energies

Review

Methods and Techniques Supporting Energy and Media Savings in Maintenance of Public Transport Buses—State of the Art and Recommendations

Andrzej Wieczorek [1], Kinga Stecuła [1,*] and Wieslaw Wes Grebski [2]

[1] Faculty of Organization and Management, Silesian University of Technology, 44-100 Gliwice, Poland; andrzej.wieczorek@polsl.pl
[2] Penn State Hazleton, Pennsylvania State University, 76 University Drive, Hazleton, PA 18202-8025, USA; wxg3@psu.edu
* Correspondence: kinga.stecula@polsl.pl

Abstract: In the article, the authors discussed the topic of energy and media savings in a public transport company. The article is of a review nature, referring to 100 sources, including scientific papers, books, conference proceedings, and websites. In the first part, a detailed literature review on environmental protection problems in road transport and methods of solving them was conducted. Subsequently, the authors reviewed the literature content on maintenance as a pro-environmental activity in transport companies. The great accent was paid to the problem of saving energy and media in the maintenance of public transport buses. Based on the literature and knowledge, the authors proposed the possibilities of conducting a rational method of managing the operation and maintenance of buses from the point of view of environmental protection, based on the strategy of predictive bus maintenance.

Keywords: energy savings; media savings; maintenance; public transport; buses

Citation: Wieczorek, A.; Stecuła, K.; Grebski, W.W. Methods and Techniques Supporting Energy and Media Savings in Maintenance of Public Transport Buses—State of the Art and Recommendations. *Energies* **2024**, *17*, 2051. https://doi.org/10.3390/en17092051

Academic Editor: Peter V. Schaeffer

Received: 24 February 2024
Revised: 13 April 2024
Accepted: 24 April 2024
Published: 25 April 2024

1. Introduction

As a result of activities undertaken by humans in the process of meeting their needs, including the recognition of needs, design, construction, production and operation, unfavorable phenomena occur in the biosphere. It is necessary to prevent or limit their occurrence. This should be done by taking actions in many areas of the organization's activity that are created by humans. These include maintenance, whose functioning determines the implementation of the company's basic activity—production or service. Its aim is, among other things, to save energy or utilities that are necessary for the proper use of technical means.

The article discusses the topic of energy and media savings in a public transport company. A literature review on environmental protection problems in road transport and methods of solving them was carried out, as well as traffic maintenance as a pro-environmental activity in a transport company. When reviewing the literature, special attention was paid to the problem of saving energy and media in maintaining public transport buses. The subsequent part of the article shows the possibilities of conducting a rational method of managing the operation and maintenance of buses from the point of view of environmental protection, based on the strategy of predictive maintenance of buses.

The paper is divided into five sections. Section 2 includes a review of the literature on environmental problems in road transport and ways to solve them. Section 3 presents the problem of vehicle maintenance as a pro-environmental activity in a transport company. Section 4 discusses selected possibilities of solutions in the field of energy and media savings in a public transport company—it refers to the concept of the use of Computerized Maintenance Management System (CMMS), strategy according to the technical condition, Key Performance Indicator (KPI), Industry 4.0, and to smart cities. Section 5 introduces the potential results of the theoretical proposed model. Section 6 summarizes the paper with conclusions.

When it comes to the literature review in Section 2, it contains 75 references (from 1 to 75), mainly articles, that focus on environmental issues in road transport and proposed solutions in this area. These articles were found in the Scopus and Web of Science databases. The authors used various combinations of keywords, such as "environment", "transport", "problem", "green", "road transport", "buses", "cars", "vehicles" and "solution", to search the literature. This chapter is divided into three smaller subchapters, concerning the technological sphere, the economic and organizational sphere (together), and the social sphere. Subsequently, in Section 3, the authors reviewed the content of the literature on maintenance as a pro-ecological activity in transport companies to be able to systematize literature and knowledge and present the content on the selected possibilities of solutions in the field of energy and media savings as a conceptual part in Section 4. This literature was collected based on the experience of the authors and the concept on which they are working. These references, from 76 to 100, focused on selected concepts of a typically technical and operational nature, as well as those related to effectiveness. Keywords used to find these papers included "maintenance", "exploitation", "environment", "energy"—with different combinations.

2. Environmental Problems in Road Transport and Ways to Solve Them—Literature Review

2.1. Technological Sphere

In the technological sphere, the main problem is related to different types of engines and energy sources. The engine is the heart of every car, powering it. Internal combustion engines (ICEs), including gasoline and diesel engines, are prevalent in many vehicles. Internal combustion engines exploit the conversion of the chemical energy contained in suitable fuels (typically hydrocarbons) into mechanical energy due to a combustion process [1]. Gasoline engines are one of the most common types of car engines. They are fueled by petrol, which provides high torque at low revs and makes them suitable for city driving [2]. Gasoline engines are usually lighter and cheaper to produce than their diesel counterparts [3]. They are also quieter, which translates into greater driving comfort. However, petrol engines typically consume more fuel than diesel engines and have higher CO_2 emissions. On the other hand, according to Hooftman et al. [4], the newest generation of petrol vehicles is still a valid solution despite its emission impacts. Diesel engines are generally more fuel-efficient than gasoline engines, which translates into a longer range on a tank [2]. Diesel engines also produce more torque, which is beneficial when driving with a heavy load or when towing. On the other hand, these engines are usually heavier and more expensive to produce. Moreover, they can generate more noise and vibration, which can affect driving comfort. In recent years, due to high emissions of nitrogen oxides and particulate matter, diesel engines have been the subject of much controversy. According to Cunanan et al. [5], most Heavy-Duty Vehicles (HDVs) currently use an ICE that is based on diesel because the energy efficiency is higher than gasoline. Engines that use fossil fuels as an energy source contribute to air pollution and greenhouse gas emissions. While progress has been made in improving the efficiency and reducing emissions of ICE engines with technologies such as turbocharging, direct injection and exhaust gas recirculation, they still have inherent limitations in terms of environmental performance. They affect the natural environment, causing, above all, air pollution. Polluted air has a strong impact on people's health and lives, as well as fauna and flora [6]. Therefore, internal combustion engines need to be improved to limit their environmental impact. According to Leach et al. [7], there is great potential to bring about different improvements in internal combustion engines in the short term through better combustion, exhaust gas treatment and control systems. When it comes to the medium term, the development of new fuel or engine systems can be observed. To meet current greenhouse gas emissions targets, it is necessary to improve the performance of such engines in terms of efficiency and exhaust pollutant levels. According to the results of the research, implementing technologies in conventional, stoichiometric SI engines can lead to an even 30% reduction in fuel consumption over a typical new car. Also, there are other technologies, such as lean-burn SI combustion, water injection, and variable compression ratio, that can reduce further fuel consumption. Moreover, these engines burning renewable energy sources can ease the expansion of renewable electricity generation by ensuring alternate storage potential when generation exceeds demand. There is also research on biodiesel. According to Ogunkunle and Ahmed [8], biodiesel combustion has been established as a control technology when it comes to increasing gaseous pollutants, and they highlight its role in building a sustainable and healthy human–environment scenario. As Knothe and Razon [9] state, biodiesel offers several advantages over conventional diesel fuel, for example, low or no sulfur content, absence of aromatics, high flash point, inherent lubricity, and biodegradability. It also reduces most regulated exhaust emissions and, importantly, is compatible with existing fuel distribution infrastructure. But there are still technological challenges, namely the reduction of NOx emissions [10] and the improvement of oxidative stability [11].

Subsequently, there are alternative propulsion technologies such as electric vehicles (EVs), hybrid vehicles, and hydrogen fuel cell vehicles. These solutions offer opportunities to reduce the environmental footprint [12]. Battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs) power themselves by using electricity and do not need an ICE. They convert the chemical energy from active materials into electrical energy. There is a difference, as when it comes to batteries, active material is stored in the system, and in the case of fuel cells, it is continuously fed into the system [5].

Electric vehicles can be powered by different energy sources. It depends on the energy system of a given country and its activities towards clean energy. Electric vehicles, need to be charged with electric energy from the grid to move, and this grid energy can be obtained from various sources, both traditional and renewable [13]. Then, EVs powered by renewable electricity offer zero emissions while driving. However, the issue of battery production and disposal/recycling is still controversial [14,15], as is the fact that in many countries' electricity comes from fossil fuels. Hence, their eco-friendliness is a complicated issue and depends on many factors. As Tabuchi and Plumer [15] note, lithium-ion batteries, commonly used in EVs, rely on raw materials such as cobalt, lithium, and rare earth elements. Cobalt mining, especially in the Democratic Republic of Congo (DRC), poses environmental and human rights concerns, with hazardous tailings and slags leaching into the environment and high exposure to cobalt and other metals among nearby communities, including children. What is more, the extraction of these metals requires smelting, emitting sulfur oxide and other harmful air pollutants. The authors highlight that about 70% of the world's cobalt supply comes from unregulated mines in the DRC, where workers (including children) mine cobalt using hand tools, risking their health and safety. The last but not least issue for discussion is the fact that they are quiet while driving, which can be an advantage for drivers and their surroundings but it also can be a disadvantage because pedestrians may not hear an approaching vehicle and may be hit by it. For this reason, in the literature and in practice, you can find solutions that introduce warning signals in such vehicles [16,17]. As Leach et al. [7] notice, some countries have ambitions to remove internal combustion engine vehicles and use EVs. However, this will take some time, even in the light-duty sector. First of all, increased electrical power generation capacity and ways of storing it will be necessary. These countries will also have to make changes to the electricity distribution system and invest in the development of smart charging systems and other infrastructure. As authors notice, it is rough to use only electricity for heavy-duty road, marine and air transport—it must be highlighted that they account for over 50% of global transport energy demand—due to the batteries' large size and weight.

Hydrogen fuel cell vehicles use this type of cell to get electric motor's power. HFCs are electrochemical devices whose task is to convert the chemical energy of hydrogen into electricity, heat, and water [5]. Their advantage is that they generate zero tailpipe emissions. HFCVs rather have proton exchange membrane fuel cells (PEMFC), as they can be characterized by, firstly, high power density and, secondly, cold-start capabilities [18]. The biggest difference between a traditional electric (battery) car and a hydrogen-powered electric car is that electricity is stored in a battery car, while in a hydrogen car it is generated. By charging a battery car, we provide ready-to-use energy. We first supply hydrogen to a hydrogen car, which must then be converted into ready-to-use energy.

The main issue connected with these types of vehicles is the production of hydrogen and the lack of proper infrastructure. According to Hosseini and Butler [19], the main challenges associated with hydrogen-powered vehicles, focus on safety, storage, and transport. Safety considerations are related to the risk of fire occurrence. Storage can also be a problem. It requires materials and methods that balance high hydrogen density, fast release kinetics, safety, and cost-effectiveness. Additionally, the establishment of infrastructure for hydrogen transport from production sites to refueling stations is essential. As Greene et al. [20] notice, the design and cost of hydrogen stations must be integrated with the production and delivery systems.

EVs and hydrogen vehicles provide zero tailpipe emissions. However, there are so-called well-to-wheels (WTW) emissions, and there, the scenario can be different [5]. The WTW emissions come from two phases: the first is well-to-pump, and the other is pump-to-wheels [21]. Well-to-pump emissions come from energy production and its transportation to the client. On the other hand, pump-to-wheels emissions are refueling and tailpipe emissions. They are emitted during refueling and exploitation of vehicles. Then, when fossil fuels are the source of energy for generating electricity or hydrogen to power the vehicle, the well-to-pump emission is great. However, when using RES as a source of energy in these vehicles, they would theoretically have zero emissions [22].

In summary, the widespread adoption of these alternative technologies remains a challenge. There are issues with infrastructure limitations, high upfront costs, and concerns about the range and availability of electric vehicle charging. Additionally, the environmental benefits of these types of vehicles depend on factors such as the source of electricity generation and the method of producing hydrogen fuel. Therefore, addressing the technological challenges associated with the different types of engines and energy sources in road transport is crucial to achieving significant reductions in greenhouse gas emissions and mitigating the environmental impact of transport. Taking actions aimed at protecting of the environment in the field of road transport is highly important [23]. Additionally, technological innovations in engine design, aerodynamics, and materials can help reduce vehicle greenhouse gas emissions and improve overall environmental performance.

2.2. Economic and Organizational Sphere

The issues related to the economic and organizational spheres of road transport include the cost of exploitation of current and future technologies. One of the important aspects is the investment in new, clean technologies. When it comes to electric and hydrogen vehicles, other costs relate to building all the infrastructure and charging/loading vehicles. Currently, there are too few places in the world where charging an electric car or powering hydrogen vehicles is possible [24]. Countries therefore face huge dilemmas related to these technologies. First, there are huge costs associated with implementing the infrastructure that will enable these vehicles to move and encourage people to buy them. Secondly, organizational issues, such as building appropriate infrastructure, are problematic. Questions arise regarding the location, the selection of appropriate entities to implement projects, the scale of projects and the number of hydrogen charging or refueling stations. In the literature, some authors conducted analyses of investment in infrastructure for charging EVs [24–26] and hydrogen vehicles [27–29]. Stecuła et al. [30] analyze even an investment in infrastructure for hydrogen city buses in a given city in Poland. This infrastructure includes mainly special stations consisting of an electrolyser, a compressor, fuel and supply storage, and a dispenser. On the other hand, it is worth mentioning that in the literature there are also papers on smart charging strategies [31,32] and fast charging methods [33,34] for electric vehicles, which is promising for the future. Another issue is also related to sources of electricity. As it was already mentioned in the previous section, countries strive to use alternative energy sources, and this would be the best solution for energy production. Then, such vehicles would have close to zero emissions. Therefore, in addition to the costs of investing in infrastructure, it is important to focus on energy sources [35], which is why countries are gradually switching to the use of photovoltaics [36], hydropower [37] and wind energy [38]. This requires massive changes in a country's energy system.

The solution in this area includes financial support, as there are some financial incentives to invest in environmentally friendly vehicles and the development of associated infrastructure. This can encourage individuals and institutions to adopt cleaner forms of road transportation. However, it must be mentioned that this matter is complicated as EVs are challenging when it comes to battery cost; it must be highlighted that one-third of the EV cost is connected with the battery [39]. It should also be mentioned that in some countries the electricity prices are very expensive, so not everyone is convinced of electricians. When it comes to pro-ecology activities on a larger scale in given countries on road transport, there are policies such as carbon pricing, fuel taxes, and vehicle emissions standards to internalize the environmental costs of transportation. On the other hand, there are disincentive factors that may impact those who continue to use vehicles emitting high levels of pollution into the air. These disincentives may come in the form of taxes, fines, or regulations aimed at reducing emissions and promoting sustainable transportation practices [40,41]. It is worth noting that some companies give the customer the opportunity to compensate for their carbon footprint in the form of an additional payment added to the ticket prices. An example can be Flixbus [42], which offers on its website the following: "with a simple click of a button, you can not only compensate the exact emissions of your trip but also make direct impact on sustainable living in your local communities".

Moreover, transport emissions can be reduced by choosing a bicycle instead of a car [43]. More and more literature writes about smart biking, highlighting the role of bikes in smart cities [44,45]. Also, sustainable transportation practices are known, such as promoting telecommuting and flexible work schedules to reduce miles travelled. It turns out that some tasks can be performed without leaving home. An example was remote work [46,47] and education [48,49] during the COVID-19 pandemic. What is more, actions are taken to optimize logistics and supply chain management to minimize emissions and environmental impact [50,51]. Collaboration between stakeholders from the public and private sectors is essential to bringing about significant change in this area.

2.3. Social Sphere

In the social sphere, there are various problematic issues regarding the impact of transport on the environment. The first problem is the lack or low environmental awareness of the people [52]. This means that pro-environmental education is not at the highest level [53]. A large percentage of the population has no knowledge or awareness of the impact of certain human activities on the environment. Another issue is the ignorance of many people; they are not interested in issues of human impact on the environment without even trying to expand their knowledge or open their minds to new knowledge. According to Moyal's and Schurr's [54] research, when people have a chance to avoid unpleasant knowledge about the potential negative results of their egoistic behavior towards others, most people refuse or avoid to having knowledge. Their research shows that the choice of being ignorant of the consequences of one's actions reduces prosocial behavior compared to situations in which people remain aware.

When it comes to activities aimed at decreasing the impact of emissions and noise on the environment and consequently on people, in this sphere they are mainly connected with increasing social awareness. In other words, raising awareness and changing societal attitudes and behaviors related to transportation choices are the most important challenges. Bamberg and Blobaum [55] in their paper explore the influence of personal norms on the decision to use public transportation instead of a car. They identified two distinct processes that highlight personal norms: anticipated feelings of guilt and perceived social norms, showing how social contexts affect individuals' perceptions and actual use of public transportation.

Promoting sustainable travel options such as public transportation, cycling, and walking, as well as encouraging carpooling and ridesharing to reduce individual vehicle usage, are good examples. Cycling and walking are especially associated with creating healthier and more equitable communities. This promotes physical activity and improves air quality. Additionally, initiatives such as carpooling [56] and ridesharing [57] can significantly reduce the number of vehicles on the road, leading to less pollution and more efficient use of transportation infrastructure. According to the results of the study [56] in Bulgaria, Canada, Spain, Finland, France, Hungary, Italy, South Korea, the United Kingdom, and the US, it is claimed that carpooling to commute to work is not common, as below 25% of the total driving time to/from work is done with others the way it was mentioned. According to Asghari et al. [57], their study of 500 millennial respondents shows that subjective norms and attitudes had the most important influence on travel sharing intentions, followed by perceived behavioral control and personal norms. Then, slightly lower respondents indicated economic benefits and sustainability as significant motivations towards carpooling. Such solutions should be promoted by, for example, educational campaigns. Social media play a big role in this regard [58,59]. They can contribute to the awareness of environmental sustainability. They can engage people in pro-environmental actions and make them more aware of the common green problems. Social media have a great deal of power in this kind of social education.

On the other hand, efforts such as promoting cycling and walking instead of driving require a multifaceted approach that includes infrastructure development, such as the construction of bike lanes and the expansion of public transit networks. It is also related to the idea of smart cities, which use technology and data to improve urban efficiency [60], sustainability [61], and quality of life [62]. In smart cities, transportation systems are interconnected and optimized using digital tools such as intelligent traffic management systems [63], real-time public transit tracking systems [64], and smart parking solutions [65]. By integrating sustainable transportation options into the fabric of smart cities, such as bike-sharing programs [66] and electric vehicle charging stations [67], communities can further reduce reliance on private cars and promote environmentally friendly travel alternatives. Additionally, smart city initiatives often prioritize pedestrian-friendly urban design, creating walkable neighborhoods and reducing the need for car travel [68]. It is also worth emphasizing the role of artificial intelligence (AI) in smart cities. Solutions based on artificial intelligence drive technical progress in cities, often also contributing to environmental benefits. According to Stecuła et al. [69], AI is often used in the urban environment through supporting electric vehicle charging infrastructure, systems connected with the reduction of emissions coming from vehicles (transport), smart grids and energy storage systems. Another trend developing in smart cities is immersive technology. An increasing number of publications relate to the usage, popularity and potential of virtual reality (VR) [70,71], augmented reality (AR) [72,73] and metaverse [74,75].

3. Maintenance of Vehicles as a Pro-Environmental Activity in a Transport Company

The knowledge about maintenance presented in the article covers basic concepts in the field of maintenance for industrial enterprises. Moreover, it indicates pro-environmental solutions that guarantee energy and media savings in their technical systems, including urban transport systems.

3.1. Maintenance—Selected Issues (Exploitation and Management of Exploitation—Strategy and Structures)

There are many definitions of exploitation. The most appropriate one from the point of view of a transport company, taking into account its complex nature, is the one that states that the operation of a technical means is a set of ordered, interconnected organizational, economic, legal, normative and technical processes from the moment of production to the moment of its liquidation (scrapping) [76]. According to Kaźmierczak [76], exploitation is use, i.e., using a technical means in accordance with its intended purpose and servicing, consisting in maintaining or restoring the suitability for operation of technical means.

The implementation of these tasks is possible due to the management of the operation of technical means, which, according to Kaźmierczak [76], includes strategy, structures (organizational, information and decision-making), activities and culture. An exploitation strategy, according to Woropay and Landowski [77], is a predetermined (modifiable during the exploitation process), ordered set of rules, methods of conduct and sequences of actions, as well as means for their implementation, concerning technical objects (technical means) in the exploitation phase, determining the effectiveness of the functioning of technical means and the operation of the exploitation system in which the process of their exploitation is carried out. Within the activity of maintenance, there are the so-called generalized strategies, which include;

- Strategy according to failures, such as Breakdown Maintenance (BM), Emergency Maintenance (EM) or Critical Maintenance (CM)—this strategy assumes that a technical asset may be damaged, and no actions are taken to prevent its occurrence;
- Strategy according to the amount of work performed: Preventive Maintenance (PvM)—the essence of this strategy is taking actions—maintenance and repairs, the aim of which is to prevent failure. They are planned based on the maintenance cycle, which is their sequence, and moreover, they are carried out every fixed period of time, or activities are planned based on other units, for example, the number of kilometers traveled or the number of vehicle operating hours;
- Strategy according to the technical condition: Predictive Maintenance (PM), which uses methods and techniques for technical condition testing.

In addition to the exploitation strategy, so-called exploitation policies are implemented. Selected exploitation policies are discussed in the next section of the article.

3.2. Saving Energy and Media as a Pro-Environmental Task in Maintenance of Public Transport Buses (Including Measures/Indicators/Models/Methods of Supporting This Task)

The growing pressure of societies feeling the effects of negative phenomena in the environment forces entrepreneurs providing transport services to take actions aimed at reducing energy and utilities in transport systems. In an industrial enterprise, there is a need to implement and operate the following systems [78,79];

- Energy consumption control system needed for machines (including vehicles) to function;
- Heating system;
- Ventilation system;
- Air conditioning system;
- Hot water system;
- Lighting system for individual parts of the plant.

Energy and media savings related to the operation of these systems will be possible if the enterprise takes technical, organizational, pro-environmental and social actions. Their examples are presented in the following publications [78–83]. These activities include operational policies, including [84]:

- "Green" Maintenance (GM);
- Sustainable Maintenance (SM).

According to Jasiulewicz-Kaczmarek [85], Green Maintenance should be understood as a set of all technical, administrative and management tasks during the life cycle of a technical measure aimed at maintaining or restoring it to a condition in which it can perform the required function in an environmentally friendly manner. The practical implementation of the Green Maintenance concept in an enterprise is determined by the presence of many factors, both internal (e.g., decision criteria when purchasing new machines or modernizing existing ones, maintenance strategy, method of planning maintenance works, repair technologies and materials used, competences and awareness) and external (e.g., design features of machines and devices) [85]. A quantitative approach to the evaluation of this policy is presented in [86]; the possibilities of using the system dynamics method for modeling and simulation of traffic maintenance are shown. Particular attention was paid to all main and effective criteria and indicators, including the maintenance ecological index and system behavior studies. The paper in [87] presents the possibilities of using artificial intelligence and machine learning methods in operation management based on the Green Maintenance policy.

The purpose of implementing the Sustainable Maintenance strategy, according to [84], is, in addition to achieving environmental benefits (exploitation facilities should be operated in a rational manner, taking into account the rational use of natural resources and reducing the impact on the natural environment (electricity consumption, emissions, waste)), to achieve certain social benefits (ensuring a proper working environment, the health and safety of employees and their satisfaction). Selected aspects of the discussed policy are presented in [88,89]. In [89], the concept of managing the operation of technical means in accordance with Sustainable Maintenance was presented based on selected measures and assigned to individual levels of enterprise management: strategic, tactical and operational. In [88], a model of periodic preventive maintenance is shown, which allows obtaining the optimal task period (maintenance or repair) for each element of the system, which allows for minimizing conventional, environmental, and social costs that are the result of maintenance and repair work. This model implements the concept of a circular economy.

A special approach to the activity of maintenance that can be implemented in an enterprise is the strategy of servicing and repairing energy-based technical means (Energy-Based Maintenance, EBM). It is proactive and focuses on optimizing energy efficiency and minimizing the consumption of resources, including energy and utilities. It involves monitoring, analyzing and optimizing the energy consumption of a technical system to increase overall efficiency and reduce costs. If energy conservation and sustainable practices are prioritized, organizations can not only extend the life of their equipment but also contribute to environmental sustainability [83]. According to [87,90], this strategy assumes that exceeding energy consumption or its losses is the first criterion at the stage of determining specific needs in the implementation of maintenance and repair tasks.

A quantitative approach to the problem of efficiency in maintenance is Key Performance Indicators (KPIs). In the EN 15341 standard, they are divided into three types: technical, organizational, and economic, and they are assigned to three levels in the organizational structure of the organization [91]. They can be used in assessing the effectiveness of technical means in maintaining operation, including the consumption of energy and utilities in this activity of the enterprise. The topics of their use in the area, which are discussed in this paper, are presented in [91–94].

A quantitative approach to an Energy-Based Maintenance strategy can provide an Energy Efficiency Indicator (EEI) and a mathematical formula that can be used to calculate its value at the level of the technical system and its components. It was first proposed by Hoang [95]. This item also includes the REEL (Remaining Efficiency—Efficient Lifetime) indicator. It provides information regarding the effective life of a technical measure before its effectiveness drops below an acceptable level at the level of the technical system or its component [90]. Another quantitative approach to energy efficiency assessment measures was proposed in [96]. A method based on failure data and status information from both the technical facility and discrete event simulations based on digital twins is shown. An algorithm for solving the problem, in which a mathematical model was implemented, was shown.

4. Selected Possibilities of Solutions in the Field of Energy and Media Savings in a Public Transport Company (Concept of the Use of CMMS, Strategy According to the Technical Condition—Using Appropriate Algorithms for Examining the Technical Condition of the Bus, KPIs, Industry 4.0, Smart City)

4.1. Strategy According to the Technical Condition of Public Transport Buses

In order to gain their competitiveness, industrial enterprises are currently trying to implement solutions consistent with the philosophy of Industry 4.0 and Smart City. These philosophies assume that an enterprise needs to collect and process more data. Therefore, there are means and ways to achieve this goal. Based on the literature research and knowledge about the current state of the environment in which humans live, it can be concluded that such enterprises will need to implement solutions consistent with the Green Manufacturing and Sustainable Maintenance policies. At the same time, a predictive maintenance strategy, which assumes that it is necessary to use prognostic methods to determine when a technical mean becomes unusable and when repairs should be carried out (determining the repair date should also take into account the availability of resources—materials and humans), is being implemented increasingly often. In transport companies, examples of pro-environmental activities include those that focus on appropriate media management (including diesel and engine oil). The consumption values of these media are the basis not only for planning repairs, but also for minimizing their quantity and limiting their impact on the natural environment.

In media management, the “full tank” method is used to determine fuel consumption. It involves assessing the technical condition based on the amount of propellant and engine fuel used, determined on the basis of the amount of fuel added to the tank. The trend in fuel consumption is determined approximately based on the observation of individual oil consumption values included in the summary generated for a selected period of time (e.g., annual, containing monthly consumption values).

The limitations of this approach to testing the technical condition include a high probability of obtaining an imprecise date when a technical measure becomes unusable, which may result in a vehicle failure, resulting in the costs of its operation and downtime. In addition, there will be a possibility of large fuel losses, which will result from the need to provide a (fueled) reserve vehicle that will perform the transport task instead of a vehicle with a damaged engine and as a result of the imprecise indication of the repair date. The repair date should be the result of an analysis of the technical condition, taking into account symptoms such as fuel and oil consumption but also others—e.g., vibrations, noise, temperature.

All this makes it advisable to develop a mathematical simulation-decision-making model for assessing the impact of the technical condition on the measures of vehicle operation efficiency, which should take into account the consumption of operating media and their impact on the natural environment. The current and future technical condition of the vehicle, identified on the basis of the detection of the diagnostic symptom trend conducted using the “series test” method, Spearman’s rank correlation, the ARI type model or other methods, will also be influenced by the time interval between subsequent measurements of the diagnostic symptom value and the length of the detection time window. Therefore, these values should constitute input data in the proposed model, as shown in Figure 1. Figure 1 shows a time series of diagnostic symptom values. These values will be influenced by the organizational solutions adopted in maintenance (e.g., an appropriately frequent inspection of the technical means). However, the values constituting the outputs of the proposed model and enabling the assessment of the benefits and negative impact of technical and organizational solutions in vehicle maintenance on the efficiency of their operation include KPI indicators and vehicle reliability measures. The developed simulation-decision-making model is shown in Figure 2, and its components are characterized in the following parts of the article. A component of this model is the technical condition prognosis chart, shown in Figure 1.

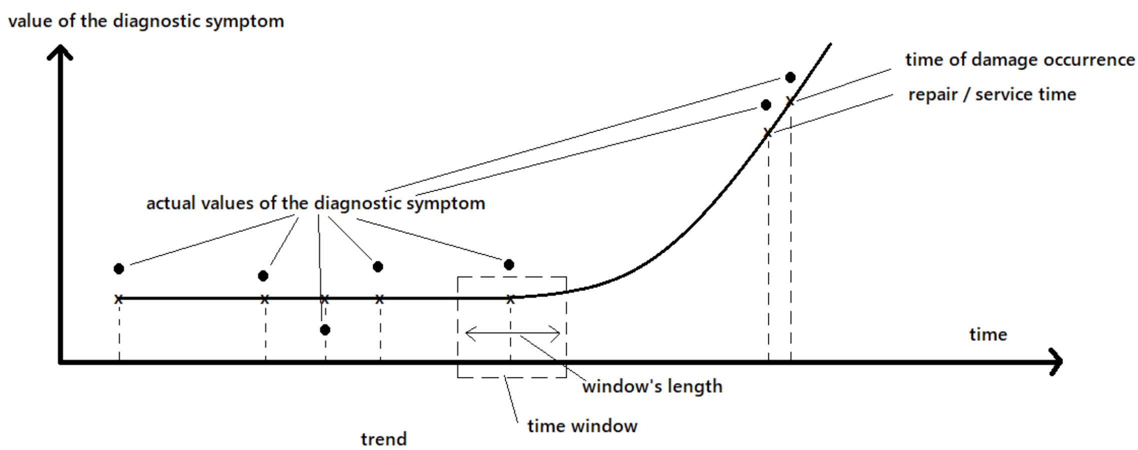

Figure 1. Time series of diagnostic symptom values [authors' own work].

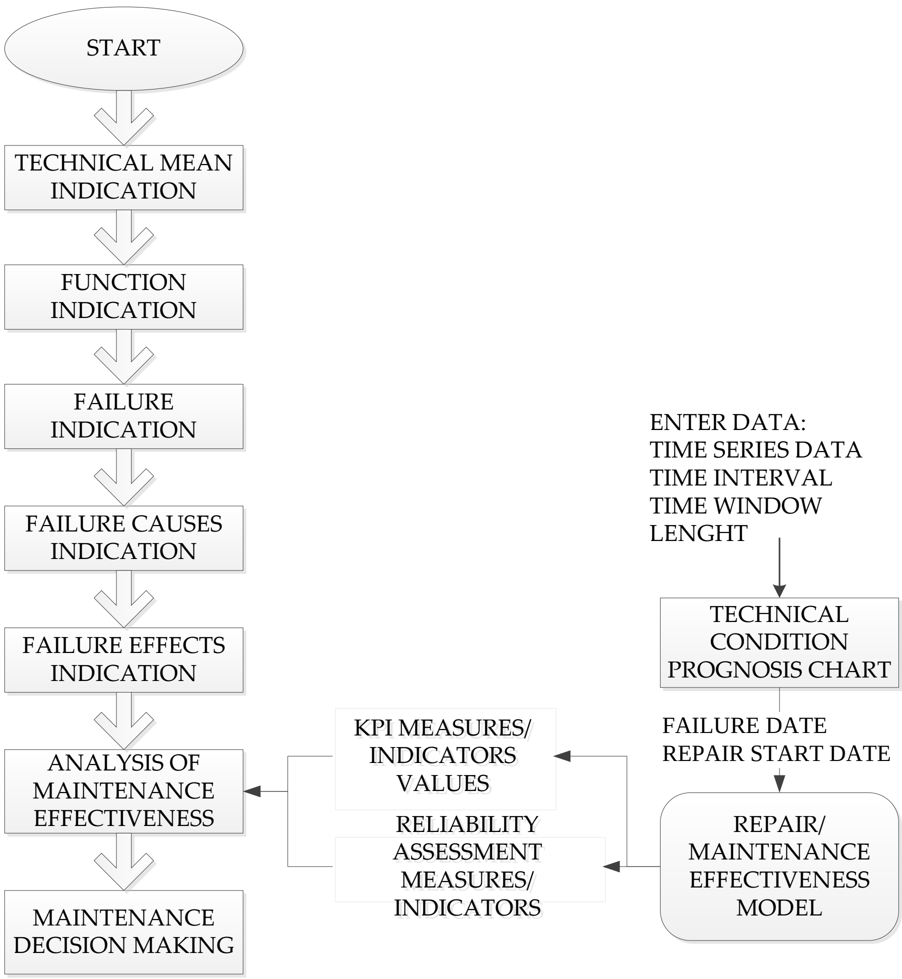

Figure 2. The concept of a simulation-decision-making model for assessing the predicted maintenance strategy [authors' own work].

4.2. Key Service Effectiveness Indicators in the Assessment of Pro-Environmental Activities in the Operation and Maintenance of Technical Systems

The implementation of the concept presented in Section 4.1 assumes the need to develop a set of measures/indicators for the purpose of assessing the effectiveness of various solutions in the field of monitoring and predicting the technical condition of technical systems. Therefore, it is possible to propose existing KPIs (standard EN 15341, they must be pro-environmental) and/or create new ones. The indicators should include the information about the following;

- The number of failures of the exploited technical system, constituting a threat to the natural environment (it is possible to create such indicators, but taking into account various threats to the environment, various causes, effects and consequences of the failures that occurred);
- The amount of expenditure on pro-environmental technical, organizational or other solutions, e.g., expenditure resulting from the need to increase the frequency of diagnostic measurements in order to carry out monitoring or predicting tasks that were the subject of considerations in point 4.1 or expenditure on the purchase of equipment and/or software necessary in order to carry out these tasks;
- Other quantities. The examples of the discussed indicators include the following;
- The indicator of the share of occurring failures in the number of potential failures, presented in (1).

$$W1 = \frac{LA}{LP} \tag{1}$$

where LA—number of exhaust system failures that occurred in the operation of the mean of transportation, LP—the number of potential exhaust system failures that may occur in the operation of the mean of transportation,

- The indicator of the share of expenditure on technology in the number of failures that occurred which is presented in (2):

$$W2 = \frac{KT}{LA} \tag{2}$$

where KT—expenditure on technical means to prevent failures from occurring.

4.3. Reliability as a Way of Assessing the Management of Technical System Operation in the Conditions of Predictive Maintenance

Since the purpose of implementing the sustainable development strategy, according to [10], is to ensure the implementation of functions required by technical measures, taking into account the rational use of natural resources and reducing the impact on the natural environment (electricity consumption, emissions and waste), the method described in Section 4.1 and 4.2 should take into account various functions performed by the technical means. Therefore, the model, the details of which will be described in Sections 4.1 and 4.2 and supporting the assessment of the effects of implementing selected actions, should include a method (model) consistent with the philosophy of operating technical means focused on operational reliability (Reliability-Centered Maintenance—RCM). This method is not used when it is intended to ensure the complete reliability of a technical measure, but only when it is necessary to achieve its reliability as required to perform the function for which the measure is used in given conditions [97,98].

The method of making operational decisions in the conditions of implementing the philosophy of operational maintenance of technical means focused on operational reliability is described in the SAE JA-1011 Evaluation Criteria for Reliability—Centered Maintenance (RCM) Processes standard by the International Society of Automotive Engineers in 1998 [97]. It is based on the following seven questions about:

1. Asset functions: what are the functions and associated performance requirements and standards for the asset in the current operational context?
2. Functional errors—failure: how can a resource lose the ability to perform expected functions?
3. Causes of failure: what causes failure?
4. Effects of failure: what happens when a given failure occurs?
5. Consequences of failure: what is the consequence of failure?
6. Proactive actions: what actions should be taken to predict failure or protect against its occurrence?

7. Other standard actions—what should be done when no proactive action can be selected?

These questions were implemented in the model in Figure 2.

The use of the RCM model using the above-mentioned questions will allow for:

- Assessment of the effects of adopting specific functions that the technical measure performs (on the basis of analyzes of reliability indicators and KPIs).
- Assessment of the effects of adopting other values of the quantities appearing in the proposed model.
- Simulation based on a complex model, the components of which are the solutions described in Section 4.1–4.3, allows the adoption of the most rational scenario consistent with the predictive maintenance strategy under the Sustainable Maintenance policy.
- Optimization of energy consumption and, based on it, decisions on servicing or repair (completion deadlines, resources), which is consistent with the Energy-Based Maintenance policy.

4.4. Social Aspects of Energy and Media Management

Pro-ecological activities cause a social uproar, which is why, in addition to technical, economic and environmental criteria, social criteria are increasingly taken into account in a comprehensive assessment of various solutions, especially in technology. Since failure is often associated with failure not only in financial terms but also poses a threat to the well-being or safety of humans—the user or operator of technical means, as well as a threat to the proper functioning of the natural environment—it is necessary to conduct an appropriate analysis. This also applies to energy and media management in technical transport systems. An opportunity to conduct analyses in the above-mentioned area is the implementation of the concept of social assessment of technology, which assumes the use of methods for assessing the opinions of users of technical means in order to determine the impact of the process of meeting needs on humans and the environment in which they live. Therefore, it is necessary to make a social assessment of the impact of a technical measure, including its structure and principle of operation, design, operational, condition and ergonomic features, operational events (defects, failures, disasters), processes and operation systems, on the ecosphere. The social assessment of the pro-environmental operational policy under the conditions of implementing the projected maintenance strategy should refer to the results of the analyses described in points 4.2 and 4.3 and should be carried out based on a set of original measures/indicators of the social assessment of the technology, which will be used in calculations based on the data. obtained from surveys completed by operators of transport technical systems. Surveys in the study should include sets of questions to solve, among others, the following problems;

- Purchase of electric/hybrid buses—drivers, passengers and those operating these technical means as well as their passengers should be asked about the safety of their use;
- The need to reduce fuel consumption of a bus with an internal combustion engine—the above-mentioned people and the management board of the public transport company should be asked about the validity of implementing eco-driving in the company;
- The need to reduce the harmful impact of a failure on people and their environment—the above-mentioned people should be asked about ways to reduce media leaks from vehicles.

An example of an indicator of social evaluation of pro-environmental activities may be the W_i measure, calculated using the formula [99], presented in (3):

$$W_i = \sum_{j=0}^{n} \left(P_{ij} \times K_{ij} \right) \tag{3}$$

where P_{ij}—probability of occurrence of i-th answer (to i-th question in the survey) for j-th rating, K_{ij}—j-th rating (from 1 to 5, where 1—the lowest rating of the i-th answer, 5—the highest rating of the i-th answer).

The probability of the i-th answer (to the i-th question in the survey) for the j-th rating can be calculated using the formula [99], presented in (4):

$$P_{ij} = \frac{n_{ij}}{N} \tag{4}$$

where n_{ij}—number of people completing the survey, answering the i-th question by selecting the j-th rating, N—number of all people answering questions using surveys.

4.5. Artificial Intelligence and CMMS

The implementation of the Industry 4.0 concept, which assumes the collection of large amounts of data needed to calculate the above-described measures and make pro-environmental decisions, according to [99], requires database systems in which data on technical measures and unintended events that occur during their operation will be collected (faults, breakdowns, disasters), repairs and services, as well as the resources needed for their implementation. For this purpose, CMMS systems are used to support the implementation of operational tasks, as well as tasks aimed at maintaining or restoring the operational suitability of technical means [100]. These tasks will result from the implementation of the adopted exploitation strategies under the conditions of selected exploitation policies. Therefore, it is necessary to undertake research on the use of systems of this class under the conditions of Green Maintenance, Sustainable Maintenance and Energy-Based Maintenance policies. This solution, preceded by the methods and tools proposed in the article, will allow for a more thorough analysis of the causes, effects and consequences (including those related to the threat to the natural environment) of failures of machines and devices, including means of transport, and will also allow for the determination of optimal levels of consumption of operating media and energy.

Having a large amount of data on the operation and maintenance of technical resources collected in database systems (CMMS, ERP, etc.) does not guarantee effective decision-making on the selection of an operation strategy, carrying out service and repair works, or selecting the appropriate resources necessary for their implementation. For this purpose, knowledge is needed, which is increasingly available in enterprises thanks to the use of artificial intelligence and machine learning.

This knowledge can be represented by a set of rules, where the rule is represented using the following notation:

IF PREMISE THEN CONCLUSION

In support using the proposed model—Figures 1 and 2, artificial intelligence can be used to select the operation and repair task and its start time, based on data on the values of indicators obtained from calculations or simulations conducted using the model proposed in the article.

4.6. Summary of the Research

Table 1 includes a summary of the literature and conceptual parts of the article. The reference numbers and the advantages and disadvantages of each part of the article are also described.

Table 1. Advantages and disadvantages of the presented research.

Literature Review Part		
Scope of Literature Study	**Number of References**	**Advantages and Disadvantages of the Presented Research**
Technological solutions	[1–23]	The strength of the presented research is a thorough comparison of various types of internal combustion engines used in vehicles by indicating their characteristic features (advantages and disadvantages), in particular their relation to the natural environment and their assessment.###Due to insufficient knowledge, it is necessary to continue research on technical solutions to the presented problems of engines, emerging at the stages of their design, construction, production and operation, improving their functioning, in particular new solutions (electric, hybrid, hydrogen drive). However, there is a lack of knowledge about the impact of maintenance and repair activities, in particular those involving the diagnosis and forecasting of technical measures, on the consumption of energy and media.
Economic and organizational solutions	[24–51]	The conducted research drew attention to existing economic and organizational problems related to the operation of vehicles with various power sources. The large number of solutions to problems is noteworthy. However, there is a lack of recommendations for transport companies to improve the functioning of their organizations, especially when vehicles with different types of drives are used. There is a lack of knowledge in this area about good practices in the management of vehicle operation, but also about other technical measures of the used transport infrastructure, aimed at reducing energy and media consumption and implemented through the use of proactive maintenance strategies. Literature research shows little knowledge about the Energy-Based Maintenance policy and its application in vehicle operation.
Social solutions	[52–75]	In the provided literature, the relationship between man and technical means are discussed. Attention was paid to the problem of social awareness in the field of environmental protection. The topics of the articles concern current problems, including those related to the implementation of measures and methods in the smart city areas. There is a lack of knowledge about methods for identifying and assessing human needs and the use of knowledge about their occurrence in the process: description of needs—design and construction of technical means. Therefore, it is necessary to study public opinions on technical measures as part of the Technology Assessment philosophy.
Exploitation strategy	[76–96]	The strength of the article is the topic of meeting social needs in the field of environmental protection through comprehensive (technical, economic, environmental and social) solutions for the use of technical means in operation, which will aim to its improvement. However, there is still insufficient knowledge about methods, models supporting the management of the operation of technical means and computer-aided tools in which they are implemented.
Conceptual part of the paper		
Necessary for the developed concept	[97–100]	Described in the conclusions in the article.

5. Potential Results of Executed Research on the Proposed Model

Several factors will influence the result (positive result from the point of view of environmental protection) of the analysis conducted using the proposed simulation model. These factors include;

- Factors resulting from the proposed RCM method: functions performed by the technical means in use (each function represents specific operating conditions; in the case of vehicles, it may be: driving in urban traffic conditions, air temperature, air humidity, slippery surface, etc.), failure resulting from the implementation of these functions, their causes, effects and consequences;

- Effectiveness of operating technical means, expressed through KPIs and reliability measures/indicators. In the case of indicators W1 and W2, referred to in Section 4.2, too many failures may be the result of internal or external causes of failures (the second mentioned includes causes of failures resulting from the fault of the user or the maintainer of the technical means. At the same time, an increase in expenditure on technical solutions (W2 indicator) may reduce the vehicle's failure rate and therefore reduce the amount of fuel consumed.

An example of the effects of the potential analysis can include the following: extreme operating conditions of the vehicle's internal combustion engine may cause frequent failure, requiring frequent diagnostic inspections, which will result in early detection of a sharp increase in fuel consumption and provide more time to prepare for repairs, and, consequently, less fuel is consumed than in the case where a sudden increase in its quantity is noticed too late and there is little time to prepare for repairs.

6. Conclusions

6.1. General Summary

Road transport has a noticeable impact on the environment. Based on the literature review, environmental problems can be observed across the following spheres: technological, economic, organizational, and social. In the technological sphere, issues stem from using internal combustion engines and fossil fuels, leading to air pollution and greenhouse gas emissions. In the economic and organizational sphere, challenges include the high cost of implementing clean technologies and building the necessary infrastructure, for example, for charging electric and hydrogen-powered vehicles. In the social sphere, challenges include low environmental awareness and a reluctance to change behavior. In every sphere, there are solutions or at least actions that can be taken to limit the impact of road transport emissions on the environment and, consequently, on people's health and lives.

The ongoing degradation of the natural environment requires action in many areas, including industry. Changes aimed at achieving this goal should be carried out in individual areas of the company's operations. This also applies to maintenance. The acceptance by the management of the exploitation strategy that will be implemented is very important. Adopting a rational, pro-environmental maintenance policy will allow for energy and utility savings in technical transport systems. This can be done because of the proposed methods and techniques described in the article.

6.2. Limitations of the Model

Unfortunately, the proposed solutions allow for the assessment of the impact of the operation strategy only within a selected scope, focusing on the predictive maintenance strategy, which is, however, included among the technical measures increasingly commonly used in operation. The development of the method should take into account aspects of new exploitation strategies, primarily Energy-Based Maintenance. Prioritizing energy savings and sustainable development practices will ensure sustainability in transport operations. In the presented approach, it was proposed to use only selected methods of trend detection and prediction of the state of technical means. Therefore, it is expected to expand the scope of their use to include new methods, including those in the area of AI. The proposed test method includes the possibility of its use to the extent that only selected diagnostic symptoms of the technical condition of vehicles are taken into account. Extending the scope of these symptoms will require the use of multi-criteria optimization methods to rationalize media and energy consumption.

Fuel consumption will be influenced by unfavorable impacts on the technical measure (road conditions) occurring in the various geographical locations. Hence, it becomes justified to include the aspect of space in the proposed model in the future. Solutions in this area include methods/tools for collecting and processing spatial data, including GIS (Geographic Information Systems) models and spatial econometric methods. Taking into account the dynamic nature of media/energy consumption processes, the use of these methods are justified.

When proposing the research method, only vehicles powered by an internal combustion engine were taken into account. In order to make the proposed method modern, it should also be possible to use it for the purpose of assessing the media/energy consumption of other types of drives (electric, hybrid, hydrogen).

6.3. Recommendations for Model Implementation

In the opinion of the authors of the article, efforts should be made to ensure that the proposed method concept has a universal character. Using it, it is possible to assess the technical condition of the vehicle, indicate the date of vehicle repair, optimize energy and utility consumption, but also there should be a possibility to plan the resources needed to carry out vehicle repairs and achieve other goals.

The innovative nature of the proposed solution—a complex model supporting simulation, optimization and decision-making—is given by proposing its supplementation with a social aspect, involving drivers, vehicle passengers and their workers of transport companies in the assessment of the fuel/energy consumption of these technical measures. The implementation of these tasks will require linking the results of using the method of social assessment of energy and media consumption with the results of technical assessment. This will be possible due to the use of artificial intelligence methods. This will be the subject of further research on the operation and maintenance of technical means, with particular emphasis on urban transport.

It is expected that the implementation of the developed concept should include the following stages;

- Indication of the technical measure that will be the subject of the analysis;
- Indication of the functions it performs;
- Indication of failures that occurred during its operation, their causes, effects and consequences;
- Selecting models for assessing individual generalized maintenance strategies—KPIs, Reliability Measures (Breakdown Maintenance, Preventive Maintenance, particularly Predictive Maintenance) and calculating the parameter values of their characteristics;
- Indication of tasks to be performed and their implementation deadlines, taking into account the amount of (optimal) energy and utility consumption.

Assessment of the Predictive Maintenance strategy will require identification of the model based on historical data on the values of KPI measures, reliability measures (the model's outputs), time intervals between subsequent diagnostic tests and the length of time windows of the reliability parameter trend detection method (the model's inputs).

Author Contributions: Conceptualization, A.W.; methodology, A.W. and K.S.; software, A.W. and K.S.; validation, A.W., K.S. and W.W.G.; formal analysis, A.W. and K.S.; investigation, A.W. and K.S.; resources, A.W. and K.S.; data curation, A.W. and K.S.; writing—original draft preparation, K.S.; writing—review and editing, K.S.; visualization, A.W. and K.S.; supervision, A.W., K.S. and W.W.G.; project administration, A.W. and K.S.; funding acquisition, A.W. and K.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interests. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Grimaldi, C.N.; Millo, F. Internal Combustion Engine (ICE) Fundamentals. In *Handbook of Clean Energy Systems*; John Wiley & Sons Limited: Hoboken, NJ, USA, 2015; Volume 2, pp. 907–938. ISBN 1118388585.
2. MotoMagazyn Rodzaje Silników Samochodowych: Od Benzyny do Elektryczności. Available online: https://motomagazyn.pl/rodzaje-silnikow-samochodowych/ (accessed on 19 February 2024).

3. Agocs, A.; Budnyk, S.; Frauscher, M.; Ronai, B.; Besser, C.; Dörr, N. Comparing Oil Condition in Diesel and Gasoline Engines. *Ind. Lubr. Tribol.* **2020**, *72*, 1033–1039. [CrossRef]
4. Hooftman, N.; Oliveira, L.; Messagie, M.; Coosemans, T.; Van Mierlo, J. Environmental Analysis of Petrol, Diesel and Electric Passenger Cars in a Belgian Urban Setting. *Energies* **2016**, *9*, 84. [CrossRef]
5. Cunanan, C.; Tran, M.-K.; Lee, Y.; Kwok, S.; Leung, V.; Fowler, M. A Review of Heavy-Duty Vehicle Powertrain Technologies: Diesel Engine Vehicles, Battery Electric Vehicles, and Hydrogen Fuel Cell Electric Vehicles. *Clean Technol.* **2021**, *3*, 474–489. [CrossRef]
6. Stecuła, K.; Tutak, M. Causes and Effects of Low-Stack Emission in Selected Regions of Poland. In Proceedings of the International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, Albena, Bulgaria, 2–8 July 2018; Volume 18, pp. 357–364.
7. Leach, F.; Kalghatgi, G.; Stone, R.; Miles, P. The Scope for Improving the Efficiency and Environmental Impact of Internal Combustion Engines. *Transp. Eng.* **2020**, *1*, 100005. [CrossRef]
8. Ogunkunle, O.; Ahmed, N.A. Overview of Biodiesel Combustion in Mitigating the Adverse Impacts of Engine Emissions on the Sustainable Human–Environment Scenario. *Sustainability* **2021**, *13*, 5465. [CrossRef]
9. Knothe, G.; Razon, L.F. Biodiesel Fuels. *Prog. Energy Combust. Sci.* **2017**, *58*, 36–59. [CrossRef]
10. Appavu, P.; Jayaraman, J.; Venu, H. NO_x emission reduction techniques in biodiesel-fuelled CI engine: A review. *Aust. J. Mech. Eng.* **2019**, *19*, 210–220.
11. Kumar, N. Oxidative Stability of Biodiesel: Causes, Effects and Prevention. *Fuel* **2017**, *190*, 328–350. [CrossRef]
12. Cox, B.; Mutel, C.L.; Bauer, C.; Mendoza Beltran, A.; van Vuuren, D.P. Uncertain Environmental Footprint of Current and Future Battery Electric Vehicles. *Environ. Sci. Technol.* **2018**, *52*, 4989–4995. [CrossRef]
13. Markowska, K.; Sękala, A.; Stecuła, K.; Kawka, T.; Sirovitskiy, K.; Pankova, O.; Vnukova, N.; Shulyak, M.; Kharchenko, S.; Shchur, T. Comparison of the Sustainability and Economic Efficiency of an Electric Car and an Aircraft—A Case Study. *Sustainability* **2023**, *15*, 1238. [CrossRef]
14. Thomas, C.E.S. How Green Are Electric Vehicles? *Int. J. Hydrogen Energy* **2012**, *37*, 6053–6062. [CrossRef]
15. Tabuchi, H.; Plumer, B. How Green Are Electric Vehicles. *New York Times*, 2 March 2021.
16. Misdariis, N.; Gruson, A.; Susini, P. Detectability Study of Warning Signals in Urban Background Noises: A First Step for Designing the Sound of Electric Vehicles. *Proc. Meet. Acoust.* **2013**, *19*, 040032.
17. Parizet, E.; Robart, R.; Ellermeier, W.; Janssens, K.; Biancardi, F.; Haider, M.; Quinn, D.; Chamard, J.-C. Warning Sounds for Electric Vehicles. In Proceedings of the Fisita World Automotive Congress 2014, Maastricht, The Netherlands, 2–6 June 2014; p. 1.
18. Staffell, I.; Scamman, D.; Abad, A.V.; Balcombe, P.; Dodds, P.E.; Ekins, P.; Shah, N.; Ward, K.R. The Role of Hydrogen and Fuel Cells in the Global Energy System. *Energy Environ. Sci.* **2019**, *12*, 463–491. [CrossRef]
19. Hosseini, S.E.; Butler, B. An Overview of Development and Challenges in Hydrogen Powered Vehicles. *Int. J. Green Energy* **2020**, *17*, 13–37. [CrossRef]
20. Greene, D.L.; Ogden, J.M.; Lin, Z. Challenges in the Designing, Planning and Deployment of Hydrogen Refueling Infrastructure for Fuel Cell Electric Vehicles. *eTransportation* **2020**, *6*, 100086. [CrossRef]
21. Cai, H.; Burnham, A.; Chen, R.; Wang, M. Wells to Wheels: Environmental Implications of Natural Gas as a Transportation Fuel. *Energy Policy* **2017**, *109*, 565–578. [CrossRef]
22. Shin, J.; Hwang, W.-S.; Choi, H. Can Hydrogen Fuel Vehicles Be a Sustainable Alternative on Vehicle Market?: Comparison of Electric and Hydrogen Fuel Cell Vehicles. *Technol. Forecast. Soc. Chang.* **2019**, *143*, 239–248. [CrossRef]
23. Gronowicz, J. *Ochrona Środowiska w Transporcie Lądowym*; Instytut Technologii Eksploatacji: Radom, Poland, 2003; ISBN 8372043132.
24. Funke, S.Á.; Sprei, F.; Gnann, T.; Plötz, P. How Much Charging Infrastructure Do Electric Vehicles Need? A Review of the Evidence and International Comparison. *Transp. Res. Part D Transp. Environ.* **2019**, *77*, 224–242. [CrossRef]
25. Kumar, R.R.; Chakraborty, A.; Mandal, P. Promoting Electric Vehicle Adoption: Who Should Invest in Charging Infrastructure? *Transp. Res. Part E Logist. Transp. Rev.* **2021**, *149*, 102295. [CrossRef]
26. Greene, D.L.; Kontou, E.; Borlaug, B.; Brooker, A.; Muratori, M. Public Charging Infrastructure for Plug-in Electric Vehicles: What Is It Worth? *Transp. Res. Part D Transp. Environ.* **2020**, *78*, 102182. [CrossRef]
27. Li, Y.; Kool, C.; Engelen, P.-J. Analyzing the Business Case for Hydrogen-Fuel Infrastructure Investments with Endogenous Demand in the Netherlands: A Real Options Approach. *Sustainability* **2020**, *12*, 5424. [CrossRef]
28. Moreno-Benito, M.; Agnolucci, P.; Papageorgiou, L.G. Towards a Sustainable Hydrogen Economy: Optimisation-Based Framework for Hydrogen Infrastructure Development. *Comput. Chem. Eng.* **2017**, *102*, 110–127. [CrossRef]
29. Apostolou, D.; Xydis, G. A Literature Review on Hydrogen Refuelling Stations and Infrastructure. Current Status and Future Prospects. *Renew. Sustain. Energy Rev.* **2019**, *113*, 109292. [CrossRef]
30. Stecuła, K.; Olczak, P.; Kamiński, P.; Matuszewska, D.; Duong Duc, H. Towards Sustainable Transport: Techno-Economic Analysis of Investing in Hydrogen Buses in Public Transport in the Selected City of Poland. *Energies* **2022**, *15*, 9456. [CrossRef]
31. Moghaddam, Z.; Ahmad, I.; Habibi, D.; Phung, Q.V. Smart Charging Strategy for Electric Vehicle Charging Stations. *IEEE Trans. Transp. Electrif.* **2017**, *4*, 76–88. [CrossRef]
32. Daina, N.; Sivakumar, A.; Polak, J.W. Electric Vehicle Charging Choices: Modelling and Implications for Smart Charging Services. *Transp. Res. Part C Emerg. Technol.* **2017**, *81*, 36–56. [CrossRef]

33. Collin, R.; Miao, Y.; Yokochi, A.; Enjeti, P.; Von Jouanne, A. Advanced Electric Vehicle Fast-Charging Technologies. *Energies* **2019**, *12*, 1839. [CrossRef]
34. Tu, H.; Feng, H.; Srdic, S.; Lukic, S. Extreme Fast Charging of Electric Vehicles: A Technology Overview. *IEEE Trans. Transp. Electrif.* **2019**, *5*, 861–878. [CrossRef]
35. Colmenar-Santos, A.; Muñoz-Gómez, A.-M.; Rosales-Asensio, E.; López-Rey, Á. Electric Vehicle Charging Strategy to Support Renewable Energy Sources in Europe 2050 Low-Carbon Scenario. *Energy* **2019**, *183*, 61–74. [CrossRef]
36. Sribna, Y.; Koval, V.; Olczak, P.; Bizonych, D.; Matuszewska, D.; Shtyrov, O. Forecasting Solar Generation in Energy Systems to Accelerate the Implementation of Sustainable Economic Development. *Polityka Energ. Energy Policy J.* **2021**, *24*, 5–28. [CrossRef]
37. Moran, E.F.; Lopez, M.C.; Moore, N.; Müller, N.; Hyndman, D.W. Sustainable Hydropower in the 21st Century. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 11891–11898. [CrossRef]
38. Bhattacharjee, S. Wind Power Technology. In *Sustainable Fuel Technologies Handbook*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 123–170.
39. Tie, S.F.; Tan, C.W. A Review of Energy Sources and Energy Management System in Electric Vehicles. *Renew. Sustain. Energy Rev.* **2013**, *20*, 82–102. [CrossRef]
40. Tan, Z.; Wu, Y.; Gu, Y.; Liu, T.; Wang, W.; Liu, X. An Overview on Implementation of Environmental Tax and Related Economic Instruments in Typical Countries. *J. Clean. Prod.* **2022**, *330*, 129688. [CrossRef]
41. Rhodes, E.; Scott, W.A.; Jaccard, M. Designing Flexible Regulations to Mitigate Climate Change: A Cross-Country Comparative Policy Analysis. *Energy Policy* **2021**, *156*, 112419. [CrossRef]
42. Flixbus 0 Emission Travel? *Sure, Just Take the FlixBus and FlixTrain!* Available online: https://www.flixbus.pl/firma/srodowisko (accessed on 20 February 2024).
43. Wolniak, R. European Union Smart Mobility–Aspects Connected with Bike Road System's Extension and Dissemination. *Smart Cities* **2023**, *6*, 1009–1042. [CrossRef]
44. Wolniak, R. Smart Biking W Smart Sity. *Manag. Qual. Jakość* **2023**, *5*, 313.
45. Wolniak, R.; Grebski, W. Smart Biking and Traditional Biking. *Silesian Univ. Technol. Sci. Pap. Organ. Manag. Ser.* **2023**, *178*, 717–734. [CrossRef]
46. Espitia, A.; Mattoo, A.; Rocha, N.; Ruta, M.; Winkler, D. Pandemic Trade: COVID-19, Remote Work and Global Value Chains. *World Econ.* **2022**, *45*, 561–589. [CrossRef] [PubMed]
47. Gupta, A. Accelerating Remote Work after COVID-19. *Cent. Growth Oppor.* **2022**, *1*, 1–2.
48. Stecuła, K.; Wolniak, R. Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 159. [CrossRef]
49. Curelaru, M.; Curelaru, V.; Cristea, M. Students' Perceptions of Online Learning during COVID-19 Pandemic: A Qualitative Approach. *Sustainability* **2022**, *14*, 8138. [CrossRef]
50. Ye, Y.; Wang, J. Study of Logistics Network Optimization Model Considering Carbon Emissions. *Int. J. Syst. Assur. Eng. Manag.* **2017**, *8*, 1102–1108. [CrossRef]
51. Jiang, J.; Zhang, D.; Meng, Q.; Liu, Y. Regional Multimodal Logistics Network Design Considering Demand Uncertainty and CO2 Emission Reduction Target: A System-Optimization Approach. *J. Clean. Prod.* **2020**, *248*, 119304. [CrossRef]
52. Ramírez, A.S.; Ramondt, S.; Van Bogart, K.; Perez-Zuniga, R. Public Awareness of Air Pollution and Health Threats: Challenges and Opportunities for Communication Strategies to Improve Environmental Health Literacy. *J. Health Commun.* **2019**, *24*, 75–83. [CrossRef] [PubMed]
53. Ajaps, S.; McLellan, R. "We Don't Know Enough": Environmental Education and pro-Environmental Behaviour Perceptions. *Cogent Educ.* **2015**, *2*, 1124490. [CrossRef]
54. Moyal, A.; Schurr, A. The Effect of Deliberate Ignorance and Choice Procedure on Pro-Environmental Decisions. *Ecol. Econ.* **2022**, *200*, 107512. [CrossRef]
55. Bamberg, S.; Hunecke, M.; Blöbaum, A. Social Context, Personal Norms and the Use of Public Transportation: Two Field Studies. *J. Environ. Psychol.* **2007**, *27*, 190–203. [CrossRef]
56. Molina, J.A.; Giménez-Nadal, J.I.; Velilla, J. Sustainable Commuting: Results from a Social Approach and International Evidence on Carpooling. *Sustainability* **2020**, *12*, 9587. [CrossRef]
57. Hartl, B.; Kamleitner, B.; Holub, S. Take Me on a Ride: The Role of Environmentalist Identity for Carpooling. *Psychol. Mark.* **2020**, *37*, 663–676. [CrossRef]
58. Hamid, S.; Ijab, M.T.; Sulaiman, H.; Md. Anwar, R.; Norman, A.A. Social Media for Environmental Sustainability Awareness in Higher Education. *Int. J. Sustain. High. Educ.* **2017**, *18*, 474–491. [CrossRef]
59. Al-Mulla, S.; Ari, I.; Koç, M. Social Media for Sustainability Education: Gaining Knowledge and Skills into Actions for Sustainable Living. *Int. J. Sustain. Dev. World Ecol.* **2022**, *29*, 455–471. [CrossRef]
60. Kinelski, G. Smart-City Trends in the Environment of Sustainability as Support for Decarbonization Processes. *Polityka Energ. Energy Policy J.* **2022**, *25*, 109–136. [CrossRef]
61. Toli, A.M.; Murtagh, N. The Concept of Sustainability in Smart City Definitions. *Front. Built Environ.* **2020**, *6*, 77. [CrossRef]
62. Jonek-Kowalska, I.; Wolniak, R. *Smart Cities in Poland: Towards Sustainability and a Better Quality of Life?* Taylor & Francis: Abingdon, UK, 2023; ISBN 1000935396.

63. Tchuitcheu, W.C.; Bobda, C.; Pantho, M.J.H. Internet of Smart-Cameras for Traffic Lights Optimization in Smart Cities. *Internet Things* **2020**, *11*, 100207. [CrossRef]
64. Lu, K.; Liu, J.; Zhou, X.; Han, B. A Review of Big Data Applications in Urban Transit Systems. *IEEE Trans. Intell. Transp. Syst.* **2020**, *22*, 2535–2552. [CrossRef]
65. Chomiak-Orsa, I.; Domagała, P.; Greńczuk, A.; Grzelak, W.; Hauke, K.; Kotwica, A.; Perechuda, K.; Pondel, M. Open Data for Simulation to Determine the Efficient Management of Parking Spaces in Smart City. *Procedia Comput. Sci.* **2022**, *207*, 3625–3634. [CrossRef]
66. Turoń, K.; Kubik, A. Business Innovations in the New Mobility Market during the COVID-19 with the Possibility of Open Business Model Innovation. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 195. [CrossRef]
67. Lazari, V.; Chassiakos, A. Multi-Objective Optimization of Electric Vehicle Charging Station Deployment Using Genetic Algorithms. *Appl. Sci.* **2023**, *13*, 4867. [CrossRef]
68. Naugain, M.; Singh, A.K. Planning for Pedestrian-Friendly Cities. In *Sustainable Infrastructure Development: Select Proceedings of ICSIDIA 2020*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 49–63.
69. Stecuła, K.; Wolniak, R.; Grebski, W.W. AI-Driven Urban Energy Solutions—From Individuals to Society: A Review. *Energies* **2023**, *16*, 7988. [CrossRef]
70. Stecuła, K. Virtual Reality Applications Market Analysis—On the Example of Steam Digital Platform. *Informatics* **2022**, *9*, 100. [CrossRef]
71. Bouloukakis, M.; Partarakis, N.; Drossis, I.; Kalaitzakis, M.; Stephanidis, C. Virtual Reality for Smart City Visualization and Monitoring. In *Mediterranean Cities and Island Communities*; Springer: Cham, Switzerland, 2019; pp. 1–18.
72. Yagol, P.; Ramos, F.; Trilles, S.; Torres-Sospedra, J.; Perales, F.J. New Trends in Using Augmented Reality Apps for Smart City Contexts. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 478. [CrossRef]
73. Guarda, T.; Lopes, I.; Bustos, S.; Ribeiro, I.; Fernandes, A. Augmented Computing and Smart Cities Sustainability. In Proceedings of the International Conference on Computational Science and Its Applications, Athens, Greece, 3–6 July 2023; Springer: Berlin/Heidelberg, Germany, 2023; pp. 123–132.
74. Bibri, S.E.; Jagatheesaperumal, S.K. Harnessing the Potential of the Metaverse and Artificial Intelligence for the Internet of City Things: Cost-Effective XReality and Synergistic AIoT Technologies. *Smart Cities* **2023**, *6*, 2397–2429. [CrossRef]
75. Bibri, S.E. The Metaverse as a Virtual Model of Platform Urbanism: Its Converging AIoT, XReality, Neurotech, and Nanobiotech and Their Applications, Challenges, and Risks. *Smart Cities* **2023**, *6*, 1345–1384. [CrossRef]
76. Kaźmierczak, J. *Eksploatacja Systemów Technicznych*; Wydawnictwo Politechniki Śląskiej w Gliwicach: Gliwice, Poland, 2000.
77. Woropay, M.; Landowski, P. Metoda Wyboru Strategii Eksploatacyjnej Złożonych Obiektów Technicznych. Proceedings of "Diagnostyka '94" Conference titled "Diagnostyka Maszyn Roboczych i Pojazdów", Bydgozcz-Borówno, Poland, 23–25 October 1984.
78. Levitt, J. *The Handbook of Maintenance Management*; Industrial Press Inc.: New York, NY, USA, 2009; ISBN 0831133899.
79. Niebel, B.W. *Engineering Maintenance Management*; CRC Press: Boca Raton, FL, USA, 1994; ISBN 0429081170.
80. Szafrański, B.; Oszczędności Energii i Mediów. Inżynieria Utrzymanie Ruchu. 2010. Available online: https://utrzymanieruchu.pl/oszczednosci-energii-i-mediow/ (accessed on 24 February 2024).
81. Guelker, M.; 8 Sposobów Na Oszczędzanie Energii. Inżynieria Utrzymanie Ruchu. 2016. Available online: https://utrzymanieruchu.pl/8-sposobow-na-oszczedzanie-energii/ (accessed on 24 February 2024).
82. PolskiPrzemysł Oszczędności w Produkcji Dzięki Monitoringowi Zużycia Mediów. Available online: https://polskiprzemysl.com.pl/utrzymanie-ruchu/monitoring-zuzycia-mediow/ (accessed on 24 February 2024).
83. Rely Ability Industrial Sustainability Recording: Energy-based Maintenance—Simple Measures for Serious Savings. Available online: https://relyability.ai/energy-based-maintenance-ebm-is-gaining-traction-as-companies-realise-the-importance-of-maintenance-to-reducing-their-energy-costs-and-achieving-their-net-zero-targets (accessed on 24 February 2024).
84. Jasiulewicz-Kaczmarek, M.; Wyczółkowski, R.; Mazurkiewicz, D. *Strategie i Metody Utrzymania Ruchu*; Polskie Wydawnictwo Ekonomiczne: Warsaw, Poland, 2023.
85. Jasiulewicz-Kaczmarek, M. *Sustainable Maintenance Assessment Model of Enterprise Technical Infrastructure*; Wydawnictwo Politechniki Poznańskiej: Poznań, Poland, 2019.
86. Kazemi, S. Proposing a Green Maintenance Model in Order to Analyses the Effects of Influential Criteria on the Environment and Green Maintenance Index, Using System Dynamics Method. *Adv. Environ. Biol* **2013**, *7*, 3529–3534.
87. Howell, M.T.; Alshakhshir, F. *Energy Centered Maintenance: A Green Maintenance System*; CRC Press: Boca Raton, FL, USA, 2020; ISBN 8770222665.
88. Franciosi, C.; Lambiase, A.; Miranda, S. Sustainable Maintenance: A Periodic Preventive Maintenance Model with Sustainable Spare Parts Management. *IFAC-PapersOnLine* **2017**, *50*, 13692–13697. [CrossRef]
89. Sari, E.; Shaharoun, A.M.; Ma'aram, A.; Yazid, A.M. Sustainable Maintenance Performance Measures: A Pilot Survey in Malaysian Automotive Companies. *Procedia CIRP* **2015**, *26*, 443–448. [CrossRef]
90. Firdaus, N.; Samat, H.A.; Mohamad, N. Maintenance for Energy Efficiency: A Review. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *530*, 12047. [CrossRef]
91. Wieczorek, A. Methods and Techniques of Prediction of Key Performance Indicators for Implementation of Changes in Maintenance Organisation. *Manag. Syst. Prod. Eng.* **2012**, *1*, 5–9.

92. Muchiri, P.N.; Pintelon, L.; Martin, H.; De Meyer, A.-M. Empirical Analysis of Maintenance Performance Measurement in Belgian Industries. *Int. J. Prod. Res.* **2010**, *48*, 5905–5924. [CrossRef]
93. Adamkiewicz, A.; Burnos, A. Kluczowe Wskaźniki Efektywności w Utrzymaniu Silników Spalinowych w Układach Energetycznych Jednostek Pływających. *Zesz. Nauk. Akad. Mar. Wojennej* **2012**, *53*, 5–16.
94. Burnos, A. Universal Maintenance Performance Indicator for Technical Objects Operated on Floating Units. *Zesz. Nauk. Akad. Morskiej Szczecinie* **2011**, *27*, 34–39.
95. Hoang, A.; Phuc, D.O.; Benoît, I.; Levrat, E.; Voisin, A. Prognostics and Energy Efficiency: Survey and Investigations. In Proceedings of the PHM Society European Conference, Nantes, France, 8–10 July 2014; Volume 2.
96. Bányai, Á. Energy Consumption-Based Maintenance Policy Optimization. *Energies* **2021**, *14*, 5674. [CrossRef]
97. Pietrzyk, A.; Uhl, T. Optymalizacja Eksploatacji Maszyn i Urządzeń. *Diagnostyka* **2002**, *26*, 29–36.
98. Wieczorek, A. Koncepcja Wykorzystania Informacji Mapowej w Realizacji Filozofii RCM w Zarządzaniu Eksploatacją Środków Technicznych. *Mechanik* **2011**, *84*, 917–926.
99. Wieczorek, A. Assessment of Usefulness of CMMS Class System for Industry 4.0 Enterprise. *Sci. Pap. Silesian Univ. Technol. Organ. Manag. Nauk. Politech. Sl. Ser. Organ. Zarz.* **2023**, *182*, 557–571. [CrossRef]
100. Eutotronic Na co Wpływa System CMMS—Ekologiczny Aspekt Wprowadzenia Systemu CMMS. Available online: https://eurotronic.net.pl/na-co-wplywa-system-cmms-ekologiczny-aspekt-wprowadzenia-systemu-cmms/ (accessed on 24 February 2024).