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Selection of Propulsion System for Electric Amphibious Bus to Alleviate Traffic Congestion in the Jabodetabek Area

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Abstract

High vehicle growth in Jakarta is not balanced with traffic growth, the level of congestion in Jakarta continues to increase every year. To overcome this congestion, innovation is needed to utilize the river as a means of public transportation. The amphibious bus is an alternative public transportation option in the Jabodetabek area to break congestion. The amphibious bus design must be supported by a propulsion system that can operate on land and water. The amphibious bus propulsion system is a must, according to river conditions and operational requirements. The selection of the drive system is carried out by means of analysis The driving criteria factors needed according to the specifications of the amphibious bus are power, efficiency, size, cost, and maneuverability. These criteria become indicators in determining the type of mover. This study aims to select the prime mover system based on criteria and specification requirements. The selection uses the process hierarchy analysis (AHP) method by giving weight to the criteria for each driver, and type of mover in the water, namely waterjets, azimuth-podded, Paddle Wheels, Cycloidal Propellers and propulsion on land diesel engines, gasoline engines, and electric engines. The results showed that the order of the propulsion selection criteria was propulsion power being the top priority, followed by maneuverability, energy efficiency, cost, operational and investment, and propulsion size and weight. The results of the AHP show that the main options are propulsion systems in water, namely waterjets and diesel engine propulsion systems on land. System Water Jet has a propulsion power of 1000 kW, has high maneuverability, energy efficiency of 85%, and a maximum speed of 60 Km/hour so it can meet the specifications of an amphibious bus drive. For operations on land, the main choice of propulsion system for amphibious buses is a diesel engine with a power of 250 HP and 800 Nm of torque providing strong torque and a wide cruising range. This system has a range of up to 800 km, a maximum speed of 120 km/h, and exhaust emissions of Euro 5.

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1. Introduction

The Jabodetabek area (Jakarta, Bogor, Depok, Tangerang, and Bekasi) is an area with a population and number of vehicles that are increasing every year. Population growth in Jabodetabek continues to increase from year to year but is not matched by traffic growth. According to BPS data, the population of Jabodetabek in 2020 will reach around 35 million people, with a population growth of around 1.2% per year [1]. Meanwhile, motorized vehicles in Greater Jakarta reached around 20 million units in the same year, the faster growth of vehicles has caused congestion in the region to increase [2]. The congestion in this area is very complex and multifactorial, including an increase in the number of vehicles, an inefficient transportation system, and a lack of adequate road infrastructure.

The impact of congestion in the Jabodetabek area is very complex and impacts many aspects, both directly and indirectly [2]. Congestion in the Jabodetabek area impacts national security and defense, disrupting mobility and logistics transfers [3]. The Greater Jakarta area is an important center for economic, political, and, social activities in Indonesia. If handled properly, it can cause social and political instability, as well as hinder mobility and logistical transportation needed to maintain national security and defense [3]. The availability of public transportation modes will reduce congestion, and the need for public transportation in the Greater Jakarta arranged alternative mode of operation utilizing stream flow [4]. Thirteen major rivers in Jakarta that connect the Jabodetabek area can be used as a mode of operation for public transportation [5]. The river flow can be used as an alternative transportation route to break congestion in the Jabodetabek area.

In order to overcome congestion and maintain the stability and security of the country, it is necessary to take concrete steps. One way is to encourage the use of public transportation that is efficient and effective in overcoming congestion, such as amphibious buses. The amphibious vehicle operates over rivers and on land because it has two propulsion systems [4]. The amphibious bus design must be supported by a drive system that is in accordance with the river conditions and the specifications for the needs of the amphibious bus. Therefore, the concept of an amphibious bus propulsion system that can operate in water is needed in an integrated mode of transportation on existing land [4].

Coutsar has planned an amphibious bus design to break down congestion in the Jabodetabek area, in his research it was found that an amphibious bus design is capable of carrying 51 passengers at a speed of 40 km/hour on water and 60 km/hour on land with one battery charge, this bus also can walk at a maximum angle of up to 30° [5]. Propulsion system analysis shows that this amphibious bus will operate with a 3 X 2000 water jet propulsion system and an NCA 1860 100 V battery electric engine [5]. The research recommends further propulsion system selection studies regarding the need for an amphibious bus propulsion system that has high maneuverability and is more environmentally friendly [5]. Purnama compared several propulsion systems for amphibious buses, namely diesel, battery, and hybrid propulsion systems. The research results show that the diesel drive system provides better performance than the diesel and hybrid drive systems in terms of speed, acceleration, and fuel consumption. However, this study only considers performance factors and has not considered environmental factors [6].

Rinaldi has designed an amphibious school bus for students in the Thousand Islands, North Jakarta, research results show that amphibious buses can operate across the sea and operate on land safely taking school students. The amphibious school bus uses type propulsion water jet 510 HP, CAT C9 Acert main engine, and Kohler 21EKOZD 21 Kw auxiliary engine [7]. Ma'ruf also conducted research on the Semarang East Flood Canal as tourism transportation. Results research shows that Speedboats with dimensions8m open length of 8 m, width of 2.2 m, and a draft of 0.4 m with driveway jet can operate tourist boats along the Semarang East Flood Canal [8]. This study recommends that in technical planning for the selection of tour boats, it is necessary to pay attention to the comfort and suitability of the propulsion system with the geographical conditions of the river flow. Setijoprajudo conducted research on alternative modes of transportation in DKI Jakarta with the Manggarai – Dukuh Atas – Karet route with a distance of 3.4 km. Results of the study dimensions water bus 11.6 m long, and 4.5 m wide using a waterjet propulsion system [9]. Another research conducted by Chen made an amphibious bus design using the OpenSim software. The results of the study explain that in the process of making an amphibious vehicle design with the principles of hydrodynamics and bionics techniques, it includes aspects of the vehicle, hydrodynamic aspects in water and on land as well as fuel consumption for operations and maneuvers [10].

2. Methods

This research aims to develop an optimized propulsion system for amphibious buses, which can operate effectively on land and in water. To achieve this goal, this research involves systematic and well-defined steps. The research steps can be seen in Figure 1.

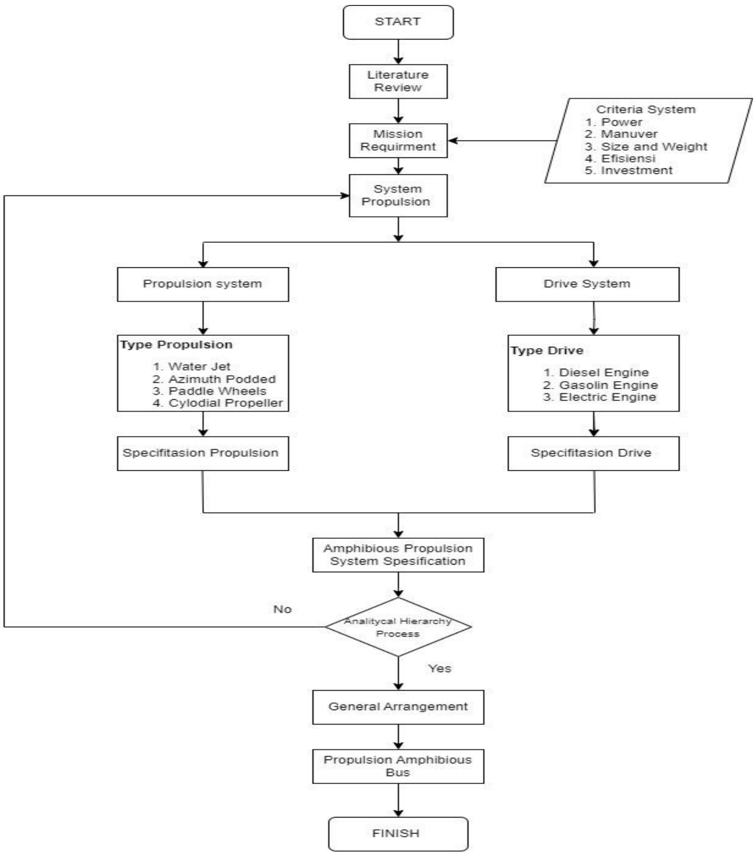

Figure 1. Chart methodology

This study began by conducting a literature review and establishing criteria for the propulsion system required by an amphibious bus. These criteria are based on the mission, vehicle concept, and vehicle dimensions [5]. Subsequently, the concept of an amphibious bus propulsion system was developed for operations on water and land separately. An in-depth analysis was carried out to study the specifications and capabilities of each propulsion system to ensure the operational capability of the amphibious vehicle both in water and on land. Types and propulsion system specifications that meet the set criteria are then combined to create an amphibious vehicle propulsion system specification. Selection of the best propulsion system is carried out using Process Hierarchy Analysis based on data obtained from questionnaires or interviews. The process of analyzing the process hierarchy involves the stages of forming a hierarchy, weighing criteria, weighing the choice of drive systems, calculating priorities, calculating consistency values, and determining priority results [11]. Through the steps of the process, hierarchy analysis is carried out, the best amphibious bus propulsion system can be determined for operations both on water and on land.

In order to obtain an optimal propulsion system, mission requirements are an important factor in determining the propulsion system specifications on land or in water. This stage also involves defining vehicle specifications, including power, maneuverability, size and weight, efficiency, and operational and investment costs. These criteria will shape the concept of a propulsion system that can operate safely and effectively in the intended environment. These criteria are based on the mission, vehicle concept, and vehicle dimensions. Subsequently, the concept of an amphibious bus propulsion system was developed for operations in water and on land. The analysis is carried out to ensure the operational capability of amphibious vehicles both in water and on land. Propulsion system types and specifications suitable for operations in water and on land are then combined to create an amphibious vehicle propulsion system specification. Selection of the best propulsion system is carried out using Process Hierarchy Analysis using data obtained from questionnaires or interviews. If the propulsion system selection succeeds in choosing the best propulsion system, the next step is to make a general arrangement which is a graphical representation of the general layout of the propulsion system in an amphibious vehicle. The goal is to choose an amphibious vehicle propulsion system that is capable of moving on land and at sea with maximum effectiveness. The propulsion system on land and in the water is adjusted to the specifications of the amphibious bus propulsion system which have been determined as in the following Table 1 [5].

Table 1. Vehicle specification

Measurement	**Value**	**Unit**
Type Electric Motor	OMD IE3-2 Pole	-
Frame Size	355LX2	
Poles	2	
Frequency	50	Hz
Frame	Cast Iron	
Power	2x710	kW
Torque	2x2274	Nm
Rotational	3000	rpm
1^{st} gear ratio	15.9	
2^{nd} gear ratio	1.17	
Tire Diameter	800	mm

The research object is an amphibious bus which is designed to break congestion in the Jabodetabek area which has two drivers, namely on land and water. The propulsion system will work alternately according to the route passed so that the placement will be different. Selection of the propulsion system is carried out to obtain the type of amphibious vehicle propulsion system in accordance with the specifications system driving force based on mathematical calculations and geographical conditions. The choice of drive type uses the AHP method by assigning values to the specifications of each drive. From these various calculations, the best propulsion system specifications for amphibious vehicles will be produced.

3. Results and Discussion

3.1. Analysis of Needs for Amphibious Bus Propulsion System Specifications

3.1.1. Propulsion System

The success of an amphibious vehicle in operating in water is highly dependent on the specifications of the propulsion system selected, as this has a direct impact on vehicle performance, reliability, and safety. This specification is also important to ensure compatibility between the propulsion systems and the needs of amphibious bus vehicles. Drive system specifications must consider various aspects of performance, such as speed, power maneuver, ability to pass obstacles, and efficient use of energy. The safety of the selected propulsion system is also a crucial factor in providing a high level of security for passengers and amphibious bus vehicles. The ability to deal with water currents, stability in traveling on water, and a reliable control system on land are also important factors in the safety aspect. Energy efficiency is also an important consideration in choosing a propulsion system that is efficient in energy use. An efficient propulsion system will provide benefits in terms of saving fuel or electricity, reducing exhaust emissions, and extending the vehicle's operational range. The reliability and durability of the propulsion system chosen are also very important so that the amphibious bus can operate consistently and survive long-term use. This will help minimize downtime and high maintenance costs. In addition, the selection of the propulsion system must also consider aspects of operational and investment costs. In addition to the initial costs of buying and installing a propulsion system, it is also important to consider long-term operational costs such as maintenance, spare parts, and energy consumption. Compatibility with the environment is also an important factor in choosing a propulsion system. In an era that is increasingly concerned about the environment, choosing an environmentally friendly propulsion system with low or zero emissions, as well as the use of renewable energy sources, has a positive impact on the environment. Following are some of the requirements for propulsion system specifications in water for amphibious bus vehicles [12].

Table 2. Specification propulsion systems in water for amphibious buses

Parameter	Waterjet	Azimuth Podded	Paddle Wheels	Cycloidal Propeller
Propulsion Power	1000 kW	800 kW	600 kW	900 kW
Maneuverability	Height	Currently	Low	Currently
Energy Efficiency	85%	78%	7%	80%
Operational and investment costs	IDR 15.000.000	IDR 12.500.000	IDR 10.800.000	IDR 14.000.000
Diameter	130 X 27 cm^2	110 X 23 cm^2	164 X 147 cm^2	200 X 50 cm^2
Weight	480 Kg	2300 Kg	270 Kg	380 Kg
Speed	60 km/h	50 km/h	45 km/h	55 km/h

Table 2 is used as a reference to meet the relevant propulsion system specification requirements for amphibious buses when operating in water. The parameters in the table include propulsion power, capability maneuver, energy efficiency, operational and investment costs, size (length, width, height), and the resulting speed. Each parameter has a different role in selecting the appropriate propulsion system for the amphibious bus because these parameters affect the vehicle's performance and reliability in the water environment [12]. Propulsion is related to the ability of amphibious vehicles to reach the desired speed in the waters, and good maneuverability provides an advantage in navigation and adjustment of the direction of movement in various water conditions. Propulsion efficiency is important to ensure optimal energy use, reduce consumption of fuel or other energy sources, and ultimately reduce operating costs and environmental impact. Operational and investment costs are also important factors in selecting a propulsion system. This consideration involves expenses related to the maintenance, care, and purchase of system components which must be proportional to the benefits and benefits obtained. In addition, the size of the amphibious vehicle (length, width, height) must also be considered to ensure practicality and take into account space limitations. Propulsion systems that are too large or heavy can affect vehicle design, maneuverability, and operational capabilities in various water conditions.

3.1.2. Drive System

In addition to the propulsion system specifications required when operating in the water, the amphibious bus propulsion system requirements when operating on land are also a very important factor in determining the vehicle's performance and reliability. When on the ground, the propulsion system must be able to provide enough power to overcome various obstacles such as slopes, obstacles, and various terrain. There are three types of propulsion systems that are the choice for the propulsion of amphibious buses when operating on land, namely diesel engines, gasoline engines, and electric engines. Each type of propulsion system has advantages and disadvantages that need to be considered according to the needs of amphibious buses when operating on land [12]. The following are ground propulsion system specifications that need to be considered for amphibious buses when operating on land.

Table 3. Needs specification ground propulsion systems for amphibious buses

Parameter	Diesel engine	Gasoline Engine	Electric Machine
Power	250 HP	280 HP	220 HP
torque	800 Nm	750 Nm	900 Nm
Fuel Consumption	10 L/100 km	12 L/100 km	0 kWh/100 km
Mileage	800 km	700 km	300 km
Maximum Speed	120 km/h	140 km/h	100 km/h
Maintenance	Medium	High	Low
Exhaust gas emissions	Euro 5	Euro 6	Zero Emission
Weight	500 kg	450 kg	400 kg
Operational Costs every month	IDR 8.000.000	IDR 9.000.000	IDR 7.500.000
Machine size	150 cm x 90 cm x 120 cm	140 cm x 80 cm x 110 cm	130 cm x 70 cm x 100 cm

Table 3 shows propulsion system specifications for diesel engines, gasoline engines, and electric engines on land amphibious buses and provides a comprehensive description of the characteristics and needs of each propulsion system to meet the needs of amphibious buses. Through this table, the selection of the right propulsion system can take into account these important factors. The use of a diesel engine drive system can provide advantages in terms of strong torque, good fuel efficiency, and a wider operational range. Diesel engines also tend to be more resistant to harsh environmental conditions and require relatively low maintenance. However, diesel engines are usually heavier and have a more complex design [12]. On the other hand, the use of a gasoline engine propulsion system offers advantages in terms of responsive power, high speed, and better performance in smoother terrain. Gasoline engines are also easier to maintain and have a more compact design. However, the fuel consumption of gasoline engines tends to be higher than diesel engines [12]. Additionally, electric engines have become a popular alternative in vehicle propulsion systems, including amphibious buses. The use of electric machines provides advantages in terms of environmental cleanliness, energy efficiency, and quiet and responsive performance. However, there are major obstacles to the use of electric machines, such as limited mileage and limited availability of charging infrastructure [12].

3.2. Analytical Hierarchy Process (AHP)

In this study, the Analytic Hierarchy Process (AHP) method was used to select an amphibious vehicle propulsion system, both when operating on land and in water. There are four propulsion system options when operating in water which is the focus of this research, namely Water Jet, Azimuth Podded, Paddle Wheels, and Cycloidal Propellers [13]. The selection of the four types of drive systems is carried out by considering the characteristics of each drive and the needs of the amphibious bus vehicle. Each propulsion system has different strengths and weaknesses, so it is necessary to carry out the selection process using the Analytic Hierarchy Process method [14]. In addition, the option of an amphibious bus propulsion system on land also needs to be considered in this study. Several types of propulsion systems that may be an option are diesel engines, gasoline engines, and electric engines. The selection of a propulsion system for ground operations will take into account factors such as torque, speed, fuel efficiency, range, and ability to traverse various types of terrain. The process of selecting propulsion systems on land will also use the Analytic Hierarchy Process method to produce optimal decisions. The calculation results from the Analytic Hierarchy Process (AHP) process are explained as follows

3.2.1. Weight and Priority Criteria for Propulsion Systems in Water

The Analytic Hierarchy Process (AHP) is a decision-making method used in multi-criteria analysis. After identifying the criteria, the next step in the AHP process is to determine the relative weight for each criterion. This relative weight indicates the relative importance of each criterion in the context of decision-making. Determination of relative weight in AHP is done through pairwise comparisons between each pair of criteria. In pairwise comparisons, each criterion is compared one by one with the other criteria and is given a relative weight that reflects the level of importance of the criterion to the criteria being compared. This relative weight is given on a scale of 1 to 9, where the number 1 indicates the same level of importance, the number 3 indicates the level of importance is slightly more important, and the number 9 indicates the level of importance is very important [15]. This relative weighting is important to obtain clear and accurate information in the decision-making process. By assigning proper relative weights, the more important criteria will have a greater influence on the evaluation and judgment of the alternatives. Furthermore, this relative weight will be used in subsequent calculations to obtain a suitability score or priority for the alternative to be selected. Table 4 is the result of weighting for all criteria on propulsion systems in water.

Table 4. Results of weighting and priority criteria for propulsion systems in water

Criteria	Relative Weight	Priority
Propulsion Power	0.382	1
Ability Maneuver	0.248	2
Energy Efficiency	0.183	3
Operational and investment costs	0.138	4
Size and weight	0.049	5
CR = 0.007		

The Consistency Ratio (CR) value of 0.007 in the table shows the level of consistency from the comparison of the priority weights that have been given to the choice of propulsion system. A CR value close to 0 indicates a good and acceptable level of consistency. With a CR value of 0.007, it can be concluded that the results of the analysis and determination of priority weights have a good level of consistency. In other words, the decision to set priority weights for each propulsion system choice is based on fairly consistent and reliable comparisons. In the AHP results, the "Propulsion Power" criterion gets the highest relative weight of 0.382, indicating that propulsion power has the top priority in selecting propulsion systems in water. These results are consistent with previous studies which emphasized the importance of strong propulsion to propel amphibious buses in water [13]. Therefore, a propulsion system capable of providing strong and effective propulsion must be a major consideration. Furthermore, the "Energy Efficiency" criterion has the second highest relative weight of 0.248, indicating that energy efficiency is an important factor in the selection of propulsion systems in water. This is in accordance with the need to optimize energy use. Then, the "Maneuverability" criterion has a relative weight of 0.183 and gets the third priority. This demonstrates the importance of the propulsion system's ability to maneuver properly in water in the success of the amphibious bus. The "Operational Costs and Investments" criterion has a relative weight of 0.138 and gets fourth priority. Despite the lower weight, operational and investment costs remain important considerations in selecting a propulsion system on the water. Furthermore, the "Weight" and "Size" criteria have the same relative weight of 0.049 and get the fifth priority. This shows the importance of considering the weight and size of the propulsion system in the design and stability of an amphibious bus in water. Overall, the results of the AHP are in accordance with previous theories and studies which emphasize the importance of propulsion power, energy efficiency, capability maneuver, operational and investment costs, as well as weight and size in the selection of propulsion systems for amphibious vehicles in the water. These results provide relevant guidance in selecting a propulsion system that suits the desired needs and priorities.

3.2.2. Weight and Priority Criteria for Propulsion Systems on Land

The selection of an amphibious bus propulsion system will gain a deeper understanding of the most important factors in selecting a propulsion system that suits the needs of an amphibious bus when operating on land. The following is the result of weighting on all criteria for the propulsion system.

Based on Table 5, each criterion has been given a relative weight based on the pairwise comparison. This weight reflects the relative importance of each criterion in selecting a ground propulsion system for an amphibious bus. The Consistency Ratio (CR) value of 0.007 indicates the level of consistency from the comparison of the priority weights that have been given.

The closer to zero, the better the level of consistency. With a CR value of 0.007, it can be concluded that the results of the analysis and determination of priority weights have a good level of consistency. This means that the decision to assign priority weights to each choice of propulsion system is based on fairly consistent and reliable comparisons. In the table, it can be seen that the "Engine Power" criterion has the highest weight of 0.32, followed by "Fuel Efficiency" 0.20, "Exhaust Emissions" 0.18, "Torque" 0.15, and "Maintenance and Maintenance" 0.14. Based on the results of this analysis, it can be concluded that in selecting ground propulsion systems for amphibious buses, the "Engine Power" factor has the highest level of importance, followed by maintenance and maintenance, torque, fuel efficiency, and exhaust emissions. These results are consistent with the theory which states that optimal engine power, efficient maintenance, sufficient torque, good fuel efficiency, and low exhaust emissions are priorities in ensuring the performance and reliability of ground propulsion systems for amphibious buses. The results of the AHP are in accordance with the theory which emphasizes the importance of the factors that have been identified in selecting ground propulsion systems for amphibious buses [16].

Table 5. Results of weighting and priority criteria for propulsion systems on land

Criteria	Relative Weight	Priority
Engine Power	0.32	1
Fuel Efficiency	0.20	2
Exhaust gas emissions	0.18	3
Care and Maintenance	0.15	4
torque	0.14	5
CR = 0.007		

3.2.3. Propulsion System Weight and Priority in Water

An effective propulsion system will enable the amphibious bus to move well in various terrain conditions when operating in water. In the analysis of the weight and priority of the criteria, the Analytic Hierarchy Process (AHP) method is used to select the most suitable propulsion system among the Waterjet, Azimuth Podded, Paddle Wheels, and Cycloidal Propeller as an option for an amphibious bus propulsion system in water. Through this method, the relative importance of each propulsion system can be identified based on predetermined criteria and specifications. This will assist in selecting the most suitable propulsion system for the amphibious bus when operating in water. Table 6 shows weighted results for the propulsion system options.

Table 6. Weighting and priority results propulsion in water

Criteria	Relative Weight	Priority
Waterjet	0,355	1
Cyloidal Propeller	0,246	2
Azimuth Podded	0,216	3
Paddle Wheels	0,183	4
CR = 0.097		

Based on the weight and priority analysis for the choice of amphibious bus propulsion system in water, analysis, and discussion can be carried out regarding the selection of the most suitable propulsion system. The Consistency Ratio (CR) value of 0.097 indicates the level of consistency from the comparison of the priority weight given to the choice of propulsion system. A CR value close to 0 indicates a good and acceptable level of consistency. It can be concluded that the results of the analysis and determination of priority weights have a good level of consistency. Based on the priority table, the propulsion system with the highest relative weight is the Waterjet with a weight of 0.355. The Waterjet has the top priority, indicating that this propulsion system is considered the most important in the context of using amphibious buses in water. Waterjet uses high water flow to generate strong thrust, providing good speed and maneuverability in various terrain conditions in Jabodetabek waters [17]. This is in accordance with the needs of amphibious buses which must be able to operate effectively in waters and in accordance with the needs of amphibious buses.

Furthermore, the Cycloidal Propeller has a weight of 0.246, the second choice as an amphibious bus propulsion system in water. Despite their lower weight than the Waterjet, Cycloidal Propellers are still considered an important choice in the propulsion of amphibious buses on water. Cycloidal Propeller uses a propeller that can rotate 360 degrees, this provides very flexible maneuverability and good turning ability. This increases the ability of the amphibious bus to adapt to various terrain conditions in the waters. However, long-term use of this propulsion can result in higher fuel consumption and increased operating costs. In addition, maintenance and maintenance of Cycloidal Propeller systems can also require a higher level of expertise and costs [18]. Azimuth Podded is the third priority with a weight of 0.216. Podded Azimuth is a propulsion system that uses propulsion that can rotate 360 degrees independently. This system provides superior maneuverability and the ability to turn with high precision. In the context of an amphibious bus, the Azimuth Podded can provide the flexibility and maneuverability needed to operate in various waters. However, the relatively large size and weight of the system can affect the overall design of the amphibious bus and limit the capacity of passengers or payload that can be carried. In addition, the initial and maintenance costs for Azimuth Podded may also be higher compared to some other options [19]. Paddle Wheels are the fourth priority with a weight of 0.183. Paddle Wheels use a rotating water wheel to generate thrust. Despite their lower weight, Paddle Wheels remain a viable option for amphibious bus applications in water. The main strength of Paddle Wheels is their simplicity and reliability. However, please note that Paddle Wheels may have limitations in terms of speed and maneuverability compared to other options.

Based on the results of the AHP analysis and discussion above, the main choice as a propulsion system in water for amphibious buses is Waterjet. This choice is based on the highest relative weight and the ability of the Waterjet to provide strong thrust and good maneuverability in various terrain conditions in the waters. Waterjet meets the needs of amphibious buses that must be able to operate effectively and safely in the water. The results of the AHP analysis are in accordance with the theory because the AHP method helps in identifying the relative importance of each option based on predetermined criteria and specifications. By considering the priority weight given to each propulsion system, Waterjet is considered the best choice for amphibious buses in water because of its ability to provide speed, maneuverability, reliability, and compliance with emission standards.

3.2.4. Land Propulsion System Weight and Priority

In choosing a propulsion system on land, there are several considerations behind this choice. The diesel engine was chosen because it has high power and torque, suitable for driving large amphibious buses. The advantages of diesel engines also lie in their good fuel efficiency, providing longer mileage with lower fuel consumption. The reliability and durability of diesel engines are also important factors in heavy operating conditions [12]. The petrol engine was chosen as an option because it has higher power compared to the electric engine, giving the vehicle good acceleration. Gasoline engines also have advantages in terms of relatively easy maintenance and repair, as well as the wide availability of spare parts on the market [20]. In addition, the gasoline engine also has a smoother sound and less vibration. Electric machines are an attractive alternative due to their environmental friendliness and high energy efficiency. Electric engines do not produce exhaust emissions, thus contributing to reducing negative impacts on the environment [21]. The use of electric machines can also reduce dependence on fossil fuels and minimize long-term operating costs. In addition, the driving experience with an electric machine also feels different. Table 7 shows the weighted results for ground propulsion options

Table 7. Results of weighting and priority of land drives

Criteria	Relative Weight	Priority
Diesel engine	0.350	1
Gasoline Engine	0.250	2
Electric Machine	0.200	3
CR = 0.097		

Based on the result, the Consistency Ratio (CR) value of 0.097 indicates the level of consistency from the comparison of the priority weight given to the choice of the drive system. The CR value of 0.097 indicates that the analysis and determination of priority weights have a good level of consistency. Based on the results of the analysis, it can be seen that diesel engines have the highest priority weight with a value of 0.350, followed by gasoline engines with a priority weight of 0.250. Electric machines have a priority weight of 0.200. Interpretation of this data can be done by cobys and suitability of the specifications of the amphibious bus propulsion system on ban diesel engines get the highest priority weight because they have several important advantages in the context of the use of amphibious buses on land. Diesel engines generally have great power, are capable of producing strong torque, and have good fuel efficiency. In addition, diesel engines are also more resistant to harsh environmental conditions and terrain, such as muddy ground or bumpy terrain. The power and durability of diesel engines make them a great choice for propelling amphibious buses on land. Gasoline engines get the second priority weight. Gasoline engines generally have good power and can provide responsive acceleration [22] [23]. Although the fuel efficiency of gasoline engines tends to be lower than that of diesel engines, in some cases of land use of amphibious buses, the speed and acceleration provided by the gasoline engine become an important factor. For example, if an amphibious bus is used for tourism or recreation purposes that require high maneuverability and speed on land. The electric engine gets the third priority weight. Electric engines were chosen because they are environmentally friendly, do not produce exhaust emissions, and have high energy efficiency. However, it is also necessary to consider the need for sufficiently large power to propel the amphibious bus on land [24] [25].

Overall, the results of the AHP analysis are in accordance with the theory and specification requirements of the drive. The AHP method helps in identifying the relative importance of each option based on predetermined criteria and specifications. In the context of the propulsion of amphibious buses on land, the diesel engine has the highest priority weight because of its strength, efficiency, and durability to match those requirements.

4. Conclusion

Based on an analysis using the Analytic Hierarchy Process (AHP) method to determine the main choice of amphibious bus propulsion in water and land. In operation in water, the prime choice propulsion system vizWater Jet with a propulsion power of 1000 kW. SystemWater Jet has high maneuverability, an energy efficiency of 85%, and a maximum speed of 60 Km/hour. In amphibious operations, systemWater Jet provides optimal performance to move in the waters so that it can meet the needs of amphibious bus propulsion specifications. For operations on land, the main choice of propulsion system for amphibious buses is a diesel engine with a power of 250 HP and 800 Nm of torque providing strong torque and a wide cruising range. This system has a range of up to 800 Km, a maximum speed of 120 Km/h, and Euro 5 exhaust emissions. Water Jet for operations on water and diesel engine propulsion systems for operations on land. Use a water Jet in the water ensures high maneuverability, while the diesel engine system on land provides the power and range required.

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