Journal of Energy and Safety Technology

JEST

RESEARCH ARTICLE Open Access

INFLUENCE FACTORS OF WIND TURBINE APPLICATION IN EXISTING BUILDING SITES

Nur Izie Adiana Abidin

Department of Structure and Materials, Faculty of Civil Engineering,
Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Corresponding author: izieadiana@utm.my

Article History

Received:	Received in revised form:	Accepted:	Published Online:
March 22, 2023	July 4, 2023	October 1, 2023	Deccmber 15, 2023

Abstract

Oil and gas are common fossil fuels consumed as a source of power, causing irreparable damage such as acid rain, greenhouse gas emissions, environmental pollution, and climate change. The importance of preserving the environment and the nature of fossil fuels have drawn much attention from many to implement renewable sources. Therefore, wind turbine implementation has shown a competitive advantage because they are a reliable source of energy, sustainable, and environmentally friendly. However, the wind turbines implementation potentially poses challenges in services, cost, and others. This paper establishes an influencing factor in wind turbine implementation at the existing building site in ensuring the project's success and minimizing the risk. This paper uses the questionnaire survey directly distributed to the green building certified facilitators, and government and private organisations experts in renewable energy implementation. Factor Analysis has been conducted as an analysis method of data reduction based on Principal Component Analysis with Varimax Rotation. The prioritization of factors was summarized based on the factor loading threshold of 0.50 and above. The Factor Analysis results revealed that the Resources, Management, Economic, Environmental, Risk and Design Factor achieved a significant loading value. The main factor of wind resources should concern the annual wind speed changes, management factor is about the service life of wind turbine, the economic factor should be given the priority on payback period, the environmental factor is focusing on the shadow flickers, risk assessment is related to the factor of interference with radio and television signal and lastly design is on the wind blade. This study is significant in providing insight into all the factors that should be taken into consideration and importance when considering the wind turbine to achieve renewable energy implementation.

Keywords: influence factors; renewable energy; wind turbine, existing site; building.

©2023 UTM Press. All rights reserved

1.0 INTRODUCTION

The world climate change and the global warming impact are increasing daily due to fossil fuel usage [1]. The future impact of climate change is projected to have extensive floods storms, increasing temperatures, and sea level rising. The construction industry is one of the contributors to Greenhouse Gas emissions (GHG) where the major sources come from buildings and the rest is from the energy and heat production from the buildings. Besides, the construction industry also emitted indirect emissions from the whole life cycle of construction which resulted in the impact of climate change. Additionally, the climate change risk and the implication due to construction can be varies based on the locations such as temperature changes (i.e: higher average temperature, extreme heat days, heat waves, bushfires and drought), extreme weather events (i.e: wind, storm, flood) and sea level rising [2]. Due to the current concern about climate change, many countries meet their needs for energy by switching from fossil fuels to renewable energy. Thus, there has been decreasing in fossil fuels due to the fact that the sources are not available everywhere [1]. The best option for meeting energy demand is to use an external power system or renewable energy sources such as biomass, solar, geothermal, wave, hydroelectric, and wind. Wind energy has been presented in Kyoto Protocol to overcome global warming, and it has brought many counties to invest in wind energy [1]

Wind energy is dependent on the availability of the energy source, wind. However, wind energy implementation must have a minor effect on biodiversity, plants, and animals, and excessive noise exposure [3]. Wind energy can impose some negative issues with which the most prominent negativity is the initial investment. The investment is expensive to maintain, making it difficult to obtain. Wind energy also may cause interruptions in electricity generation and is claimed to cause visual pollution. At a specific time, wind turbines also may cause problems with the network connection and noise, making it difficult to live or work nearby. In fact, wind turbines also may cause death to migratory birds, affecting the ecological environment. Additionally, technical sufficiency is crucial in achieving the project's success in terms of adequacy and equipment. Other than that, government incentives have been an issue and have significantly contributed to funding wind energy projects that have attracted attention from investors [4].

Therefore, it can be seen that the investment in a wind turbine is quite complex, with different indicators to be considered. Eventually, this study aims to establish an influencing factor in wind turbine implementation at the existing building site. Several studies have been conducted on wind turbine implementation where they are looking into a single factor to find the potential of wind turbine implementation such as risk, awareness, and impact on ecological and envrionment. This study's main contribution consists of 6 main factors and 30 sub-factors which are considered effective for investors, researchers, and decision-makers to invest in wind energy projects. The main factors considered are wind resources, management, economics, environmental, risk assessment, and design. All the sub-factors are analyse using weightage factors that will be possible to precisely determine something that should be considered because wind energy plays an important role in the development of sustainability in the social and economic context. The main factor of wind resources is concerned with the annual wind speed changes, the management factor is about the service life of wind turbine, the economic factor is to prioritise on payback period, the environmental factor is focused on the shadow flickers, risk assessment is related to the factor of interference with radio and television signal and lastly design is on the wind blade.

2.0 LITERATURE REVIEW

2.1 Renewable Energy in Malaysia

One of the game changers for a nation's economic development might be known to be renewable energy. Renewable energy deployment can help to secure the energy supply and to address the difficulties of climate change. Malaysia has been committed to developing renewable energy sources since 2001 to diversify its energy sources the electricity production. However, based on the lesson from the previous unsuccessful efforts, Malaysia Government formulated another policy in 2008 named as National Renewable Energy Policy and Action Plan to achieve a holistic approach to renewable energy. The aim is to generate electricity from renewable energy sources [5].

Afterward, the government introduced the Feed-in Tariff (FiT) program in 2011 due to the capability of increasing the generation of volume from renewable energy. The FiT benefits to provide a special price for a long term supply of renewable energy and increasing the generation of electricity from renewable energy from 61MW to 985 MW. As of 2011, Malaysia has installed a capacity of renewable energy with a total recorded 1,1,39.04 MW. Currently, the Government has developed the Renewable Energy Transition Roadmap (RETR) 2035 to achieve 25% of the national target by the enhancement of existing programs on renewable energy and at the same time to scale up the projects on renewable energy by exploring new strategies. As Malaysia is taking action to reduce its dependency on fossil fuels and towards achieving utilisation of clean energy with renewable energy, therefore Malaysia initiates strong support to implement a policy. The policy should be systematic and able to change transformatively in all aspects of energy, social and economic. At present, Malaysia is planning to increase the renewable energy share to 20% by 2025 in the national energy mix [6]. This study is to address one of the renewable energy that is potentially to be implemented in Malaysia which is wind energy by focusing on the factors that should be taken into consideration.

2.2 Wind energy

Wind energy is the initiative to reduce reliance on fossil fuels and is part of the solution to resolve the ever-growing global energy needs [7]. Wind energy is said to be the most promising clean energy source for further mitigating global warming caused by the combustion of fossil fuels. Thus, wind energy has developed rapidly over the last two decades, with an installed capacity of 24.33GW in 2001 to 650.76GW in 2019 [8]. The air motion from the wind produces kinetic energy. The wind turbine then catches it to make the rotational and produce electrical power without creating hazardous waste and air pollution to the environment. As technology improves, the current wind turbine is reliable, efficient, and cost-effective for power production. Wind turbine comprises several main components: rotor, gearbox, anemometer, generator and yaw motor, foundation and control system. Wind turbine comprises several type of main components namely as rotor, gearbox, anemometer, generator and yaw motor, foundation and control system [9].

Wind turbines, also known as renewable and clean energy resources, started to receive attention as an effort to improving with the environment. The advancement of wind power technology development, urgency towards environmental protection, and the enhancement to utilize wind resources for power generation have started to develop. It is among the technology designed to generate power with a clean source and has gained a place, especially in new industries' development [10]. Wind turbines use wind energy to generate electricity; therefore, understanding the variability of the wind at the site is crucial. The wind is influenced by geographical conditions, time, the proportion of space, topography, and climatic region [11].

2.3 Influencing factor for wind turbine implementation

According to Eryilmaz and Navarro [12], choosing an optimal wind turbine for a specific site has become a critical problem during the design process. It depends on several factors, such as site condition, characteristics, and other parameters. Manifestly, obtaining an optimal wind turbine depends on several criteria. Furthermore, there are numerous types of wind turbines which commercially available, and thus it is desirable to choose the most suitable based on the existing site condition to achieve optimum capacity benefit. Meanwhile, Lee et al. [13] highlighted that it is extremely important to select appropriate wind turbines, especially the cost that makes up the majority of the total cost. Additionally, the suitability of the location to implement a wind turbine also affects its capacity factor. Therefore, evaluating and selecting renewable energy alternatives with several criteria and factors is crucial to ease the decision-making process. Other than that, Wang et al. [14] also found that wind turbine is affected by multiple criteria such as cost and rotor diameter. Hence, the decision of wind turbine selection is considered restrictive and conflicting and thus requires a comprehensive and agreeable decision-making scheme. In the literature highlighted by Supciller and Toprak [1], many approaches are proposed to select the wind turbine, such as interviews, metaheuristics, and probabilistic. However, these approaches and other available models of decision-making are easy because of only one criterion under consideration. Besides, Golestani et al. [15] highlighted that implementing wind turbine projects has many economic, technical, and environmental challenges. Basically, the implementation requires high consideration of initial cost, operation, maintenance, site availability, and governmental regulation. The many uncertainties need a decision-making approach that considers all parties to find the best alternatives. Thus, multiple criteria must be considered to find a compromise solution. This paper aims to establish multiple factors in selecting the wind turbine to reap the greatest benefit from the wind energy implementation since selecting wind turbines involves many judgments such as technicality and economic and environmental issues. Figure 1 shows the distribution of factors, while Table 1 shows the distribution of sub-factors for wind turbine implementation based on the critical review conducted, which helped to utilise during the questionnaire survey development.

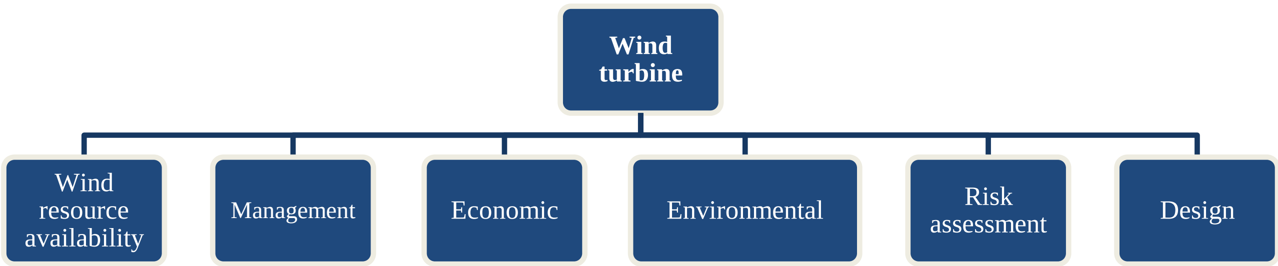

Figure 1. Factors for wind turbine implementation

Wind resource is the fundamental factor determining whether the potential site or region can be potentially installed for economic viability. Assessment of wind is vital to consider the wind direction, wind speed, wind distribution, annual wind speed patterns, turbulence intensity, wind power density, turbine annual energy production, and other factors that can generate electricity [18]. Since certain countries have observed sufficient potential wind power, another important factor that must be achieved is economically viable. The investment in wind power is expected to be a much less expensive alternative, with low cost and high-profit potential. Furthermore, the cash flow is expected to be positive and have a shorter investment period. An investment in wind energy requires smart investments, with 20 years of life and a 15-year payback period [17]. Other significant factors are environmental impact because there's a conflict between energy expansion and local environmental protection. Environmental protection concerns the landscape's visual, noise, and ecological impact. These environmental impacts can cause annoyance which causes challenges in the planning and operation of wind turbines [18]. Jaber [19] has highlighted that wind turbines are known to have zero-emission of harmful substances; however, wind power does have an environmental impact on certain populations and species. Thus, efforts to mitigate the potential effects should be considered during the planning phase. Meanwhile, economic incentives and investments are effective factors in determining the solutions for a wind turbine [15]. Jeroen et al. [20] highlighted wind turbines, a rapidly growing technology and renewable power generation in today's global. Despite their distinct advantage, small wind turbines remain a novelty due to a lack of maturity in the technology. Furthermore, wind turbines also often experience energy yield disappointment which consequently causes poor economic viability. Therefore, economic optimization should be considered using several parameters to achieve maximum economic performance.

Meanwhile, Rolik [21] highlighted those possible risks in implementing a wind turbine project that should be carried out to reduce the negative impact of the proposed development. The risk can be an internal and external factor based on the current economic condition. Besides, the risk in wind energy projects and any other project is considered as an unspecified impact or condition that can affect the overall scope, cost, and quality. Therefore, it is the process of identifying, analysing, and responding to project risks to reduce the impact of adverse events and thus increase the probability of positive risks. The author also added that the wind energy project assessment is performed by determining and documenting risk characteristics that may affect the project's entire lifecycle. Therefore, taking into account the factors influencing the success.

Table 1. Factor and Sub-factor for wind turbine implementation at existing building site

Main Factor	Sub-factor
Wind Resources	Annual wind speed changes
	Expected mean wind power density
	Estimate the turbulence intensity
Management	Service Life
	Lowest buy-back period and buy-back period
	Discount rate`
	Switchable tariff
	Investment and production incentives
Economic	Payback period
	Return on Investment
	Expected annual energy and cost savings
	Cost of connection and foundations
	Cost of repair and maintenance
	Capital and Investment cost
Environmental	Shadow flicker
	Noise and Vibration
	Visual Impact
	Ecological impact
	Aesthetics
	Land use
Risk Assessment	Radio and television signal interference
	Technical support issues
	The severity of windstorm
Design	Wind blade design
	Tower type
	Tower heights
	Wind system size
	Compliance with safety and performance standard
	Rotational speed
	Appropriate wind location

3.0 METHODOLOGY

In the first phase, a questionnaire containing the influence factors for wind turbine implementation was designed, which was established from the critical literature review. Then, a pilot survey was conducted with the experts to confirm on the factors listed. The questionnaire for the pilot survey allows for flexibility for the experts in providing explanations for the practical implementation of wind turbines based on their knowledge and experiences.

The response from the pilot will then lead to the actual questionnaire design. The questionnaire consists of two sections. The first section is respondent's demographic information and another section focuses on the influence factors in which respondents were asked to rank the factors according to the level of influence based on a 5-point Likert scale (where; 1 = not influence at all; 2 slightly influence; 3 influence; 4 more influence; 5 = extremely influence.

3.1 Pilot survey

A pilot survey aims to validate the findings from the literature on a small sample prior to proceeding the actual survey on a larger sample. A pilot survey was conducted on ten (10) Green Building Certified Facilitators experts. The result of this session has gathered several information and feedback such as (i) the questionnaire structure (ii) the relevancy of the influence factors under the main category (iii) modification of whether the factors are relevant to wind turbine implementation (iv) to answer the questionnaire for reviewing the timing. In addition, the pilot survey assists in adding new factors and removing the least relevant factor or possibility of ambiguous questions. The final outcome assists in developing the final questionnaire to disseminate a broader scale.

3.2 Sample size determination

For the distribution of the actual survey, a list of green building facilitators was obtained and the questionnaire was directly distributed to the respondents by meeting them personally through an appointment setting and via email. The selection of these facilitators is based on their experts in renewable energy implementation, who qualified by the Real Estate Housing Developers Association (REHDA), Malaysia Green Building Council (MGBC), and Malaysia Carbon Reduction and Environmental Sustainability Tool (MyCREST). The survey was also distributed to government departments such as the Ministry of Energy, Green Technology and Water, and Public Work Department Malaysia. There are only 54 respondents who had successfully answered the survey from the total population of 110 due to the limitation of experts specifically in a wind turbine or renewable energy implementation.

3.3 Analysis method

Before conducting the analysis, each factor response was stored in Statistical Package for Social Science (SPSS). The first analysis conducted is Reliability Analysis in order to check the internal consistency of the item in the questionnaire based on the Cronbach Alpha value. The acceptable indication of this reliability analysis ranges from 0 to 1, in which the acceptable alpha value is $\alpha \geq 0.7$. A higher coefficient indicates higher reliability [24]. Afterward, since the research aims to identify the influence factors, an Exploratory Statistical Package for Social Science (SPSS) is used to conduct the Factor Analysis to reduce the data and prioritize the factors according to their significant value. There are several protocols when analyzing using the Factor Analysis, such as (i) adequacy of sampling by achieving the minimum value of Kaiser-Meyer-Olkin of 0.50 (ii) the statistical significance with Barlett's Test of Sphericity $P<0.50$ (iii) selection of factor of extraction and rotation which is Principal Component Analysis(PCA) with Varimax rotation which allow establishing an empirical summary of data by minimizing the number of variables that have high loading on each factor (iv) Finally, the factor loading of 0.50 was set which allow retaining the influence factors with a value 0.50 and above. The factor of extraction of PCA was help to determine the number of factors to explain. It is commonly used to describe the data obtained in an empirical summary. Furthermore, PCA is the best solution to reduce a large number of variables into a small set. While, in terms of the rotational method, orthogonal rotation was selected as it is easy to interpret and report whereby high item loading is maximised and low item loading is minimized. Additionally, orthogonal is also assumed that each factor is uncorrelated with the other(Costello and Osborne, 2005). For the value of factor loading, according to Pallant (2014) that items loaded above 0.40 can be strong enough to proceed for further analysis. Therefore, this paper selects the value of 0.50 as the factor loading which according to Kaiser (1974) is the minimum acceptable requirement.

The next step is to conduct the Analysis of the Factor Score (FS) and Weightage Factor(WF). The Factor Score is meant to assign the numerical score value for a detailed indication of each variable based on the percentage value. Factor Score is conducted by multiplying the Factor Loading (FL) of the sub-factor with the average mean value to produce the FSsc. The equation of FSsc is shown below [22]:

$$FS = FL \times Y$$

Where,
FS= Factor Score; FL = Factor loading ; Y = Mean value (1)

Meanwhile, the Weightage Factor involves normalization of 1 or 100 with the overall total weightage value. The equation of Weightage Factor is as follows [23]:

$$\pi \text{ subcriteria} = \frac{\%\text{ Stratum in Variables (sub-criteria), FSsc}}{\%\text{ Stratum in Criteria, FSc}} \qquad (2)$$

Where;

FS_{sc} = Factor score for item in the sub-criteria
ΣFSc = Cumulative of factor score in the criteria
Table shows the result of factor loading from Factor Analysis and Weightage Factor. The sub-criteria is arrange according to their importance.

4.0 RESULTS AND DISCUSSION

4.1 Sampling Adequacy and Statistical Significance

The literature review found six influence factors with 40 sub-influence factors to implement the wind turbine at the existing site: resource availability, management, economic, environmental, risk assessment, and design. The first assessment is the sampling adequacy, where it has achieved Kaiser-Meyer Olkin of 0.779 and Bartlett's Test of Sphericity has shown its value Sign = 0.000, revealing the statistical significance.

4.2 Demographic of Respondents

The first demographic of respondents is about the level of education, 47% have a Bachelor's Degree, 36% have a Diploma, 13% have a Master's Degree and 4% are having a doctorate study. Education level is able to influence the perspective of respondents in interpreting the information which eventually affects the responses. Furthermore, it reflects the respondent's ability to understand the main aim of the data to be achieved. The details of the percentage as shown in Figure 2.

Figure 3 shows the distribution of respondents' experiences in renewable energy projects. Since renewable energy is just recently getting attention and thus not many stakeholders become experts. Therefore, it is relevant that the experts involved in the data collection have less than 10 years of experience. Nevertheless, the aggressive movement towards renewable energy has produced experts to have experienced less than 5 years which represents 56% of them. While 24% of experts have experience between 5-10 years, 10% have experienced 11-15 years 3% between 16-20, and lastly, 7% have experienced more than 20 years. A well-experienced respondent as an expert in renewable energy is highly needed to help researchers to obtain a valuable response that represents the respondent's true practice.

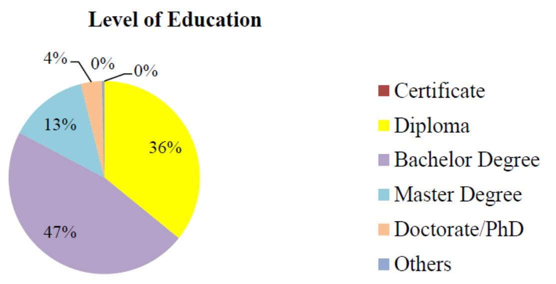

Figure 2. Respondent's level of education

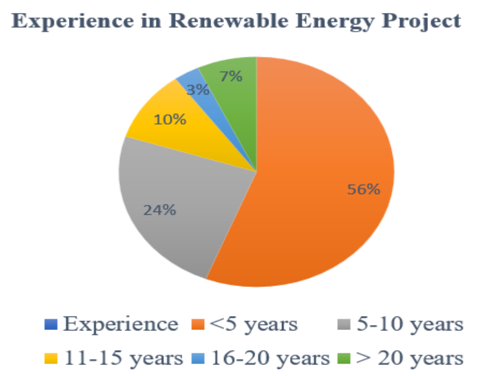

Figure 3. Respondent's experience in renewable energy project

4.3 Factor Analysis, Factor Score, and Weightage Factor

Then, a data rotation was conducted based on Principal Component Analysis with Varimax rotation. As a result, the data have eliminated 2 of 32 sub-factors because the factor loading value less than 0.50. After that, the Factor Score and Weightage Factor were conducted and Table 2 presented the results for the sub-influence factor.

The sub-influence factor under the availability of the resources consists of annual wind speed changes, expected mean wind power density, and turbulence intensity. Annual wind speed change helps to show the wind blew over a time period that measures in meters per second, m/s. It helps to indicate whether low or high energy could be obtained because a low mean speed indicated as little energy would be obtained [24, 25]. For expected mean wind power density, also known as wind energy per unit area of the site measured in watts per square meter, W/m2 is used to determine the amount of energy on-site for conversion by a wind turbine [24,26]. While turbulence intensity is intended to determine the mean wind speed because it might be affected based on the available rough surface, such as vegetation density, buildings, and terrain condition [11, 24,27]. The second influence factor in implementing the wind turbine is management. These consist of service life, buy-back period, discount rate, investment, and production incentives. The service life is the expected lifetime or a period acceptable to perfume the services. Thus, the best scheme for the system is needed for the investor's benefit to ensure it offers useful life to gain better investment [28]. The government usually gives the lowest buyback period to allow the installer to sell their excess energy to export to the grid [26]. The economic conditions influence the discount rate and decide whether the project is feasible to conduct and worth investment since it analyses the present value of future cash flows [29, 30].

The third influence factor is economic. The payback period has been the most influential sub-factor with a factor loading of 0.822 because it requires calculating the year to recover the original investment. A shorter payback period is desirable for most investors [28,25]. The second most influential sub-factor is the return on investment to evaluate investment efficiency by dividing the net profit by the upfront investment cost. The expected annual energy and cost savings is the next important sub-factor which is the annual average energy produced that is influenced by the wind speed available in the region. This can be measured within the hours that the wind turbine can produce electricity each day and on a monthly basis [25]. Then, the capital and investment cost also has become one of the most important sub-factor that are concerned with costs related to purchasing mechanical equipment, installation of technical parts, engineering services, connection to the national grid, and other construction work [4, 28] Apart from capital and investment costs, repair and maintenance have become a concern because good maintenance is important in ensuring better system performance to make it last for 20-30 years. At the early stage of operation, it is encouraged to have the weekly inspection and every four weeks for preventive maintenance. Other types of maintenance can be conducted once or three times a year [28]. Next is the environmental factor in which shadow flicker has been the most concerned sub-factor. Shadow flickers are due to the rotating blades that cast moving shadows and thus mitigation measure is needed by assessing the shadow path to the nearby building, avoiding using gloss surface blades, and appropriate site selection based on the surroundings [11, 31].

Other than that, careful planning of wind turbines requires minimizing the noise by measuring the distance needed between the existing development. The induced noise and vibration may be subject to annoyance and dissatisfaction in some people. Besides, it may also disturb human activity such as sleep and physiological effect, such as hearing loss and ringing of the ears [11,24,31,32,33]. Visual impact is also critical, usually experienced when private property surroundings such as neighbour's and public view, including recreation areas and roads. With that, a proper angle degree, distance, and prominent turbine level should be viewed [11, 31]. Other than that, the construction of wind turbines requires road access and delivery of heavy equipment which can cause ecological impacts such as disturbance with flora and fauna, loss of habitat, and damage to the soil. Furthermore, when there is ground or overcast clouds, the flying birds might lower their fly paths and easily pose a threat from the rotating blade's ears [11, 24, 31, 32]. The aesthetical sub-factor has been controversial due to the possibility of disrupting the scenic view. However, computer modeling may assist in accurately predicting the aesthetic impact of the surrounding area as it will assist the design process [26,34,35]. Lastly, the land-use factor is important to prevent the occurrence of a destructive environment and mitigate a large amount of cut and fill slopes, which may cause an unpleasant view [11,24,31,32]. There are three important sub-factor under the risk assessment: technical support, interference with radio and television signals, and the severity of windstorms. This generally occurs when the wind turbine is located close to the connecting line between the sender and receiver or at the signal tower whereby the waves have been cut through by the rotating blades [32]. Technical support issues occur due to the local technical condition such as wind turbine equipment requiring to be purchased from a manufacturer outside the region. The severity of windstorms is required as it will be caused to the risk of flexibility with wind turbine operation. The final influence factor is concerned with the design factor.

Under the design factor, the most influential sub-factor is wind blade design, tower type, tower heights, wind system size, compliance with safety and performance standards, rotational speed, and appropriate wind location. Wind blades are designed that come in ranges of sizes whereby differ based on the wind turbine size. The invention of wind blade size started with 8m long up to 40m long, which was used for a land-based commercial system [11]. Meanwhile, wind turbine tower consists of several types which are free-standing, tilt-up, and guyed lattice. Freestanding is required for a large foundation as a base which makes it the most expensive tower type option; Tilt-up is mostly made up of a tube of pipe with guyed wired as support; Guyed lattice is where the base of the tower and its guyed is directly attached to the foundation of concrete [36,37]. In terms of tower heights, generally, higher wind turbines can capture more power because the wind speed increases when the elevation increases. A minimum value for tower height is approximately two times the building height, tree, and other possible obstructions. Nevertheless, the height consideration should also include other elements such as cost and the reasonable limit for the project [7,9,37]. The wind system also consists of several sizes ranging from small, intermediate, and large. The decision to choose the system size is based on the amount of energy produced for the building. After all, understanding the relevant laws and regulations provided by the authorities is vital as it helps to govern the decision of wind turbine installation [9]. The last sub-factor is rotational speed, known as the rotor's revolutions around its axis per minute (rpm). The ideal rotational speed is when it is compatible with the wind speed installation [9].

Table 2. Main Factor and Sub-Factor for Wind Turbine Implementation

Main Factor	Sub-factor	Source	Factor Loading (FL)	Mean (Y)	FL x Mean=FSsc	Weightage	%
Wind Resources	Annual wind speed changes	[24,25]	0.783	3.910	3.064	0.361	36.1
	Expected mean wind power density	[24,26]	0.719	3.980	2.813	0.331	33.1
	Estimate the turbulence intensity	[11, 24,26,27]	0.669	3.850	2.618	0.308	30.8
				3.913	**8.495**	**1.000**	**100**
Management	Service Life	[14, 28]	0.779	4.170	3.032	0.238	23.8
	Lowest buy-back period	[26]	0.693	3.930	2.697	0.211	21.1

	Discount rate`	[29, 30]	0.645	3.740	2.510	0.196	19.6
	Switchable tariff	[28]	0.593	3.860	2.308	0.181	18.1
	Investment and production incentives	[28]	0.570	3.760	2.218	0.174	17.4
				3.892	**12.765**	**1.000**	**100**
Economic	Payback period	[14, 25, 28]	0.822	4.040	3.384	0.195	19.5
	Return on Investment	[25]	0.769	4.070	3.166	0.182	18.2
	Expected annual energy and cost savings	[25]	0.759	4.100	3.125	0.180	18.0
	Cost of connection and foundations	[26]	0.721	4.130	2.968	0.171	17.1
	Cost of repair and maintenance	[36]	0.628	4.190	2.585	0.149	14.9
	Capital and Investment cost	[14, 28]	0.524	4.170	2.157	0.124	12.4
				4.117	**17.385**	**1.000**	**100**
Environmental	Shadow flicker	[11, 31]	0.810	3.870	3.129	0.195	19.5
	Noise and Vibration	[11, 24, 31, 32]	0.749	3.850	2.893	0.180	18.0
	Visual Impact	[24, 31]	0.715	3.780	2.762	0.172	17.2
	Ecological impact	[11, 24, 31, 32]	0.695	3.940	2.684	0.167	16.7
	Aesthetics	[26,34,35]	0.614	3.700	2.372	0.148	14.8
	Land use	[32]	0.568	4.037	2.194	0.137	13.7
				3.863	**16.034**	**1.000**	**100**
Risk Assessment	Interference with radio and television signal	[32]	0.781	3.770	3.001	0.343	34.3
	Technical support issues	[32]	0.767	3.910	2.948	0.336	33.6
	The severity of windstorm	[26]	0.731	3.850	2.809	0.321	32.1
				3.843	**8.758**	**1.000**	**100**
Design	Wind blade design	[11]	0.894	3.800	3.517	0.176	17.6
	Tower type	[36, 37]	0.869	3.780	3.419	0.172	17.2
	Tower heights	[36, 37]	0.834	3.870	3.281	0.165	16.5
	Wind system size	[36]	0.768	3.800	3.021	0.152	15.2
	Compliance with safety and performance standard	[9]	0.591	4.110	2.325	0.117	11.7
	Rotational speed	[9]	0.562	3.960	2.211	0.111	11.1
	Appropriate wind location	[36]	0.541	4.220	2.129	0.107	10.7
				3.934	**19.903**	**1.000**	**100**

4.4 Automated Influence Factor for Wind Turbine Implementation at the Existing Building Site

All of the information from the weightage factor has been inserted into Microsoft Excel in the form of drop-down list which was developed to ease the process of selection of the Factor. Microsoft Excel will automatically produce the total weightage and its indication with the level of influence. For example, when the selection of factors reaches the percentage of 100-81, it indicates highly influenced, 80-54 is moderately influenced 53-27 is slightly influenced and 26-0 is not influenced. Table 2 to Table 7 shows the drop-down list of influence factors for wind turbine implementation. This automated influence factor leads to a quicker and more consistent decision towards each main factor and sub-factor since it has extensive data to be analysed. Additionally, it helps to reduce errors in calculating the results and leads to better decisions.

a. Wind resource Factor

Table 2. Wind resource factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage (%)
Wind resource	1	Annual wind speed change	36.1
Wind resource	1	Expected mean wind power density	33.1
Wind resource	1	Estimate the turbulence intensity	30.8
	3	**GRAND SUM WEIGHT**	**100**

b. Management Factor

Table 3. Management factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage (%)
Management	1	Service life	23.8
Management	1	Lowest buy-back period	21.1
Management	1	Discount rate	19.6
Management	1	Switchable tariff	18.1
Management	1	Investment and production incentives	17.4
	5	**GRAND SUM WEIGHT**	**100**

c. Economic Factor

Table 4. Economic factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage
Economic	1	Payback period	19.5
Economic	1	Return on investment	18.2
Economic	1	Expected annual energy and cost savings	18
Economic	1	Cost of connection and foundations	17.1
Economic	1	Cost of repair and maintenance	14.9
Economic	1	Capital and investment cost	12.4
	6	**GRAND SUM WEIGHT**	**100**

d. Environmental Factor

Table 5. Environmental factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage
Environmental	1	Shadow flicker	19.5
Environmental	1	Noise and vibration	18.0
Environmental	1	Visual impact	17.2
Environmental	1	Ecological impact	16.7
Environmental	1	Aesthetics	14.8
Environmental	1	Land use	13.7
	6	**GRAND SUM WEIGHT**	**100**

e. Risk Factor

Table 6. Risk factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage
Risk	1	Interference with radio and television signal	34.3
Risk	1	Technical support issues	33.6
Risk	1	The severity of windstorm	32.1
	3	**GRAND SUM WEIGHT**	**100**

f. Design Factor

Table 7. Design factors for wind turbine implementation

Main Factor	No	Sub-factor	Weightage
Design	1	Wind blade design	17.6
Design	1	Tower type	17.2
Design	1	Tower heights	16.5
Design	1	Wind system size	15.2
Design	1	Compliance with safety and performance standard	11.7
Design	1	Rotational speed	11.1
Design	1	Appropriate wind location	10.7
	7	**GRAND SUM WEIGHT**	**100**

5.0 CONCLUSION

Wind energy has recently emerged as one of the most promising renewable sources of energy for replacing fossil fuel consumption. Choosing an optimal wind turbine for a specific site is important in implementing the wind turbine to achieve optimal long-term solutions. Manifestly, the wind turbine implementation involves an optimal selection that depends on several factors, such as the amount of power generated, wind speed conditions, and several others. Since there are many different types of wind turbines commercially available, thus it is desirable to choose the most suitable type based on the existing site conditions. This research achieves the objectives of finding the influence factors in implementing wind turbines at the existing sites through the weightage factor. The factors are found through a critical literature review and questionnaire distribution to the renewable energy experts to confirm the 30 sub-factor available under the wind resource, management, economic, environmental, risk assessment, and design factors. Nevertheless, the most significant factor under wind resources is annual wind speed changes because it achieves the highest weightage (36.1%). Additionally, the service life of wind turbines should also be given priority as it also has achieved the highest weightage for management criteria (23.8%). Besides, the decision maker or investors also should determine the payback period concerning the investment decision and the potential of shadow flicker as both have been given the highest concern under economic and environmental factors with a weightage of 19.5%. Meanwhile, to avoid disruption to occupants or people surrounding, the risk factor of interference with radio and television signals also plays a crucial role with a weightage of 34.3%. Lastly, implementing wind turbines has exploited design factors that concern the physical part which is wind blade design as it gained the highest priority with a percentage of 17.6%.

All the parties involved in the wind turbine project may have different objectives based on the existing site conditions. Owners or investors may seek less initial investment, while the users may prefer high production. The variation of interest among the parties and the potential uncertainties at the site may lead to a complex decision-making process. Therefore, it is necessary to specify carefully the objective of the implementation and the actual preferences which will influence the factors to be selected during the decision-making process to achieve optimal results. This research may be expanded that could be addressed in future studies such as focusing on the local context of ongoing projects to get more accurate factors that can be applied for real similar site development.

Acknowledgements

This paper and the research behind it would not have been possible without the exceptional support of my supervisor, colleagues and family.

References

[1] Supciller, A. A., Toprak, F. 2020. Selection of wind turbines with multi-criteria decision-making techniques involving neutrosophic numbers: A case from Turkey. *Energy*. 207: 118237.
[2] Hurlimann, A.C., Warren-Myers, G., Brown, G.R. (2019). Is the Australian construction industry prepare for climate change?. *Building and environment*. 153: 128-137.
[3] Kuczyński,W., Wolniewicz, K., Charun, H. 2021. Analysis of the wind turbine selection for the given wind conditions. *Energies.* 14(22): 1–16.
[4] Dong, W., Zhao, G., Yüksel, S., Dinçer, H., Ubay, G.G. 2022. A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renew Energy*. 185: 321–337.
[5] Mohd Chachuli, FS., Mat, S., Ahmad Ludin, N., Sopian, K. 2021. Performance evaluation of renewable energy R&D activities in Malaysia. *Renewable and Sustainable Energy Reviews*. 163: 544-560.
[6] Mohd Chachuli, F.S., Ahmad Ludin, N., Md Jedi, M.A., Hisham Hamid, N. (2021). Transition of renewable energy policies in Malaysia: Benchmarking with data envelopment analysis. *Renewable and Sustainable Energy Reviews*. 150: 111546.
[7] Rivkin, D.A., Anderson L.D., Silk, L. 2013. *Wind Turbine Control Systems*, United States, Jones and Barlett Learning.
[8] Liu, P., Meng, F., Barlow, C.Y. 2022. Wind turbine blade end-of-life options: An economic comparison. *Resource, Conservation and Recycling* 180: 106202.
[9] Wizelius, T. 2015. *Developing Wind Power Projects: Theory and Practice*, United States, Routledge.
[10] Zhao, Z., and Huang, W. 2011. Multi-objective Decision-making on Wind Power Projects Based on AHP Method.
[11] Burton, T., Jenkins, N., Sharpe, D., and Bossamyi, E. 2011. *Wind Energy Handbook*, United Kingdom, John Wiley and Sons Ltd.
[12] Eryilmaz, S., Navarro, J.A. 2022. Decision theoretic framework for reliability-based optimal wind turbine selection. *Reliability Eng System Safety*, 221: 108291.
[13] Lee, A.H.I., Hung, M.C., Kang, H.Y., Pearn, W.L. 2012. A Wind Turbine Evaluation Model Under a Multi-Criteria Decision Making Environment. Energy Conversion and Management. 64: 289–300.
[14] Wang, J., Xu, L., Cai, I., Fu, Y., Bian, X. 2022. Offshore wind turbine selection with a novel multi-criteria decision-making method based on Dempster-Shafer evidence theory. *Sustainability Energy Technology Assessments*. **51**: 101951.
[15] Golestani, N., Arzaghi, E., Abbassi, R., Garaniya,V., Abdussamie, N. 2021. The Game of Guwarra : A game theory-based decision-making framework for site selection of offshore wind farms in Australia. 326: 129358.
[16] Dayal, K.K., Cater, J.E., Kingan, M.J., Bellon, G.D., Sharma, R.N. 2021. Wind resource assessment and energy potential of selected locations in Fiji. *Renew Energy*. 172: 219–237.
[17] Adeyeye, K.A., Ijumba, N., Colton, J.S. 2021. Low Wind Speed Areas. *Processes.* 9: 1463, 1–21.
[18] Guan, J., Zepp, H. 2020. Factors affecting the community acceptance of onshore wind farms: A case study of the Zhongying wind farm in Eastern China. *Sustainability* 12(17): 6894.
[19] Jaber, S. 2014. Environmental Impacts of Wind Energy. *J Clean Energy Technology*. 1(3), 251–4.
[20] Jeroen, D.M., Kooning, D., Arash,E., Simon, D.Z., Jeroen,D.M., Lieven,V. 2021. Techno-economic optimisation of small wind turbines using co-design on a parametrised model, Sustainable Energy Technologies and Assessments. Sustainable energy technologies and assessments. 45,

101165.
[21] Rolik.Y. 2017. Risk Management in Implementing Wind Energy Project. *Procedia Engineering*. 278-288.
[22] Dien, J., Frishkoff, G. (2005). Introduction to Principal Components Analysis of Event-Related Potentials. 1-42.
[23] Maletta, H., & Aires, B. (2007). Weighting. *Spsstools*. 1–19. Retrieved from http://www.spsstools.net.
[24] Nelson, V. 2009. *Wind Energy Renewable Energy and the Environment*, Boka Raton, CRC Press.
[25] Moustafaeipour, A. 2013. Economic evaluation of small wind turbine utilization in Kerman, Iran. *Energy Conversion Managament*. 73, 214–25.
[26] Kang, H. Y., Hung, M. C., Pearn, W. L., Lee, A.H.I., Kang, M.S. 2011. An Integrated Multi-Criteria Decision Making Model for Evaluating Wind Farm Performance. *Energies* 4(11):2002–2026.
[27] Earnest.J. 2015. *Wind Power Technology*. Delhi, PHI Learning Pvt. Ltd.
[28] Wang, J., Xu, L., Fu.Y., Bian, X. 2022. Offshore wind turbine selection with a novel multi-criteria decision-making method based on Dempster-Shafer evidence theory. *Sustainable energy technologies and assessment*. 51: 101951.
[29] Oxera. *Discount Rates for Low Carbon and Renewable Generation Technologies*, Oxford, Oxera Consulting Ltd.
[30] Khatib, B.H. (2012). The Discount Rate - A Tool for Managing Risk in Energy Investments. *International Association for Energy Economics*. 9–10.
[31] Manwell, J.F., Mcgowan, J.G and Rogers, A.L. 2009. *Wind Energy Explained Theory, Design and Application*, United Kingdom, John Wiley and Son Ltd.
[32] Wagner, S R, Bareib, and G. Gudati. Wind Turbine Noise. (Springer, Germany) (1997).
[33] Radun, J., Maula, H., Saarinen, P., Keränen, J., Alakoivu, R., Hongisto, V. 2022. Health effects of wind turbine noise and road traffic noise on people living near wind turbines. *Renew Sustain Energy Rev*. 157:112040.
[34] Tara. 2011.Wind Energy: Aesthetics, Property Values, and Sound. *Wind Energy*, 5–8.
[35] Lee, A. H. I., Hung, M. C., Kang, H. Y., Pearn, W.L. 2012. A wind turbine evaluation model under a multi-criteria decision making environment. *Energy Conversion Management*. 64: 289–300.
[36] Stapleton, G., Neill, S., Milne, G., Reardon, C., and Riedy, C. 2013. Solar Photovoltaic. Australian Government Department of Industry. 375-380.
[37] Clark, R.N. 2014. *Small wind planning and building successful installation*, United Kingdom, Elsevier Inc.