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Environmental Impact Reduction Analysis on PT XYZ Asphalt Production using Life Cycle Assessment (LCA) and Analytical Hierarchy Process Method (AHP)

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ABSTRACT

Research was conducted on the environmental impact analysis of the asphalt production process at PT XYZ, with the aim of identifying and determining the magnitude of the environmental impact of asphalt production. It also aimed to identify alternative strategies to reduce the environmental impact of asphalt production. The data used consists of primary and secondary data. The analysis method to determine the magnitude of the environmental impact of asphalt production was carried out using the LCA (Life Cycle Assessment) method with the ReCiPe 2026 Midpoint and Endpoint methods. Meanwhile, the analysis of the environmental impact reduction program was carried out using the AHP (Analytical Hierarchy Process) method with Expert Choice 11. The production process of 1 metric ton of asphalt distributed at PT XYZ produces endpoint impacts including human health of 63,062.033 Pt, ecosystem of 8,440.988 Pt, and resources of 72.541 Pt. Meanwhile, the most dominant midpoint impact is global warming, with a characterization value of 5,360,044.8 kg CO_2 eq. The unit with the highest impact contribution is the storage unit, due to its high electricity consumption. Uncertainty analysis or Monte Carlo simulation was performed on the data using the dataset. Based on the uncertainty analysis conducted on the grave, it is known that 1 metric ton of distributed asphalt produces an ecosystem environmental impact of between 171,651.00 and 417,824.27 Pt, human health between 2,181,108.80 and 3,917,701.50 Pt, and resource between 117,301.19 and 243,365.28 Pt. The environmental program priority selected through the AHP method is the "Automation of Heater Switch On/Off Shutdown with Temperature Sensor" program. This program can reduce the midpoint global warming impact by 16.7%, the endpoint human health impact by 16.7%, and the ecosystem impact by 16.7%.

Keywords: Analytical Hierarchy Process; Asphalt; Environmental Impact; Environmentally Friendly; Life Cycle Assessment.

INTRODUCTION

The industrial sector in Indonesia continues to grow in line with the increase in the country's population. The industrial sector aims to support the facilities and infrastructure provided by the government for the community. Infrastructure, as one of the key components of public facilities, supports the continuity of social and economic activities (Akmaludin & Suryanto, 2016; Sudradjat et al., 2020; Jaya et al., 2020). According to Wahyuanto et al. (2024), infrastructure plays a vital role in promoting economic growth and improving people's quality of life. With adequate infrastructure, the community gains better access to education, health care, and public services, ultimately improving overall welfare (Finnveden & Potting, 2014; Sonnemann et al., 2018; Barahmand & Eikeland, 2022).

Given its crucial role in economic development, infrastructure includes various sectors such as transportation, energy, clean water, and information and communication technology (Maysaroh & Arif, 2022). According to Soumena et al. (2024), well-developed infrastructure enhances the efficiency and effectiveness of the production and distribution of goods and services. For example, good roads and transportation networks can improve production processes by lowering logistics costs and reducing travel times.

Infrastructure development is supported by road construction, which relies on the availability of raw materials such as asphalt (Sari, 2017; Putri, 2017; Maharani, 2022). Asphalt is a material used for road pavement that functions as a binder and filler between aggregates. It is a hydrocarbon compound with adhesive properties, high water resistance, and viscoelastic and thermoplastic characteristics, typically brownish-black in color. Asphalt is composed of carbon, hydrogen, sulfur, oxygen, and chlorine (Isma et al., 2019).

Currently, road construction in Indonesia is still dominated by the use of petroleum-based asphalt (Wirahaji et al., 2018). Asphalt offers several advantages, including durability under traffic loads, economic construction costs, a smooth surface, and flexibility (Ichsan et al., 2023). It serves as a binder between aggregates and fills voids in the aggregate structure to enhance pavement strength and stability (Lestari et al., 2013; Holý & Remišová, 2019; Maisarah & Dian, 2024).

Asphalt not only serves as a construction material but also as an important component in maintaining the sustainability and quality of road infrastructure. One of the major suppliers of asphalt in Indonesia is PT XYZ. Asphalt can be obtained from natural sources or derived as a by-product of petroleum processing. The asphalt produced by PT XYZ is obtained from petroleum refining residues, meaning that its production must follow the petroleum processing stages.

PT XYZ is part of the Jatimbalinus Regional Marketing Unit (Asphalt Products) and is located on Jalan Harun Tohir, Pulopancikan District, Gresik Regency. PT XYZ officially began operations on August 11, 1990, functioning as a supply point to distribute asphalt to regional marketing units across East Java, Bali, NTB, NTT, and the regions of Kalimantan, Sulawesi, Maluku, and Papua. The company has a dedicated wharf for asphalt transport vessels and an asphalt storage facility consisting of seven storage tanks. In addition, PT XYZ operates a car loading station for distributing bulk asphalt via tanker trucks and a drum fabrication facility for producing and filling asphalt drums.

In general, the asphalt production process consists of several stages, including preheating in the heat exchanger, heating in the furnace, evaporation in the evaporator, separation in the fractionation column and stripper, condensation and cooling in the condenser and cooler, and separation from water in the separator. The finished asphalt is then transferred for stockpiling and distribution to consumers. During the storage process, asphalt is filled into drums fabricated at the in-house drum factory.

However, the asphalt industry is one of the contributors to environmental issues in Indonesia. According to Rilwani and Agbanure (2010), the asphalt production process generates significant environmental impacts, including greenhouse gas emissions, air pollution, high energy consumption, soil contamination, and groundwater pollution. These impacts arise from petroleum processing through to asphalt refining. Florkova et al. (2021) reported that the greatest impacts come from air pollution and greenhouse gas emissions. The production process releases pollutants such as volatile organic compounds (VOCs), particulate matter (PM), and harmful gases including carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). These emissions not only threaten human health but also contribute to global climate change.

Despite its environmental risks, the asphalt industry plays an important role in driving economic growth and supporting infrastructure development. Nevertheless, this progress must align with the principles of sustainable development or the Sustainable Development Goals (SDGs). Therefore, the industrial sector needs to adopt a life cycle management (LCM) system. One key application of life cycle management is the life cycle assessment (LCA) method, which supports improved corporate environmental management. The implementation of LCA is regulated under ISO 14040:2016 (Groen et al., 2014; Ziyadi & Al-Qadi, 2019).

LCA is conducted to assess environmental impacts throughout a product's life cycle, from resource extraction and production to product use and end-of-life disposal. It provides a comprehensive evaluation of all stages and their potential environmental consequences. The results of LCA help identify environmental improvement opportunities (Hermawan et al., 2013). These improvements can be developed into environmental enhancement programs, with LCA serving as an analytical tool to determine which programs are most effective.

As part of Indonesia's commitment to environmental protection, the government enacted Law No. 23 of 1997 on Environmental Management and ratified the Kyoto Protocol through Law No. 17 of 2004 on the Kyoto Protocol to the United Nations Framework Convention on Climate Change. LCA is also recognized in the Regulation of the Minister of Environment and Forestry No. 1 of 2021 concerning the Company Performance Rating Assessment Program in Environmental Management (PROPER). In line with these regulations and sustainability principles, the industrial sector must identify the potential environmental impacts arising from its production processes.

Furthermore, industries need to develop strategies to mitigate these impacts. The environmental impacts identified through the LCA study are evaluated, classified, and analyzed to develop impact reduction strategies, which can take the form of environmental improvement programs. These programs are then analyzed using the Analytical Hierarchy Process (AHP) method, which allows decisions to incorporate subjective judgments from multiple stakeholders. Thus, environmental improvement strategies can be tailored to the company's specific conditions (Saputra & Nugraha, 2020). The identification and analysis of environmental programs through AHP are expected to yield the most effective strategies to reduce the environmental impact of asphalt production at PT XYZ.

Considering that the SimaPro database used in this study is not directly related to asphalt industries in Indonesia, resulting in potential uncertainty, this research also proposes uncertainty analysis and sensitivity analysis using Monte Carlo simulation in SimaPro to identify critical variables influencing the final results.

The research objectives are to (1) quantify the environmental impacts of asphalt production at PT XYZ, (2) determine the uncertainty intervals for these impacts through Monte Carlo simulation, and (3) determine the priority of alternative improvement programs using AHP. The benefits of this study are twofold: for PT XYZ, the results provide a foundational evaluation for decision-making in environmental management and serve as a reference for implementing targeted impact reduction programs; and for the broader academic and industrial community, the study offers a methodological framework for integrating LCA, uncertainty analysis, and AHP in the context of the asphalt industry.

METHOD

Research Thinking Pipeline

The research thought flow is compiled as a basic reference in the implementation of research. The research thought flow is a description of the flow of the research series in a systematic and directed manner, so that it can facilitate the implementation of research. The preparation of the thought flow of research implementation began with a discrepancy between the existing conditions and the expected conditions of the asphalt processing process at PT XYZ. In addition, PT XYZ also wants to make efforts to improve and reduce the environmental impact of its asphalt production process. This research is based on a research framework that includes research ideas, objectives, secondary data collection, and primary data collection.

Research Stage

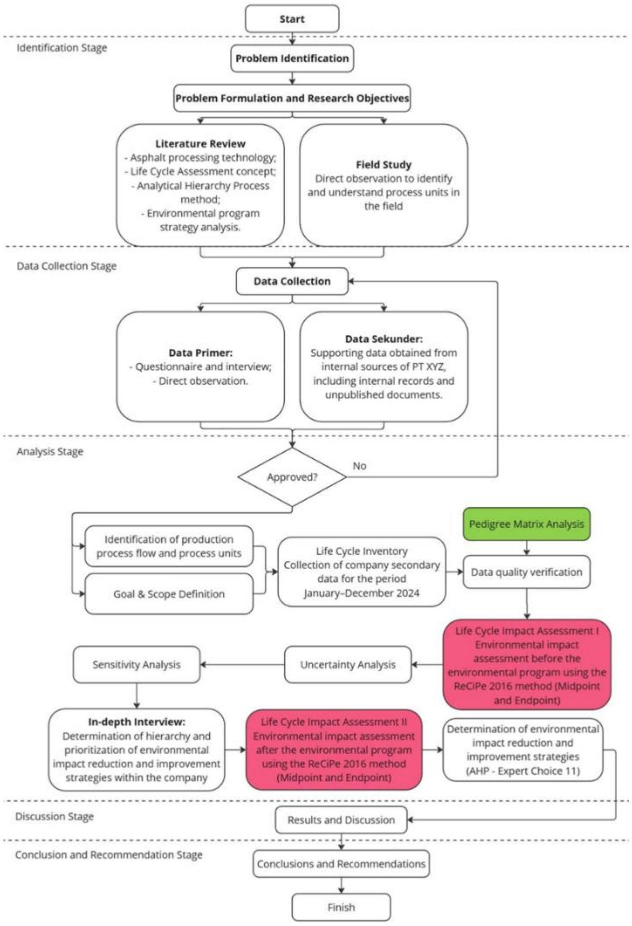

Figure 1. Research Stages

RESULTS AND DISCUSSION

It can be seen that the overall impact of the ReCiPe 2016 (H) method has an impact value. This is due to the use of *datasets* in the *grave* process. Which includes asphalt transportation units to consumers and asphalt use units by consumers. It can be seen that the characterization results of 1 metric ton of distributed asphalt produced 9 *midpoint* impacts and 3 *endpoint* impacts.

Midpoint

Global warming is defined as the increase in global average temperature triggered by the trapping of solar longwave radiation by greenhouse gas (GHG) emissions. The accumulation of these emissions increases the concentration of GHGs in the atmosphere which has an impact on strengthening capacity *radiative forcing*, so that the earth's surface temperature continues to rise (Huijbregts *et al.*, 2017). Impact *midpoint global warming* resulting from the asphalt production process of 5.360.044,800 kg CO_2 eq/ton of distributed asphalt.

Stratospheric ozone depletion refers to the phenomenon of ozone depletion in the stratosphere due to the release of ozone-depleting substances (ZPO). This decrease in ozone concentration in the atmosphere results in an increase in ultraviolet B (UVB) radiation that reaches the earth's surface, thus adversely affecting human health (*human health*). Technically, ZPO emissions inhibit the protective function of the atmosphere in filtering out radiation, which causes most of the UVB to be passed directly to the earth (Huijbregts *et al.*, 2017). Impact *stratospheric ozone depletion* produced from the asphalt production process of 0.029 kg CFC11 eq.

Ozone formation, human health refers to the formation of ozone compounds in the troposphere through photochemical reactions between NOx and *Non-Methane Volatile Organic Compounds* (NMVOC), which has a negative impact on human health. This indicator is measured in kg of NOx equivalent (Huijbregts *et al.*, 2017). Based on the results of the study, the impact of the formation *ozone formation, human health* The resulting asphalt production process is 3,357 kg NOx eq/ton of distributed asphalt.

Fine particulate matter formation refers to the formation of primary and secondary aerosols in the atmosphere dominated by particles less than 2.5 μm in diameter (PM2.5). These particulates are a complex mixture of organic and inorganic compounds formed by the emission of SO_2, NH_3, NOx, and other substances. Exposure to PM2.5 has a significant negative impact on human health (*human health*), ranging from respiratory tract disorders to the risk of premature death (Huijbregts *et al.*, 2017). In this study, the asphalt production process was recorded to produce an impact on the formation of fine particulates of 2,420 kg PM2.5 eq/ton of distributed asphalt.

Ozone formation, terrestrial ecosystems refers to the formation of ozone compounds in the atmosphere which results in a decrease in the quality of terrestrial ecosystems. Ozone is formed through a photochemical reaction between NOx and *Non-Methane Volatile Organic Compounds* (NMVOC). The presence of this compound has a negative impact on vegetation, such as inhibiting seed production and accelerating the aging process in leaf tissue. This impact indicator is measured using the equivalent kg of NOx released into the air (Huijbregts *et al.*, 2017). Based on the results of the study, the impact of the formation *ozone formation, terrestrial ecosystem* The resulting asphalt production process is 3,357 kg NOx eq/ton of distributed asphalt.

Terrestrial acidification is a phenomenon of changing soil acidity through an increase in the concentration of hydrogen ions (H+) triggered by the deposition of inorganic compounds from the atmosphere, such as NOx, NH_3, and SO_2. This condition results in a decrease in the diversity of plant species due to changes in soil nutrient stability. In LCA studies, this category measures soil acidity levels based on substance emissions calculated relative to SO_2 equivalent.

The impact of the formation of *terrestrial acidification* resulting from the asphalt production process is 8,279 kg SO_2 eq/ton of distributed asphalt.

Marine eutrophication It occurs due to leachate runoff with high nutrient content, especially phosphorus and nitrogen, from the soil carried by river flows to the sea. The accumulation of these nutrients triggers a decline in the quality of marine ecosystems through a reduction in dissolved oxygen levels (*dissolved oxygen*), which in turn led to the death of various marine species. This indicator is measured in equivalent kg N units (Huijbregts *et al.*, 2017). Impact of the formation *marine eutrophication* The resulting asphalt production process is 0.0000000005 kg N eq/ton of distributed asphalt.

Impact categories *fossil resource scarcity* represents the threat of depletion of energy reserves due to the high demand for global extraction. Non-renewable resources that are the focus of this indicator include *crude oil*, natural gas, as well as various types of coal and peat. This indicator is measured in units of equivalent kg of oil (Huijbregts *et al.*, 2017). Impact of the formation *fossil resource scarcity* The resulting asphalt production process is 14,809,936 kg of oil eq/ton of distributed asphalt.

Water consumption is defined as water utilization during the production cycle or other operational activities that result in a decrease in the availability of clean water locally. This phenomenon has a negative impact on human health (*human health*) and ecosystem quality. In the LCA study, this indicator is measured using the *Water Consumption Potential* (WCP) expressed in equivalent m3 of water consumed (Huijbregts *et al.*, 2017). Impact *water consumption* The resulting asphalt production process is 7,826,360 m3/ton of distributed asphalt.

Endpoint

This research produces three main categories of *endpoint* impacts, namely human health, *ecosystem quality*, and resource availability. The value of the impact on *human health* was recorded at 4.993 DALY. The *Disability-Adjusted Life Years* (DALY) unit represents the accumulation of environmental burden equivalent to the loss of one year of a person's healthy life due to health problems or premature death. A value of 4.993 DALY theoretically indicates that the accumulation of all emissions and toxic substances produced has the potential to reduce a person's life expectancy by approximately 4.99 years if directly exposed. However, in the context of a dynamic environment, the substances that cause such impacts have high mobility and dispersion. This causes the risk of exposure to become widespread, so that individual human health impacts are not significantly concentrated at one specific point.

Impact value on *ecosystem quality* recorded at 0.015 *species.yr*. Units *species.year* It is defined as the estimate of the number of species lost in an area within one year due to the accumulated environmental burden. Specifically, this impact is triggered by ecosystem degradation caused by environmental toxicity, acidification, and land conversion (Huijbregts *et al.*, 2017). Theoretically, the value is 0.015 *species.yr* indicates the potential loss of 0.015 species over an area of 1 km2. However, given that the emissions that cause these impacts have high mobility and dispersion in the atmosphere, their effect on the decline in ecosystem quality in the field is not significantly concentrated at one specific point.

The results of the analysis showed the impact *of resources* of 6,773,168 USD2013, which reflects economic losses due to the extraction of fossil and mineral materials. The USD2013 unit represents the monetary value lost due to the extraction of fossil or mineral resources from nature (Huijbregts *et al.*, 2017). This figure projects an increase in surplus costs (additional costs) that must be borne by the public in the future. The increase occurred because the extraction and exploration process became more energy-intensive along with the reduction of easily accessible resource deposits in nature.

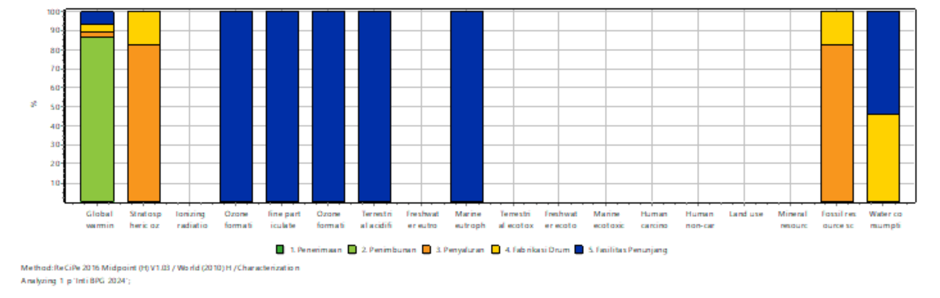

Figure 2. Impact Characterization *Stuart O'T* per Asphalt Production Process Unit

Uncertainty Analysis

The analysis of uncertainty in the asphalt production process was carried out by examining the cumulative effect of data variability based on the results of data quality *assessment*. The most commonly used uncertainty analysis is the numerical approach using Monte Carlo simulations (Hauschild *et al.*, 2018). These simulations can be accessed through various LCA software, such as SimaPro. The uncertainty analysis procedure includes determining the probability distribution as well as evaluating the results of the uncertainty analysis.

Data Probability Distribution

The determination of the data probability distribution is carried out based on the data quality assessment score to identify the value of the uncertainty factor. The parameter is then used in the standard square calculation of geometric deviation at a 95% confidence interval (SD_{g952}) assuming a *lognormal* distribution. Overall, the data contained in the data inventory is primary data or monitoring so that it has good data quality and is representative of conditions in the field. Thus, Monte Carlo simulations are only carried out using data involving the use *of datasets* from SimaPro software. This is due to the use of *datasets* from the SimaPro software having a high uncertainty value.

Evaluation of Uncertainty Analysis Results

Uncertainty analysis was carried out using Monte Carlo simulation through SimaPro software by applying the LCIA ReCiPe 2016 (H) method and iteration 1,000 times. The output of this analysis presents the probability distribution parameters for each impact category, which include mean (*mean*), median, standard deviation (SD), as well as confidence intervals at the lower limit of 2.50% and upper limit of 97.50% (Zungeru et al., 2018)..

Uncertainty analysis was performed on units using *datasets*. As for this study, *the dataset* was used in *the grave process* for the asphalt transportation unit to the consumer and the asphalt use unit by the consumer.

All categories of impacts on *the grave* process as a result of the characterization and normalization of impatience analysis have a probability distribution value. This is due to the limited data on asphalt transportation units to consumers and the use of asphalt by consumers. Thus, *datasets* are used on these units. The results of characterization and normalization in the uncertainty analysis show that the asphalt production impact category does not represent a single value, but rather a percentile range of 2.5% to 97.5%. This variability is influenced by the uncertainty factor inherent in the data, where the width of the interval is highly dependent on the value of the characterization factor. The level of data quality is inversely proportional to the range of uncertainty; The more optimal the data quality score, the narrower the impact value interval. Furthermore, the analysis of this uncertainty is continued to the weighting stage in the LCIA. Table **1** presents the weighting results of uncertainty analysis.

Table 1. Uncertainty Weighting Serious Asphalt Production Process

Impact Categories	**Units**	**Statistical Parameters of Probability Distribution**				
		Mean	**Median**	**SD**	**2,50%**	**97,50%**
Ecosystems	Pt	295.325,33	296.443,61	58.663,16	171.651,00	417.824,27
Human health	Pt	2.821.634,30	2.752.699,50	428.633,27	2.181.108,80	3.917.701,50
Resources	Pt	170.739,32	166.755,49	32.718,49	117.301,19	243.365,28

Based on **Table 1**, it can be seen that the weighting results of the uncertainty analysis of *the endpoint* impact category all have a probability distribution value. This is due to the parameter uncertainty factor that affects each of the impact categories. In *the grave* process, a dataset *from Ecoinvent 3 is used*. So that the data obtained is approach data and not direct monitoring or observation data. Figure **3** and **Figure 4** present the characterization and weighting of the analysis *of the grave* uncertainty of the asphalt production process.

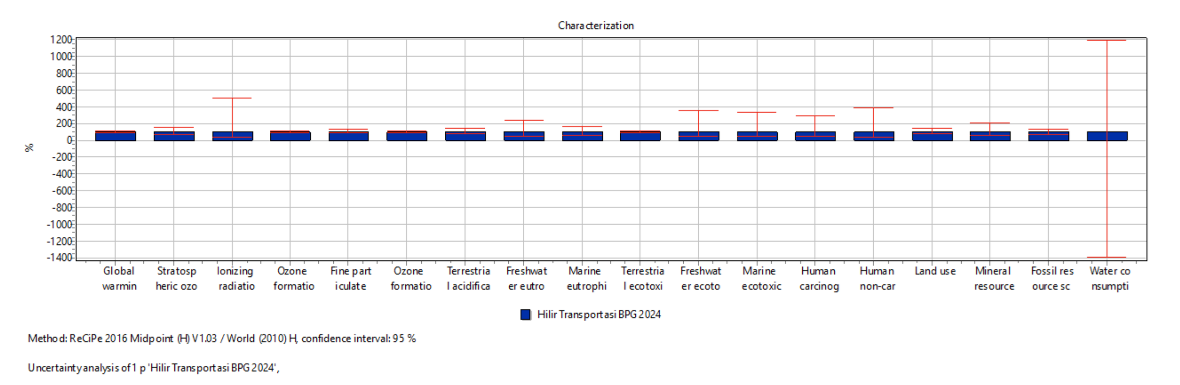

Figure 3. Characterization of Uncertainty *Serious* Asphalt Production Process

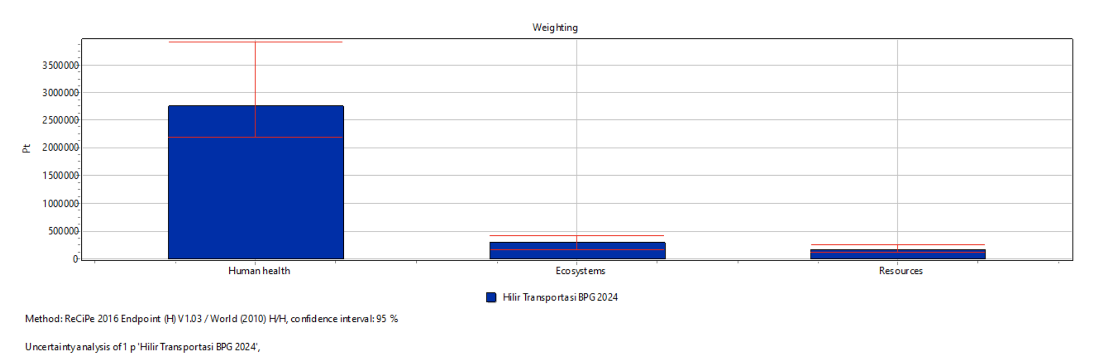

Figure 4. Normalization of Uncertainty *Serious* Asphalt Production Process

Program Prioritization Using AHP

The process of determining priorities begins with the preparation of a hierarchical structure that connects between the main objectives, assessment criteria, and various program alternatives. The next stage involves a comparative assessment to determine the priority weight of each program recommendation over the other alternatives. The results of this analysis will be used to identify the programs with the highest priority ratings. The steps in the analysis of the determination of the program include:

1. Identify various alternative program recommendations.
2. The arrangement of the hierarchical structure is based on the criteria that have been set.
3. Determination of priority levels through *pairwise comparison* between alternatives.
4. Evaluate the consistency of the assessment to ensure the validity of the weighting results.

Determination of AHP Criteria

The results of the LCA study provide a comparative picture of the environmental burden resulting from the asphalt production process. In this study, the determination of improvement priorities was carried out using *the Analytic Hierarchy Process* (AHP) method based on three main criteria, namely:

1. Environmental aspects
   Consider the amount of impact reduction potential that can be accommodated through the implementation of environmental programs.
2. Technical aspects
   Consider the level of operational complexity of the program as well as the availability of supporting resources and infrastructure in the implementation of improvements. Also consider the ease of application, operation, and repair or maintenance.
3. Financial aspects
   Consider the value of investment feasibility from a corporate perspective, which includes the allocation of implementation costs, operational and maintenance costs, cost savings, return *on investment*, and labor competency development costs.

The determination of the priority weight of the criteria in the AHP method is carried out through an interview process with company representatives. The respondents consisted of two representatives of the HSSE function (Junior Supervisor HSSE and Office Service – HSSE Administration) and two representatives of the Hoarding and Distribution function (Junior Supervisor Receiving & Storage). Based on the results *of the in-depth interview*, the priority order of criteria was obtained as follows: financial aspect, followed by technical aspect, and finally environmental aspect.

Prioritization of Recommendation Programs

After calculations were made on the recommendations of environmental programs for the landfill units, the programs were assessed using *pairwise comparison*. As for this stage, an analysis will be carried out using Expert Choice 11 software. Figure **5** presents the results of the priority analysis of the program selection aspect.

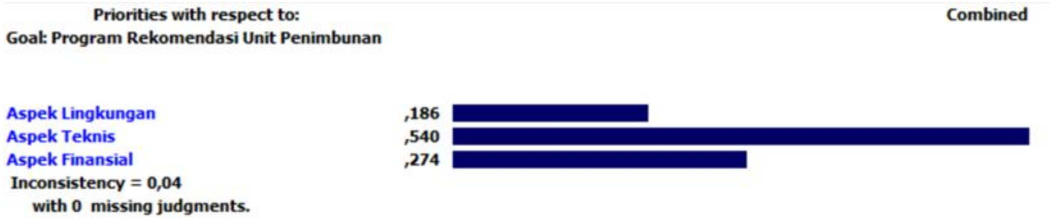

Figure 5. Results of Analysis of Priority Aspects of Program Selection

Based on Figure **5**, it can be concluded that the technical aspect is the main priority criterion in determining the implementation of the program with a weight of 0.540. These priorities are based on the parameters of ease of installation, ease of operation, and ease of maintenance. The financial aspect occupies the second position with a weight of 0.274, which considers the amount of investment, the amount of savings, and *the cost of operation and maintenance*. Meanwhile, the environmental aspect is the last consideration with a weight contribution of 0.186. Thus, it can be concluded that the technical aspect is a priority aspect for the implementation of the program in the stockpile unit.

In addition, it can be seen that the inconsistency *ratio* is 0.04. The maximum limit of the *inconsistency ratio* set is 10% or 0.1. If the calculation results exceed the threshold value, the assessment that has been carried out is considered inconsistent and requires re-evaluation or revision of the paired comparison matrix (Falatehan, 2016). Therefore, it can be concluded that the priority assessment of the selection aspect of this program is of consistent value, and does not need to be improved.

Figure **6** presents the results of the program priority analysis on the stockpile unit.

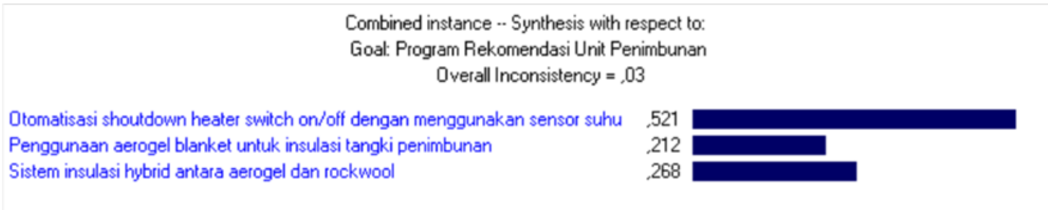

Figure 6. Results of the Priority Analysis of the Stockpiling Unit Program

Based on Figure **6**, it can be concluded that the program "Automation *of Shutdown Heater Switch On/Off* with Temperature Sensors" is a priority program in the selection of repair programs between the program "Use of Aerogel *Blankets* for Insulation of Stockpile Tanks" and the program "Hybrid Insulation System between Aerogel and *Rockwool*". In the AHP analysis with the Expert Choice 11 software, a value of 0.521 was obtained, which is the highest value.

Managerial Implications

Based on **Figure 5**, it is known that the priority aspects in the selection of programs in order consist of technical aspects, financial aspects, and environmental aspects. Based on **Figure 6**, it is known that the priority of the program in the stockpile unit is the program "Automation *of Shutdown Heater Switch On/Off* with Temperature Sensor". This program was chosen because, among other programs, it is a program that is not too complicated in terms of operation, maintenance, and installation. In addition, financially this program also does not require large costs like other programs.

The application of this program has been carried out at PT XYZ. However, there is no Standard Operating Procedure (SOP) that regulates the implementation of this program. So, it is recommended to prepare SOPs as a general guide that directs the *heater shutdown* process at a certain temperature. This aims to ensure that the innovations carried out are recorded in the company. In addition, if in the future there are other technologies that are more suitable for reducing electricity use in the stockpile unit, it can be used as a reference for efficiency calculations.

CONCLUSION

During the production process of 1 metric ton of asphalt distributed at PT XYZ, the endpoint impacts were produced, including human health of 63,062,033 Pt, ecosystem of 8,440,988 Pt, and resources of 72,541 Pt. Meanwhile, the most dominant midpoint impact was global warming with a characterization value of 5,360,044.8 kg CO_2 eq. It is known that the hotspots or units with the greatest impact contribution rate are in the stockpile unit, which is caused by the high electricity consumption.

Uncertainty analysis or Monte Carlo simulation was performed on data using *datasets*. Based on the uncertainty analysis carried out on *grave*, it is known that 1 metric ton of distributed asphalt produces ecosystem environmental impacts between 171,651.00 – 417,824.27 Pt, *human health* between 2,181,108.80 – 3,917,701.50 Pt, and *resources* between 117,301.19 – 243,365.28 Pt.

The priority aspects in determining environmental programs consist of technical aspects (0.540), financial aspects (0.274), and environmental aspects (0.186). For the weighting of environmental programs, among others, the program "Automation *of Shutdown Heater Switch On/Off* with Temperature Sensors" is 0.521, the program "Use of Aerogel *Blanket* for Insulation of Stockpile Tanks" is 0.212, and the program "Hybrid Insulation System between Aerogel and *Rockwool*" is 0.268. Thus, the priority of the environmental program selected through the AHP method is the program "Automation *of Shutdown Heater Switch On/Off* with Temperature Sensor". This program is able to reduce the impact *of global warming midpoint* by 16.7%, and the impact of *human health endpoints* by 16.7%, and *ecosystem* by 16.7%.

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