, and base (Zhang et al., 2019). The data collected in this study are only on the base of the transmission towers, as shown in Figure 2. A rating method is used to systematically evaluate and quantify the extent of corrosion on the towers and provide a clear and standardised assessment of the tower’s condition. The assessment involves mainly non-destructive tests and visual evaluation. The test equipment is obtained from the Universiti Tenaga Nasional Geology laboratory (UNITEN).

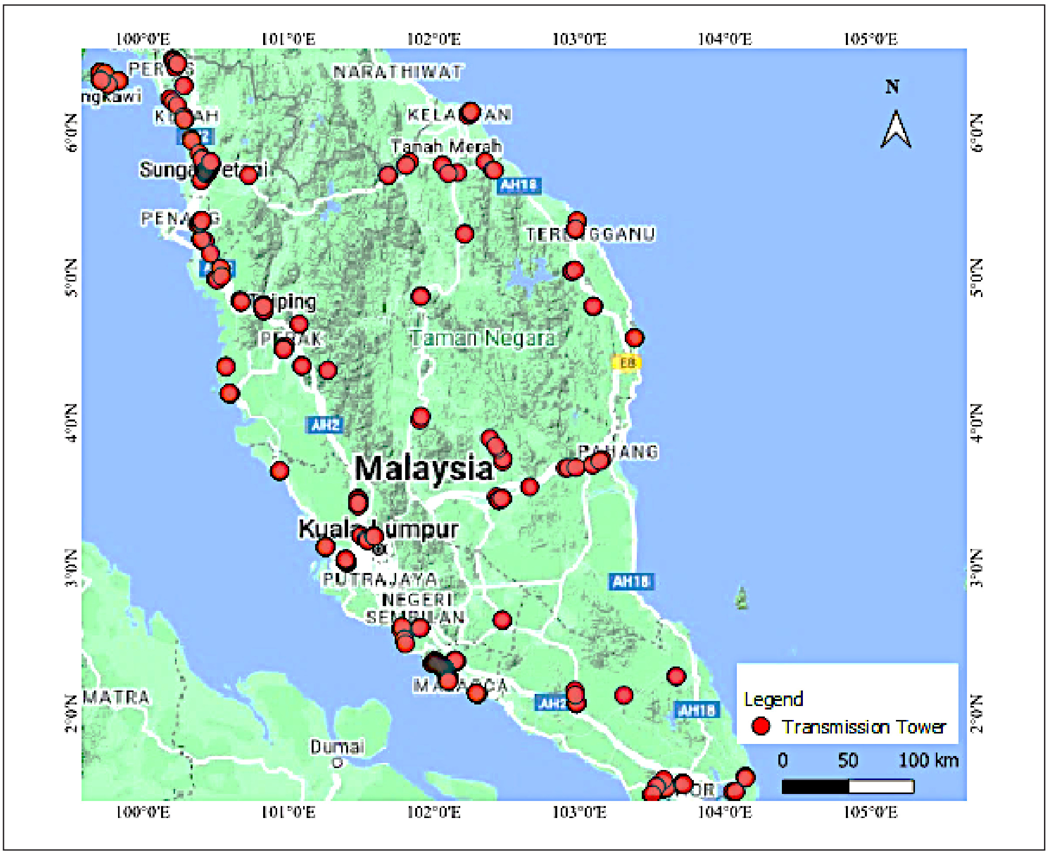


Figure 1. Study area in Peninsular Malaysia

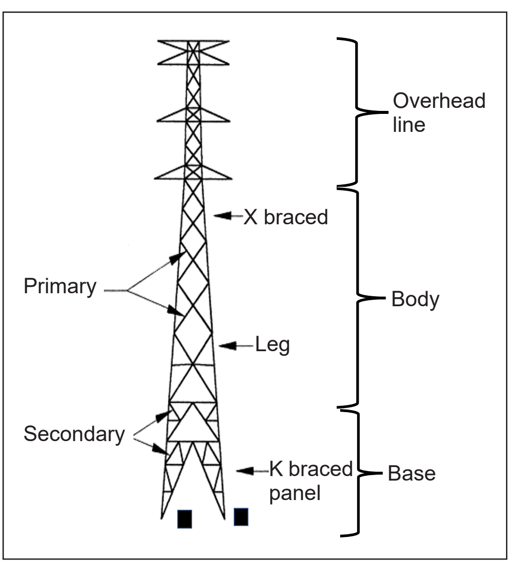


Figure 2. Design of transmission tower

Referring to the condition assessment of the transmission tower by Zhang et al. (2014), the condition of critical items considered are the structural member, foundation, and environmental condition. Therefore, the assessment criteria shown in Table 1 are based on the three elements. The assessment implies a rating system from one to five to classify the failure probability as very low, low, medium, high, and very high, which is also applied in a study by Chitpong et al. (2016). Depending on the atmospheric environment, the structural members, especially steel, are highly prone to corrosion, which can lead to structural failure. Thus, most steel members are coated and galvanised to increase sustainability.

Structural Member

The structural member is the main component of the transmission tower, which is crucial to giving a proper assessment for maintenance purposes. Based on visual observation, galvanised coating thickness and corrosion condition are the assessment methods involved.

Galvanised Thickness. Galvanised coating thickness is conducted using equipment (Elcometer) to measure the thickness of the zinc layer (Ricci et al., 2018). Rodger et al. (2017) studied galvanised steel's corrosion and measured the galvanised thickness using the Elcometer gauge. It is a universally used coating thickness gauge since it provides precise, consistent measurements and fast data processing to calculate an average coating thickness. The measured value in the micron meter is represented in a rating between one and five (Table 2).

Table 1
Assessment criteria for each element

Element	Assessment Criteria
Structural member	• Galvanised thickness • Corrosion condition
Foundation	• Foundation condition • Soil resistivity
Environment	• Atmospheric corrosion level

Table 2
Rating of galvanised coating thickness (Usman & Khalid, 2021)

Description	Value	Rating
The thickness of the galvanised coating is adequate.	>80	5
Thin	80–60	4
Moderately Thin	60–50	3
Very Thin.	50–40	2
The layer of galvanised coating is very thin. Monitoring is necessary against corrosion.	<40	1

Corrosion Condition. Corrosion assessment based on visual inspection often requires checking the metal's surface for corrosion symptoms such as rust, pitting, and discolouration. The inspection is interpreted in a rating of zero and seven, as in Table 3. The condition reference of visual assessment is as in Figure 3. In a previous study by Usman and Khalid (2021), a similar method was used to determine the corrosion condition of steel members, which was done by using ratings from 1 to 5.

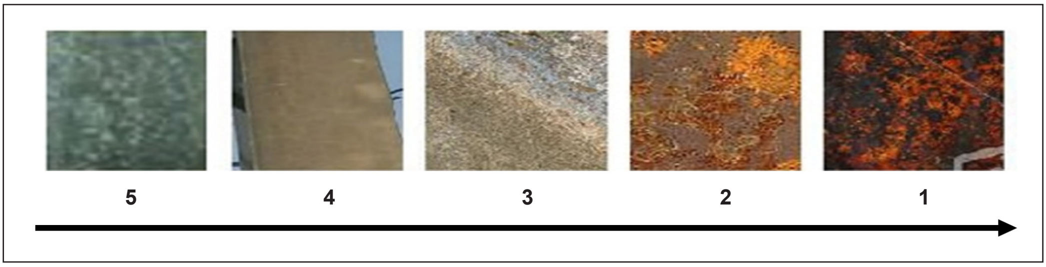


Figure 3. Visual assessment for corrosion rating (Usman & Khalid, 2021)

Table 3
Rating of corrosion assessment (Usman & Khalid, 2021)

Description	Rating
Like new, galvanised layers are intact with no or little rust.	5
Good condition, galvanised layer intact with powdery rust.	4
Minimum adequacy. Most of the galvanised layers are corroded, and steel is exposed with a layer of rust	3
It is not functioning as designed, and steel members are lost due to rust.	2
Potentially hazardous: loss of steel section	1

Foundation

The foundation is the base component of transmission towers supporting the concrete pole to the ground. The soil condition and concrete pole placement determine the form and depth of foundations. Jyothi and Mahesh (2017) discovered that the tower legs are set in concrete, which generally provides good protection to the steel. It is found that cracks in concrete could cause water and deposited salt to immerse into the concrete, creating corrosion and decreasing the reliability of the foundation leg.

Foundation Condition. Besides visual observation on the concrete foundation, the rebound hammer and ultrasonic pulse velocity (UPV) test are included as non-destructive testing. Rebound hammer tests provide an instant indication of compressive strength on concrete. It is similar to a study by Krishnasamy et al. (2020), where the rebound hammer test performs the transmission line against corrosion. The test involves striking a spring-loaded hammer against the concrete's surface and measuring the hammer's average rebound number, which is directly related to the compressive strength of the concrete. The estimated average value of the rebound hammer test is represented in a rating between one and five, as shown in Table 4. High rebound numbers imply that the concrete has a high compressive strength to withstand heavy loads and impact.

UPV test is used to inspect concrete quality and cracks within the concrete by emitting electronic waves through the concrete. The procedure involves sending an ultrasonic pulse through the concrete and measuring the time it takes for the pulse to travel through the material and return to the surface. The test is used to determine the density and uniformity of the concrete. The measured value of UPV in km/sec is represented in a rating between one and five (Table 5). The study of UPV by Usman and Khalid (2021) revealed that concrete is of good quality

Table 4
Rating of rebound hammer test (Usman & Khalid, 2021)

Concrete quality	Value	Rating
A very good hard layer	> 40	5
Good layer	30–40	4
Fair	20–30	3
Poor Concrete	< 20	2
Delaminated	0	1

with low porosity, void content, and crack density, making it strong, durable, and resistant to damage from weathering. UPV was also used to assess the condition of the transmission tower foundation.

Table 5
Rating of UPV (Usman & Khalid, 2021)

Concrete Quality	Value	Rating
Very good	> 4.0	5
Good, but maybe porous	3.5–4.0	4
Poor	3.0–3.5	3
Very poor	2.5–3.0	2
Very poor and low	2.0–2.5	1

Soil Resistivity. Soil condition is necessary as the influence of soil resistivity is crucial in constructing transmission towers. Waters (1952) states that soil resistivity and corrosion are closely related. Soil resistivity depends on the geographical type, such as a riverbank or a mountainous area, water content, soil texture, and more. It is found that soils with a high moisture content have a lower resistivity, which is about 1.5 Ohm-m, whereas soils with a low moisture content have a higher resistivity, reaching up to 10,000 Ohm-m. Moreover, corrosion is more likely to occur in soils with lower resistivity (Sing et al., 2013).

Table 6
Rating of soil resistivity (Usman & Khalid, 2021)

Corrosivity	Value	Rating
Essentially noncorrosive	>20,000	5
Mildly Corrosive	10,000–20,000	4
Moderately corrosive	5,000–10,000	3
Corrosive	3,000–5,000	2
Highly corrosive	1,000–3,000	1

The soil resistivity testing method uses the Wenner Probe method with four electrodes. Sing et al. (2013) conduct soil resistivity tests using the Wenner probe method, the most common and convenient method for determining soil resistivity. Soil assessment is conducted near or under the towers to test the resistivity of the soil. Hence, the measured value of soil resistivity in ohm-cm is represented in a rating between one and five, as shown in Table 6. A higher rating of soil resistivity indicates good soil condition.

Environment

The environmental factor involved in this assessment is the atmospheric corrosion level, which is presented using a corrosion hazard map. Figure 4 illustrates the corrosion hazard level developed by Adriyanshah et al. (2022). The corrosion hazard map is obtained from 17 weather stations owned by the Meteorological Department of Malaysia (MET). The data are climate and wet deposition, which consist of temperature, humidity, rainfall, sulphates, nitrates, and chloride. The map is represented in five levels: (1) level one indicates the lowest corrosivity environment, (2) level two indicates the low corrosivity environment, (3) level three indicates the medium, (4) level four indicates the high and (5) level five indicates the highest corrosivity environment.

The corrosion hazard level is considered due to the interaction between the metal surface and its environment. Metal surfaces interact with gases, liquids, and other elements that make up the atmosphere, resulting in atmospheric corrosion (Syed, 2006). According to a study by Fathoni et al. (2013), water (in the form of rain, humidity, and dew), oxygen, and sulphur dioxide are the main contributors to atmospheric corrosion, which can result in the production of rust and other types of corrosion on metal surfaces. Temperature, acidity, and pollution are additional causes of air corrosion.

The atmospheric area is determined by the distance to the main pollutants emitted in industrial settings, such as dust particles, SO_4, NO_3, and carbon emissions. Industrial

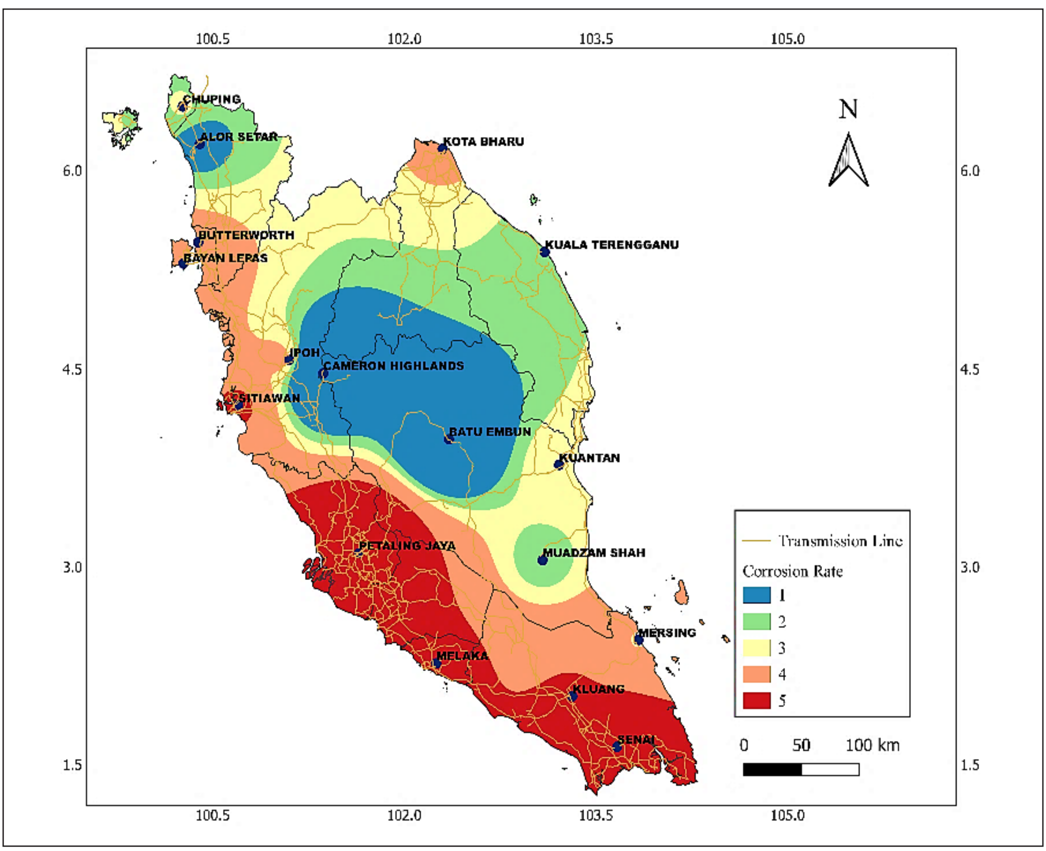


Figure 4. Corrosion hazard map (Adriyanshah et al., 2022)

pollution is mainly sourced from factories, power plants, and transportation. At the same time, coastal areas are known for their high chloride concentrations and salt aerosols in the air and moisture, which can contribute to atmospheric corrosion (Feliu et al., 1999). On the other hand, the distance from roads is influenced by vehicle combustion. The increased exhaust combustion from vehicles, which causes NO_2, NO_3, and particulate matter emissions, speeds up corrosion (Kumar et al., 2020).

Thus, this study also includes the environmental element to identify the condition rating of the transmission towers according to three areas: (1) coastal, (2) industrial, and (3) distance from the road because of the atmospheric corrosion decreasing the galvanised coating thickness, and finally lead to corrosion.

Analysis Method

Analytical Hierarchy Process (AHP)

AHP is a decision-making technique that determines the importance of priority in performance evaluation (Daneshmand et al., 2011; Tanaka et al., 2010; Triantaphyllou & Mann, 1995). Unlike Multicriteria Decision Making (MCDM), AHP is more likely applicable for complex decisions in various measures and comparisons, which are much more complicated to compute (Beynon, 2002; Lin & Yang, 1996; Saaty, 1977). The process of determining the weightage using AHP is determined by a pair-wise comparison of each assessment criterion against one another. The comparison is made by referring to the importance scale in Table 7 (Rajesh & Malliga, 2013; Saaty, 2008, 1977). The scale of numbers between one and nine shows the dominance of one criterion over another. Scale one is considered equally important, while scale nine is characterised as one criterion contributing higher importance to another.

Table 7
Importance scale (Rajesh & Malliga, 2013)

Scale	Definition	Explanation
1	Equally important	Two criteria contribute equally to the subject
3	Moderately important	Slightly favour one criterion over another
5	Strongly important	Strongly favour one criterion over another
7	Very strongly important	One criterion is favoured very strongly over another
9	Extremely important	The evidence favouring one criterion over another is the highest

Note. 2,4,6,8 can be used as intermediate favours

Health Index (HI)

To evaluate the overall health condition of transmission towers, researchers frequently apply the health index (HI) (Manninen et al., 2021; Naranpanawe et al., 2020). According to research by Hjartarson et al. (2003), HI is a helpful way to assess the overall condition of a complex asset because transmission towers are frequently evaluated based on their components or characteristics. The weighting of each criterion is acquired from AHP, and the scoring or rating from the condition assessment is needed to calculate the HI value. Additionally, it is essential to note that the weightage values dictate the precision of the HI value (Irfan & Handika, 2019). The formula used to determine the overall HI is given in Equation 1, where R is the rating score, R_{max} is the rating score, and W is the weighted average of each criterion.

$$\%HI = \frac{\sum(R \times W)}{\sum(R_{Max} \times W)} \times 100 \quad [1]$$

The overall condition of the transmission tower is determined from the known HI (%), as shown in Table 8. The HI (%) value is classified from "very good" to "very poor". In addition, the elements included in AHP and HI are from structural members and foundations of the transmission tower. The environmental element is not involved in the corrosion analysis of transmission towers, as it is used to classify the transmission tower into different atmospheric areas, coastal and industrial, and the distance from the road.

Table 8
Health index value (Haema & Phadungthin, 2012)

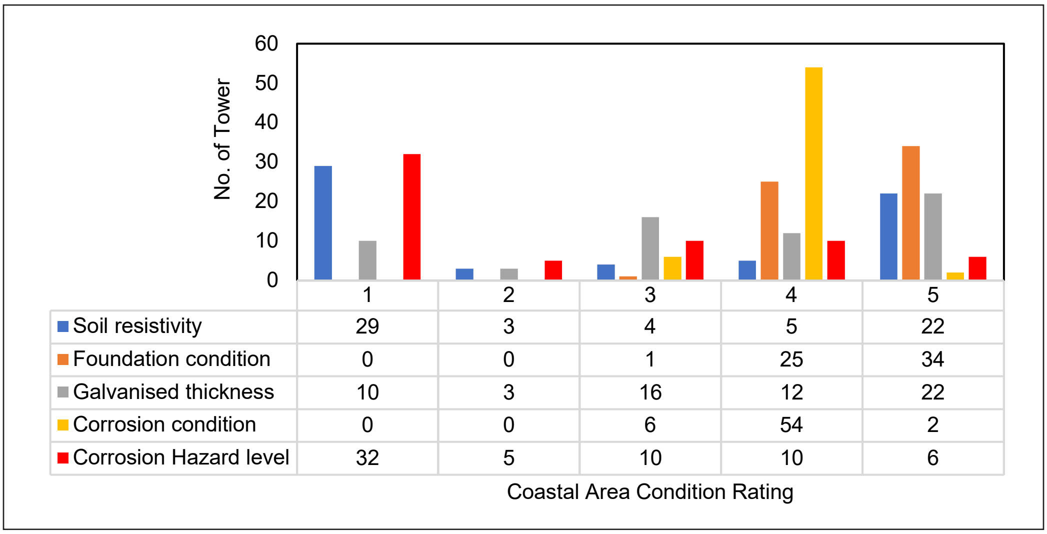
Condition	Requirement	HI (%)	HI Score	Colour code
Very good	Normal maintenance	86–100	5	Blue
Good	Normal maintenance	71–85	4	Green
Fair	Increase diagnostic testing	51–70	3	Yellow
Poor	Plan to replace or rebuild, considering the risk	31–50	2	Orange
Very Poor	Immediately assess risk	0–30	1	Red

RESULTS AND DISCUSSION

Condition Rating of Transmission Tower

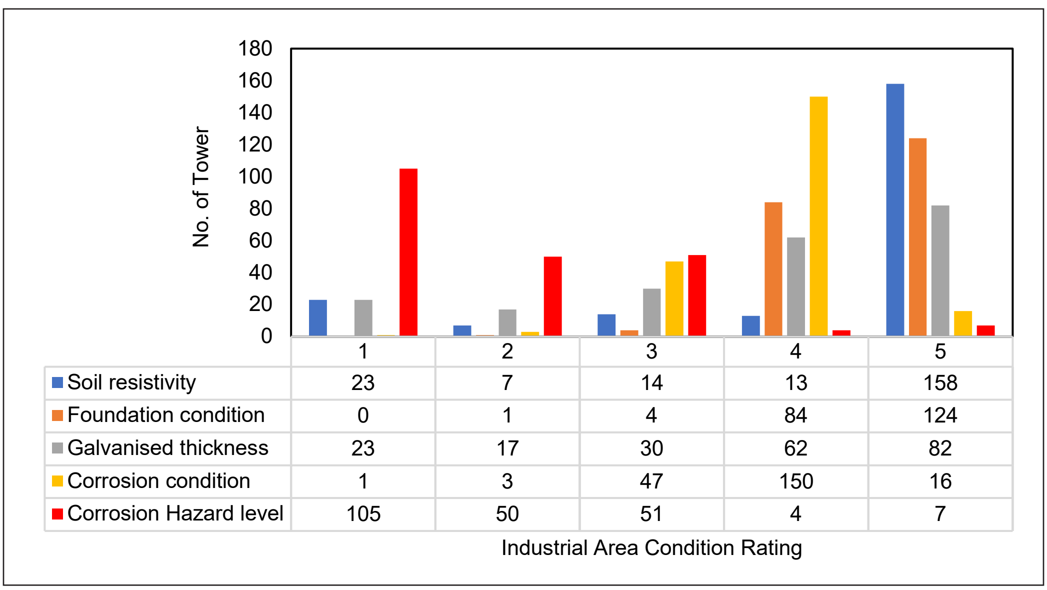
The result of the condition rating is analysed according to three different atmospheric areas: coastal area, industrial area, and distance from road. Figure 5 shows the condition rating in the coastal area. Focusing on the maximum number of towers for each assessment criterion from Table 1, the maximum number for soil resistivity and corrosion hazard levels fall under rating 1, foundation condition and galvanised thickness are at rating 5, while corrosion condition is at rating 4. The soil in the coastal area appears corrosive, and the atmospheric corrosion is high because chloride is the major pollutant in the coastal area (Pongsaksawad et al., 2021).

The condition rating for the industrial area is as in Figure 6. For soil resistivity, foundation condition, and galvanised thickness, the maximum number falls under rating 5. In contrast, the corrosion conditions were rated at rating 4, and the corrosion hazard level



	1	2	3	4	5
Soil resistivity	29	3	4	5	22
Foundation condition	0	0	1	25	34
Galvanised thickness	10	3	16	12	22
Corrosion condition	0	0	6	54	2
Corrosion Hazard level	32	5	10	10	6

Figure 5. Condition rating in the coastal area

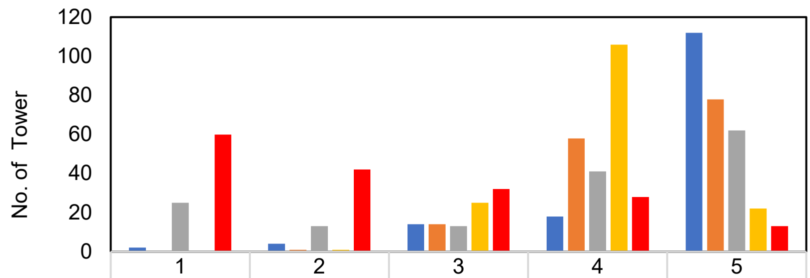


	1	2	3	4	5
Soil resistivity	23	7	14	13	158
Foundation condition	0	1	4	84	124
Galvanised thickness	23	17	30	62	82
Corrosion condition	1	3	47	150	16
Corrosion Hazard level	105	50	51	4	7

Figure 6. Condition rating in an industrial area

at rating 1. The corrosion hazard level at level 1 might be due to the pollutants emitted from the industrial sectors, such as sulphur dioxide and nitrogen dioxide. Figure 7 shows the road areas or areas with the domination of vehicle combustion, where the resulting pattern is near the industrial area result.

However, the atmospheric corrosion level recorded in the three environments is in rating 1, where the atmospheric corrosion is relatively high. The reason for this is the high presence of pollutants in the air. Industrial activities such as manufacturing, power



	1	2	3	4	5
Soil resistivity	2	4	14	18	112
Foundation condition	0	1	14	58	78
Galvanised thickness	25	13	13	41	62
Corrosion condition	0	1	25	106	22
Corrosion Hazard level	60	42	32	28	13

Distance From Road Condition Rating

Figure 7. Condition rating in the distance from the road

generation, and chemical processing can release various corrosive compounds into the air, including acids, bases, and factory emissions. The salt spray, humidity, and temperature fluctuations in coastal areas also contribute to corrosion. The atmospheric sea salt particle itself accelerates the corrosion of steel and can cause damage to metal surfaces and structures (Wang et al., 2022). On the other hand, pollutants emitted in road areas are influenced by vehicle exhaust, which harms human health and the environment.

As a result of the findings, it is reasonable to conclude that atmospheric corrosion is significantly high due to pollution in the area. Most transmission tower contributions in the coastal, industrial, and road areas are at ratings 4 and 5, which indicates that the criteria are in good condition. This occurrence could be due to the excellent management of the maintenance schedule.

Health Index of Transmission Tower

Towards Corrosion Hazard Level

The importance and priority of each assessment criterion are compared using a scale of one to nine to obtain the weightage of the assessment criteria (Table 7). Applying Equation 1, HI is calculated by including the weightage of each assessment criterion and the condition rating. The weightage of each element is used to determine the consistency ratio (CR), where the CR must be lower than 10% (Huang et al., 2018; Saaty, 2008). The weightage of each element is 9.5% (soil resistivity), 18.6% (foundation condition), 51.0% (galvanised thickness), and 20.9% (corrosion condition). Based on the weightage, the CR obtained is 2%.

The criteria with the highest importance among assessment criteria are galvanised thickness, followed by corrosion condition. Both criteria have the same element, a structural member that is the most vulnerable to atmospheric corrosion as it is made of steel. The thickness of galvanised coating plays an important role because steel degradation is most likely to accelerate as the protection breaks down, as stated in research by Eyre-Walker et al. (2014). Soil resistivity has the lowest weightage as the importance is the lowest. The consideration is made because the air's corrosion rate spreads faster than in the soil due to the presence of dissolved oxygen, which can inhibit the corrosion process.

Figure 8 illustrates the correlation between HI scores and corrosion hazard levels of transmission towers, along with the corresponding number of towers at each hazard level. Among 434 towers assessed, 106 are classified in level one, dominated by a HI at a score of 5. Even though the HI indicates good condition, the atmospheric area around those 106 towers is highly corrosive, marked as level 1 in corrosion hazard level. Therefore, an increase in the deterioration rate of the towers is expected because heavy industries, coastal industries, and more conquer the atmospheric area on level 1. Most towers at corrosion hazard between level 1 to level 3 give HI score of 3 to 5.

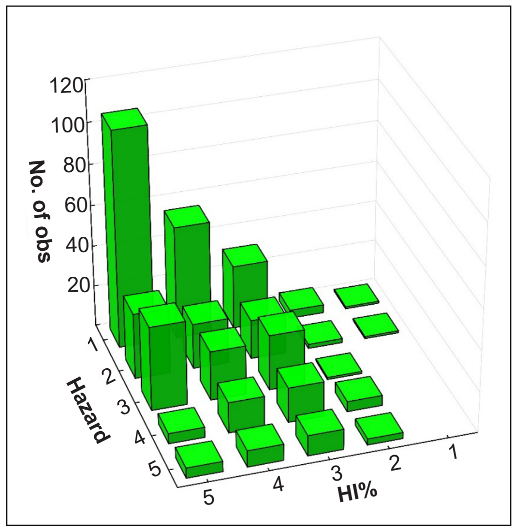


Figure 8. Corrosion hazard level by HI% score of transmission tower (x: Health Index, y: Corrosion Hazard Level, z: Number of towers)

Towards Atmospheric Area

Based on the graph in Figure 9, among 434 towers in this study, 143 towers close to industrial, 28 close to coastal, and 76 close to roads are 71% to 85%, indicating good

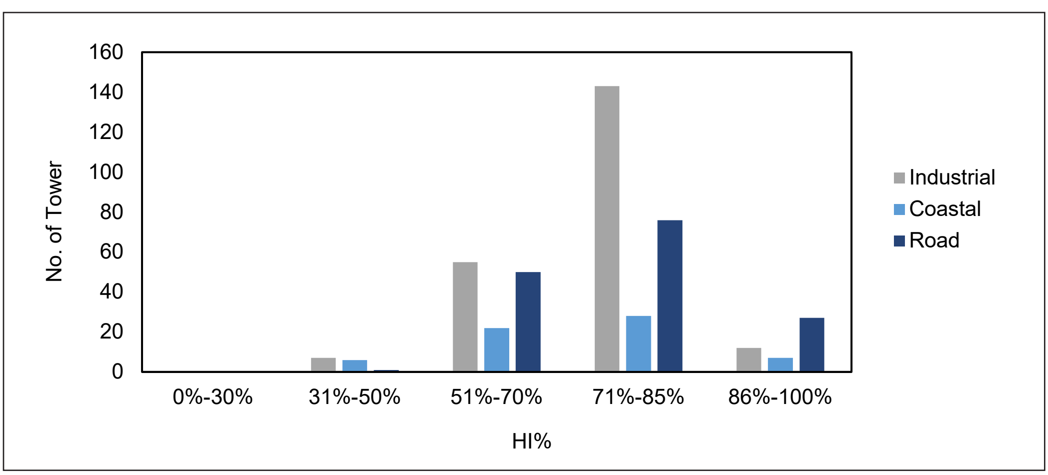


Figure 9. HI% in different environmental distances

condition and requiring regular maintenance. There are only seven towers close to the industrial sector, six towers close to the coastal sector, and one close to roads with HI between 31% to 50%, meaning poor conditions and a need to consider risk assessment. No towers are falling between 0% to 30% (very poor condition). Another possible reason is that the galvanised coating may have been suitable for the environment, as in research by Soufeiani et al. (2020) on suitable galvanised coatings for different types of corrosion. Regarding analysis, this might be due to the excellent maintenance done by the Energy Commission. The tower might have been considering corrosion prevention in the area with a higher corrosion rate.

Towards the Current Service Life of Transmission Towers

A bag plot represents the relationship between towers and age to the HI (Figure 10). The colour of the bag plot is darker from the centre and lighter towards the outer, indicating a higher to lower distribution of towers. In a previous study by Haema and Phadungthin (2012), the health index for overall towers indicated that most are in good condition, between 50% and 70%.

The darker colour is between HI 58% to 88%, with service life between 10 to 45 years and 50% of 434 towers (Figure 10). In addition, there are towers between HI 68% to 88% with service life between 50 to 60 years, generally in good condition due to excellent maintenance routine. Only two out of 434 towers are in HI, between 30% and 40%, which is considered in bad condition. Further investigation into the tower discovered that the

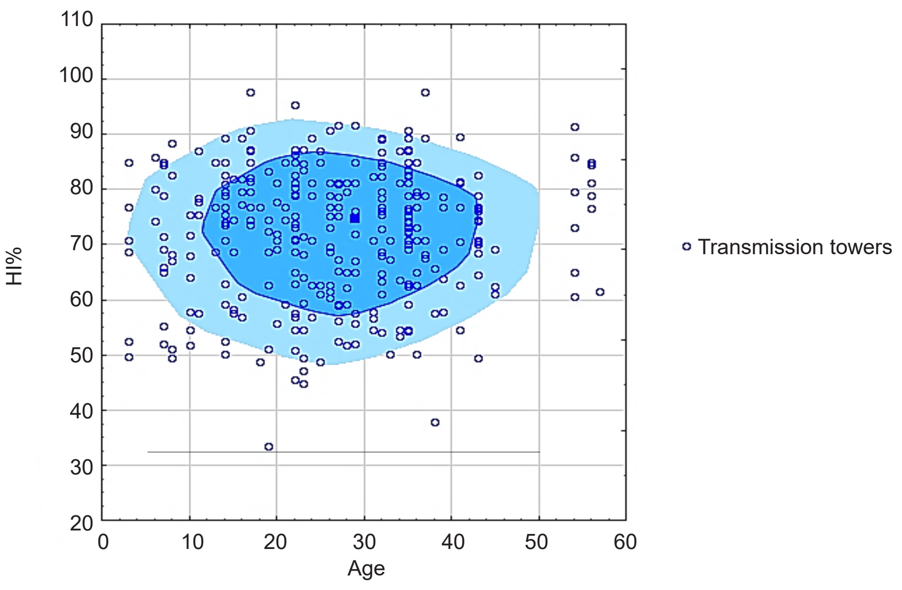


Figure 10. Distribution of transmission towers age and HI (Dark blue: high number of towers, Light blue: low number of towers, Outer range: least number of towers)

towers are in an industrial area, one in the northern part and another in the southern part of Peninsula Malaysia. This situation could be classified as unusual since most of the towers around the area have scored 40% and above. A detailed risk assessment is suggested at both towers immediately to prevent structural failure.

Based on the HI, the HI for 434 transmission towers is illustrated in Figure 11. The map is represented in five colour codes where the HI for red colour is ranging from 0% to 30%, orange colour ranging from 31% to 50%, yellow colour ranging from 51% to 70%, green colour ranging from 71% to 85%, and blue colour ranging from 86% to 100%. As seen in the map, among the 434 transmission towers are yellow, green, and blue, as indicated in Table 8. The map illustrated that most towers are in good condition and only need normal maintenance.

CONCLUSION

This study discovered that the condition of transmission towers in three different atmospheric areas is mainly at ratings 4 and 5, which indicates good condition. However, the corrosion hazard levels recorded at rating 1 signify that those three areas have a very high corrosion level. Analysis of HI in three different atmospheric areas shows that most of the tower has HI of 71%–85%. Furthermore, the number of towers is the highest between 10 to 45 years, with HI 68% to 88%. Meanwhile, a few towers at 50 to 60 years have an HI of 60%–90%, which is good health. From 434 towers, only two falls in HI of 30% to 40%, where both towers are 19 and 39 years old. Implementing HI in transmission towers assessment ensures the safety and reliability of transmission towers. Besides providing valuable information on structural health, the authorities can take practical measures to prevent disastrous failure.

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