Efficiency Evaluation of the Rolling Mills Production: A Data Envelopment Analysis Approach

by Apriani Soepardi

Available online at: http://proceeding.rsfpress.com/index.php/ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 228-237

Efficiency Evaluation of the Rolling Mills Production: A Data Envelopment Analysis Approach

Apriani Soepardi[1], Mochammad Chaeron[2], Mira T. Kuncoro[3], Gunawan Wijiatmoko[4]

[1,2,] Universitas Pembangunan Nasional Veteran Yogyakarta,
[3]PT Shopee Internasional Indonesia,
[4]Badan Pengkajian & Penerapan Teknologi (BPPT), Indonesia
[1] apriani.soepardi@upnyk.ac.id; [2] m.chaeron@upnyk.ac.id; [3]gunawan.wijiatmoko@bppt.go.id

Abstract

The steel industry is one of the industries that concentrate on energy, and types of upstream industries are prioritized in Indonesia. National steel demand will continue to increase up to 32 million tonnes in 2025 to make the steel industry remain competitive. The amount of energy used in the production process, i.e., the energy of LNG and electricity, and the high prices of raw materials to make the steel industry should be able to use all three of these things efficiently. On the other hand, the activity of the production process is often a breakdown on a rolling machine that makes the production process on the stage rolling line stop, except the reheating furnace, was still burning. This leads to the inefficiency of using energy and reduce the productivity of reinforced concrete that can be generated. One of the causes of the breakdown in the rolling machine is negligence labor. The study aims to calculate the level of efficiency in production units, rolling mills one and two. The disruption of the production process is the breakdown in the production of rolling mills. The research uses the approach of the Data Envelopment Analysis model CRS input-oriented. From the evaluation is known that there are eight concrete iron production units are inefficient by an average of 98%. Then, a significant improvement potential values of input parameters using the unit of production of rolling mills is the use of electrical energy by 93.56%, amounting to 65.20% of LNG energy, labor amounted to 49.00%, and raw materials by 11.92%. One of the causes of the potential value improvement or inefficient use of the input parameter is the breakdown of the engine components, namely rolling bearings, adjuster gap, entry/exit guide, caliber, and coupling.

Keywords: energy efficiency, iron-steel industry, DEA method, rolling mill

I. INTRODUCTION

The steel industry is one part of the primary metal industry included in the upstream industry prioritized in Indonesia. This sector plays a significant role in supplying vital raw materials for development in various fields, from infrastructure provision, production of capital goods, and transportation to weaponry. The projection of national steel consumption will continue to increase to 32 million tons in 2025. Based on the amount of consumption and its significant role, the steel industry's existence is very strategic for a country. The steel industry is an energy-intensive industry, so the national steel industry's immense burden is the high cost of energy. The price of natural gas in Indonesia reached US $ 7.30 per MMBTU, which is more expensive than the price of natural gas in other countries such as Malaysia, which is only US $ 4.47 per MMBTU, Singapore US $ 4 per MMBTU, and Vietnam US $ 4.24 per MMBTU (AAAT, 2013; IISIA, 2015).

PT. XYZ is one of the national steel companies in Indonesia. This company produces national standard steel products, known as concrete rebar. The company produces concrete rebar of various sizes using billets as raw material by two production units, Rolling Mills 1 and Rolling Mills 2. The production processes at rolling mill production units respectively go through the production process stages of reheating furnaces, roughing mills, intermediate mills, finishing mills, finishing facilities, inspection, and packaging processes. The reheating furnace process is one of the concrete iron production process stages, namely heating the billets at the temperature of 1200^0C, which uses liquid natural gas (LNG) and electricity as fuel. Meanwhile, for the finishing facility and rolling line production process stages, namely roughing mills, intermediate mills, and finishing mills using electricity as fuel.

Based on observations, rolling mill production units often experience interruptions in the production process, namely the occurrence of breakdowns in rolling machines. The disruption was the interruption of the production process from the rolling line stage to the finishing facility. However, the initial stage of the production process, namely the reheating furnace process, will continue. Thus, this causes inefficiency or waste of energy use, namely LNG and electricity. Another consequence of the rolling machine's breakdown is the low productivity of billets turning into the concrete bar. When there is a breakdown during the production process, the billets cannot be adequately processed and become reject products. Meanwhile, one of the causes of the breakdown, which causes the production process to stop, is negligence by the workforce.

The opportunity to measure efficiency in rolling mill production units can be done by considering several input variables that affect efficiency: energy, raw materials, and labor during the concrete iron production process and the effect of production disruptions such as the rolling machine breakdown. This efficiency measurement is carried out to evaluate the use of the input variable on the resulting output, namely concrete iron. So, the company can still compete with other national steel industries.

In this study, the measurement of efficiency in rolling mill production units, a Data Envelopment Analysis (DEA) tool, is used as a benchmarking method by analyzing and comparing the variables that affect efficiency between production units. The DEA method can also show the reference set of the inefficient concrete iron production unit and identify the variables causing the inefficient. The concrete iron production unit's performance can be increased. The results of these calculations will provide information on each production unit's relative efficiency level and considerations for improvements made to prevent rolling machine breakdowns at the rolling line production process stage so that the company can continue to grow and cope with competition well. Based on the description above, a problem can be formulated as determining the relative efficiency level in rolling mills based on the effect of the disturbances that occur. This research aims to analyze the relative efficiency level in the production units of the rolling mill units based on the influence of the disturbances that occur. The study's benefits provide information and knowledge on how much the relative efficiency level in the rolling mill production units is affected by several production disruptions and the improvements that can be provided for production units not efficient.

II. LITERATURE REVIEW

The DEA is a mathematical programming technique used to evaluate a decision-making unit (work unit) responsible for using several inputs to obtain a targeted output. DEA is a technique based on linear programming to measure the relative performance of organizational units characterized by various inputs and outputs. The DEA method was as a tool for evaluating the performance of an activity in an entity unit (organization), from now on, referred to as the Decision-Making Unit or DMU (Ramanathan, 2003; Smirlis et al., 2006; Wu et al., 2014).

The DEA approach emphasizes evaluating the performance of the DMU. The analysis carried out is based on an evaluation of the relative efficiency of comparable DMUs. Furthermore, efficient DMU will form a frontier line. If the DMU is on the frontier line, then the DMU can be relatively efficient compared to other DMUs. In addition to producing efficiency values for each DMU, DEA also shows units that become the reference for inefficient units (Wu et al., 2014). The term DMU in the DEA method can take various units such as banks, hospitals, units from factories, departments, universities, and schools. Two factors influence the selection of the DMU (Ramanathan, 2003):

1. DMU must be homogeneous units. These units perform the same task and have the same objectives. The inputs and outputs that characterize the performance of the DMU must be identical, except that they differ only in intensity and quantity/size.
2. The relationship between the number of DMU to the number of inputs and outputs is sometimes determined based on the "rule of thumb," namely, the number of DMU is expected to be greater than the number of inputs and outputs. The sample size should be two or three times more than the total number of inputs and outputs.

II.1. System Overview

PT XYZ is a steel industry company with Industrial National Standards (SNI) that produces everything from scrap metal to concrete with various qualities and diameters depending on consumer orders. The company has two production kitchens, the steel melting and the rolling mills. The steel melting production kitchen produces scrap into billets with 9 mm 120 mm x 120 mm. The billets will be the raw material for the rolling mills. The rolling mill production units are divided into two: the concrete iron production unit one (rolling mills 1) and the concrete iron production unit (rolling mills 2). Rolling mills 1 produces rebar with a diameter between 9-13 mm, while rolling mills 2 produces rebar with a diameter between 19-50 mm. The steel melting production unit is currently out of production. This is due to the increase in the price of raw materials, such as scrap. Therefore, company management prefers to import billets from China until an undetermined time. Import billets were chosen with the consideration from company management that the costs incurred for importing billets were cheaper than producing billets themselves in a situation of increasing scrap prices.

In this study, the research scope was limited to billets' rolling process into concrete iron found in the production kitchen for rolling mills first and rolling mills second. The rolling process has an essential role in producing concrete iron. This process functions to change the size and shape of billets into finished products, namely concrete iron, with the diameter and length according to customer orders.

II.2. Rolling Mills Production Process

The process of producing concrete iron is carried out based on the make to order system based on consumer demand. Consumers place orders through the marketing of PT XYZ. The request is then forwarded to the Production Control Division of the rolling mill production units for scheduled production schedules. The production process for rolling mill units starts with the preparation of billets in the billet warehouse. The billet is lifted using a crane and then placed on the billet charging wagon. In the billet charging wagon, billets will undergo a physical inspection process of billets by the Quality Control (QC) section of the rolling mill production units. This physical inspection includes the billet's length, the smoothness of the surface of the billet, and whether the billet is bent or not. Billets that do not pass physical inspection will be returned to the billet warehouse for special handling by the steel melting production units.

The capacity to transport billet cranes is about ten billets with billets of 9 mm x120 mm x 120 mm. After the billet is placed on the billet charging wagon and passes the inspection, the billets will then move one by one on the charging roller towards the charging pusher as the queue for the billets to enter the reheating furnace. The billet will then be driven by the collecting pusher to enter the reheating furnace. The billet undergoes a heating process for two hours, one by one from the reheating furnace pushed by the side pusher leading to the rolling process. The time interval between billets leaving the reheating furnace is 80 seconds.

A reheating furnace is a place for heating to billet temperature about 1200^{0}C. There are several heating zones in the reheating furnace, namely the heating zone and the soaking zone. There are eight burners in the zone, while in the soaking zone, there are four burners. The heating zone is the initial zone of billet heating, where the billet temperature reaches 1000^{0}C. Meanwhile, the billet temperature is maintained in the soaking zone until the billets leave the reheating furnace and heat the billets 1200^{0}C. The fuels in the reheating furnace process are natural gas and electricity. The reheating furnace has a size of 12 mm x 14 m. The carrying capacity of each reheating furnace at rolling mills one and rolling mills two is 110 billets. The next stage of the process is the rolling process. The rolling process is divided into three areas, roughing mills, intermediate mills, and finishing mills. In the rolling mills 1, there are 19 roll stands. Roll stand 1-6 is a roughing mills area, then roll stand 7-13 is an intermediate mills area, and roll stand 14-19 is a finishing mills area. The different areas in the rolling process are related to changes in the billets' shape and size. Between the 8 and 9 roll stands, a crop shear machine functions to cut billet heads about 10 cm. The purpose of cutting the billet head is to remove the billet head that may crack due to the rolling process.

The next stage is the concrete iron will enter the finishing facility area. This area consists of a flying shear engine, temp core, cooling bed, and cold shear. The concrete iron that comes out of the last roll stand from each production kitchen already has the diameter according to the order, but the concrete iron's length is not yet according to the order. There is a difference in the process between a concrete iron production units one and a concrete iron production unit 2. This is due to differences in the resulting diameter of each production kitchen. In unit 1, the concrete iron that comes out of the last roll stand from the finishing mills area will go through a cooling process (temp core) by spraying the iron water. From this process, the temperature of the concrete iron drops to about 200^{0}C. The next process is cutting 36 meters of concrete by a flying shear machine. Then, the concrete iron will enter the cooling bed machine. At this stage, the concrete iron will go through a tensile test and comparative test by the QC department. The tensile and comparative testing inspection was carried out in the QC control room using pieces of concrete samples in the cooling bed.

After the inspection stage, the concrete iron is declared according to the SNI standard. It will move towards the run-out table and enter the next stage, cutting the length of concrete iron along 12 meters or according to the order by a cold shear machine. Concrete iron from the cooling bed, which has SNI standard and cut by a cold shear machine, will be re-inspected, including the cut results and weighing the concrete iron after the binding process. The operator carries out the binding and weighing process with the help of a crane. Furthermore, concrete iron that conforms to SNI standards or passes the inspection will enter the concrete iron warehouse and be ready to be shipped. Meanwhile, concrete irons that do not comply with SNI standards at the time of inspection, tensile and comparative tests will receive special handling by the marketing department and stored in a non-SNI standard concrete steel warehouse.

III. RESEARCH METHODOLOGY

In this study, observations were made on the shop floor. The data obtained in this study are primary data and secondary data. Secondary data in the form of concrete iron production data, labor data, natural gas usage data, electricity usage data, rolling process machine breakdown frequency data will be used as input data processing for this research.

DMU is an object of research. The objects in this research are concrete iron production unit 1 (rolling mills 1), symbolized by the letter A and concrete iron production unit 2 (rolling mills 2), symbolized by the letter B. The period used for each iron production unit concrete is the last six years. The number of DMUs selected is under the calculation of determining the minimum number of DMUs in relative efficiency analysis using DEA. In this case, the input and output parameters are defined as matters relating to the concrete iron production process at PT XYZ. Inputs are defined as resources utilized by the DMU or conditions that affect the performance of the DMU.

Meanwhile, the output is a benefit resulting from DMU operation activities. The explanation of the input and output parameters in the concrete iron production units were obtained based on brainstorming and literature studies. The following is an explanation of the input and output parameters used in this study.

1. Raw material input parameters. The primary raw material to produce concrete iron billets. The billets used are imported billets imported from China and billets produced by PT XYZ in the steel melting production units. The cost of production and procurement of expensive raw materials is a consideration to make the most of raw materials. Thus, billets, as the primary raw material for steel production, can be identified as a production variable that affects steel production performance. Therefore, billets can be used as one of the input parameters in measuring this efficiency.
2. Labor input parameters. Almost all concrete iron production processes are carried out using machines under the supervision of the production and maintenance of machines carried out by human workers. Thus, the use of labor is still the main thing for the steel industry in general. However, the number of workers must still be adjusted to the needs not to reduce production performance. Therefore, the worker can be used as one of the input parameters in measuring this efficiency.
3. Natural gas energy usage parameters. The steel industry is one of the energy-intensive industries. The use of energy in natural gas is needed as fuel in the billet heating process, which is one of the crucial steps in producing steel. During this process, the billets are heated to a temperature of about 1200^{0}C. To then go to the rolling process stage. Excessive energy use will increase production costs, and conversely, using too little energy will cause product failure. Therefore, the use of energy in natural gas is one of the input parameters in measuring this efficiency.
4. The use of energy in the form of electricity. As an energy-intensive industry, electrical energy plays a vital role in the stages of the concrete iron production process. Electrical energy is a driving force for almost all machines in the concrete iron production process and fuel in the billet heating process. Excessive use of electricity will increase production costs, and conversely, the use of less than needed electricity will cause product failure. Therefore, the use of energy in the form of electricity is one of the input parameters in measuring this efficiency.
5. The output parameter is the number of concrete iron products. The number of concrete iron products produced can assess the concrete iron production process's success. In general, implementing concrete iron production activities produces concrete iron in optimal quantities to maximize profits. Therefore, the number of concrete iron products can be used as an output parameter to evaluate the performance's performance and measure efficiency in this study.

The mathematical model of calculating efficiency between DMUs uses the input-oriented CRS model. Each model has one objective function and thirteen limiting functions. The first limiting function represents the total number of computed DMU inputs. In contrast, the second to thirteenth limiting function represents input and output for each DMU. Calculating the value of efficiency, input slack, output shortfall, and lambda in this study will be carried out using MaxDEA Basic 6.4 software.

IV. FINDING AND DISCUSSION

The calculation of the efficiency value of each DMU in the last six years showed that eight DMUs were not efficient. Inefficient DMU shows an excess of at least one or more resource use (input) to the resulting output. Input parameters used are labor, raw materials (billets), LNG, and electricity. Each of these inputs contributes to the cause of the inefficiency of the DMU. Figure 1 shows the large contribution of input parameters that causes the inefficiency of the inefficient DMU. The contribution of the input parameters that causes DMU inefficiency is obtained from the calculation of potential improvement, namely the difference between the actual amount of use of each input parameter and the optimal amount of use of each input parameter to the resulting output, the concrete iron.

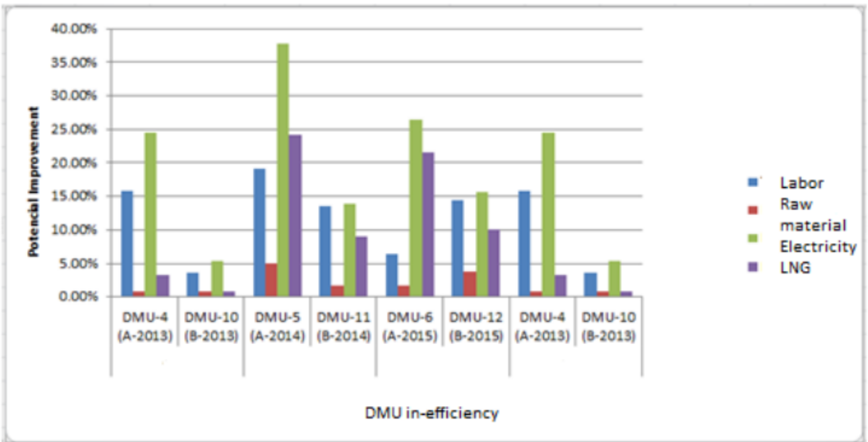

Figure 1. Contribution of input parameters to the causes of inefficiency

Based on this figure, it can be seen that the input parameters that contribute to the inefficiency of the DMU inefficient are different every year. For DMU-2 (A-2011), DMU-1 (A-2012), DMU-4 (A-2013), and DMU-10 (B-2013), the dominant causes of inefficiency are the use of electrical energy and labor. Production disturbances cause inefficiency in the use of electrical energy. Meanwhile, labor inefficiency is more due to the company's human resource management in hiring employees where the company's employees are divided into two, namely outsourcing and permanent employees. As an energy-intensive industry, the use of input variables in LNG and electricity is the main thing in the production process other than raw materials. It is in line with Hu & Wang (2006), Wei et al. (2007), and Soepardi et al. (2018). However, the use of LNG and electricity energy is precisely the most significant cause of DMU inefficiency. Therefore, indications of the causes of inefficiency in LNG and electricity energy will be explained as follows.

1. Use of input parameters in the form of LNG. The gas is the fuel in the billet heating process. The billet heating process occurs in the reheating furnace machine. The billet process is one of the most critical stages in the production process. The billet is heated until it reaches a temperature of about 1200^{0}C. After the heating process, the billets will undergo a rolling process until the packaging process. The rolling process is changing the shape and size of the billet into concrete with the diameter of the order. The rolling process in each production kitchen is carried out by a rolling machine or a roll stand. Steel production kitchens 1 (rolling mills 1) have 19 roll stands, and concrete iron production kitchens 2 (rolling mills 2) have 16 roll stands. One of the causes of inefficiency in using LNG is the breakdown of the rolling machine (stand roll), which causes the production process to stop. However, the billet heating process will continue to maintain the stability of the billet temperature. This, of course, leads to wasteful use of LNG, and also the production of concrete iron is not optimal because the rolling production process has stopped. Figure 4.21 shows the total rolling machine breakdown time each year in the last six years.
2. Use of input parameters in the form of electricity. Electricity plays a role in the healing process of billets to produce wind on the reheating furnace's burners. The wind comes from the fan in the reheating furnace, and the fan is turned on using electricity from a DC motor. Also,

electricity is the driving force of all machines in the production process, including the standing roll, which is turned on using electricity from a DC motor. Each roll stand has a DC motor to supply electricity. As with LNG's inefficiency, one of the causes of inefficiency in electricity use is the breakdown of the rolling machine (stand roll), which causes the rolling billet production process to stop. In contrast, the billet heat process continues and the use of electric power as a driving force because the rolling machine is unstable due to the halt of the production process at various times. It is known that during the breakdown time, the rolling process will stop while the heating process will remain.

A rolling machine or stand a roll is a machine used in the production process stages in a rolling line. The rolling line consists of three phases: roughing mills, intermediate mills, and finishing mills. The production process stages in the rolling line will change the billet's shape and size into concrete with the order's diameter. The rolling or stand roll machine consists of several constituent components: the bearing, gap¸ exit adjuster and entry guide, caliber, and coupling. When a breakdown occurs in the rolling machine's constituent components, the rolling line's production process stages will stop. As a result of the production process at the rolling line stopping, among others, is the next stage of the production process, namely the finishing facility, which is the process of cutting billets according to orders, the inspection process until the packaging process of rebar will also stop so that no iron is produced within a specific time.

Meanwhile, there will be billets wasted due to a rolling machine breakdown. Because it is known that, if during the production process and there is a breakdown, the rolling machine will not be able to crank the billets that are being processed. As a result, the billets will be thrown upwards out of the machine and cannot be reprocessed. Another consequence is, even though the production process stops, the billet heating process or the reheating furnace process will continue to burn. Thus, there is waste or inefficiency in the use of LNG and electricity.

One way to optimize the use of input parameters under the calculations using the DEA method is to minimize breakdowns on rolling machines. If the frequency of rolling machine breakdown occurs, it can reduce the amount of inefficiency or waste in input parameters. The next step is to identify the causes of DMU inefficiency caused by inefficiency or wasteful use of input parameters, especially LNG and electricity, which have the most significant potential improvement value. As previously explained, the rolling machine consists of several components. The first component with the most significant breakdown frequency is the bearing on the rolling machine or the standing roll. The breakdown in the first bearing is installing the bearing on the roller shaft, which still uses the Special Service Tool (SST) method. This method uses a unique tool called a hammer, which functions to hit the bearings to enter and be attached to the roller shaft. However, this method can damage both the bearing itself and the scratching of the roller shaft surface. This is because the force of the hammer that is received by the bearing area will vary, depending on the workforce's strength in charge of attaching the bearing to the roller shaft.

Therefore, one of the prevention is to replace the SST method using a device called press fit. This tool will work by pressing with the same amount of force in each bearing area to bear damage, and scratching of the roller shaft will not occur. The second cause of the breakdown in bearings is inconsistency in the work team whose task is to lubricate the bearings at the beginning of the first shift, checking bearing components, and monitoring the production process every shift change. Inconsistency of the work team in lubricating and checking rolling machine components occurs in the bearing component and occurs in the adjuster gap, and exit and entry guide components. So, one of the prevention is to conduct periodic training for the workforce.

Labor becomes one of the input parameters for calculating the efficiency value of each DMU. This is because labor is one of the factors that cause a breakdown in the rolling machine so that the production process will stop for a while and cause billets not to be rolled to become concrete iron. Also, it causes waste or inefficiency in using LNG and electricity as fuel in the billet heating process, which will not stop even though the production process at the next stage is stopped.

The third cause of a breakdown in the bearing is misalignment, which is the misalignment of the right and left bearing positions. The cause of misalignment is that the bolts on the bearings cannot withstand the vibration's magnitude in the production process. The bolts' inability to withstand vibrations is caused by the bolt tightening process, which uses the conventional method, namely human labor. This can happen because the strength of the bolt tightening varies between workers. Therefore, one prevention is to use a tool called a hydraulic tension bolt. A tool will tighten high-quality bolts by providing rotational strength to tighten the bolts according to existing standards. It is known that the types of bolts used in rolling machines are high-quality bolts with grade 8.8 of various sizes.

The next rolling machine component that experiences a breakdown is the coupling. The breakdown that occurs in the coupling is caused by the lifetime of the tool. Where should the coupling's lifetime be for two years but entering the lifetime of four years, the coupling components are still used. The coupling's high purchase price has become one of the considerations for the company's management not to buy new spare parts but instead prefers to continue making repairs when the coupling breaks down. One of the precautions to minimize the breakdown frequency on the coupling is buying new spare parts. Therefore, it is expected that the frequency of the coupling breakdown can be minimized to minimize the interruption of the production process. The next component is the caliber. The caliber's cause to experience a breakdown is the work team's inconsistency in recording the number of billets that have been rolled by that caliber—the capacity for each caliber as 250 tons. Therefore, preventing the breakdown from occurring, which causes the workforce to do repeated training for the workforce.

V. CONCLUSION AND FURTHER RESEARCH

The efficiency value less form one means that all or part of the resources used have not been used optimally and do not have the best comparison with the output produced. The input variable contributing to DMU inefficiency from the largest to the smallest is natural gas, electricity, labor, and raw material inputs. As an energy-intensive industry, natural gas and electricity are the main things used in the production process other than raw materials and labor. However, it is precisely the use of natural gas and electricity energy as input parameters that is the most significant contributor to the DMU's inefficiency. However, all types of input parameters have potential improvement values. There was still waste or inefficiency in the use of input parameters to the resulting output. The factors that cause waste or inefficiency in the use of input parameters are the breakdown of the rolling machine, or it can be called a standing roll. We suggest further research to be conducted for many steel industries in Indonesia to promote a more comprehensive understanding of efficiency evaluation.

REFERENCES

AAAT-Agency for The Assessment and Application of Technology. (, 2013). Planning of Energy Efficiency and Elasticity 2013. (In Indonesian).

Hu, J. L., & Wang, S. C. (2006). Total-factor energy efficiency of regions in China. *Energy Policy*, *34*(17), 3206-3217.

IISIA-Indonesia Iron Steel Industry Association. (, 2015). Role and prospect of the national steel industry. (in Indonesian).

Ramanathan, R. (2003). *An introduction to data envelopment analysis: a tool for performance measurement*. Sage.

Smirlis, Y. G., Maragos, E. K., & Despotis, D. K. (2006). Data envelopment analysis with missing values: An interval DEA approach. *Applied Mathematics and Computation*, *177*(1), 1-10.

Soepardi, A., Pratikto, P., Santoso, P. B., Tama, I. P., & Thollander, P. (2018). Linking of barriers to energy efficiency improvement in Indonesia's steel industry. *Energies*, *11*(1), 234.

Wei, Y. M., Liao, H., & Fan, Y. (2007). An empirical analysis of energy efficiency in China's iron and steel sector. *Energy*, *32*(12), 2262-2270.

Wu, J., Chu, J., Sun, J., & Zhu, Q. (2016). DEA cross-efficiency evaluation based on Pareto improvement. *European Journal of Operational Research*, *248*(2), 571-579.

Efficiency Evaluation of the Rolling Mills Production: A Data Envelopment Analysis Approach

ORIGINALITY REPORT

8%	5%	6%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	"Biochar Making Machines Design for Increasing Food Security", Proceeding of LPPM UPN "Veteran" Yogyakarta Conference Series 2020 – Engineering and Science Series, 2020 Publication	1%
2	Submitted to School of Business and Management ITB Student Paper	1%
3	Submitted to UPN Veteran Yogyakarta Student Paper	1%
4	N H Nasution, S Efendi, Tulus. "Sensitivity Analysis in Data Envelopment Analysis for Interval Data", Journal of Physics: Conference Series, 2019 Publication	1%
5	Submitted to Universiti Malaysia Pahang Student Paper	1%
6	www.researchgate.net Internet Source	1%

7	A. Soepardi, M. Chaeron, G. Wijiatmoko. "Barriers to Improved Energy Efficiency in The Indonesian Steel Industry: Empirical Evidence", 2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 2019 Publication	<1%
8	journal.iaincurup.ac.id Internet Source	<1%
9	repository.unri.ac.id Internet Source	<1%
10	Apriani Soepardi, Pratikto Pratikto, Purnomo Santoso, Ishardita Tama, Patrik Thollander. "Linking of Barriers to Energy Efficiency Improvement in Indonesia's Steel Industry", Energies, 2018 Publication	<1%
11	Jean Carlos Cardoso, Ana Carolina Petit Inthurn. "Easy and efficient chemical sterilization of the culture medium for in vitro growth of gerbera using chlorine dioxide (ClO2)", Ornamental Horticulture, 2018 Publication	<1%
12	Submitted to University of Westminster Student Paper	<1%
13	Zhao Yao, Yu Qing-bo, Li Rong. "Investigation on prediction of steel slab heating	<1%

characteristics in a walking beam heating furnace", 2011 IEEE 3rd International Conference on Communication Software and Networks, 2011
Publication

14	mail.palarch.nl Internet Source	<1 %
15	Apriani Soepardi, Patrik Thollander. "Analysis of Relationships among Organizational Barriers to Energy Efficiency Improvement: A Case Study in Indonesia’s Steel Industry", Sustainability, 2018 Publication	<1 %
16	Chu, Jun-Fei, Jie Wu, and Ma-Lin Song. "An SBM-DEA model with parallel computing design for environmental efficiency evaluation in the big data context: a transportation system application", Annals of Operations Research, 2016. Publication	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		