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# Analysis of Efficiency by Cost Curve Model on Local Government Water Supplies Companies in Indonesia

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***Abstract:*** *Many local government water supplies companies (PDAMs) in Indonesia set average price of water below its average cost that caused some losses. It is one of some causes of many unhealthy PDAMs. In this situation, generally they do not have a standard or good estimate of average cost of production which is important for setting the right fare. Hence it needed to compile the benchmark average production cost which can be used to review the production cost of each. Therefore, the cost curve model is used, after eliminating the data of outliers. Quadratic Curve Cost Model is more appropriate in describing the pattern of the average cost of production of drinking water in 330 PDAMs in Indonesia, so it can be used as a benchmark. The benchmark of average water production cost was Rp.3,332 /$m^3$, while the actual cost was Rp.3,629 /$m^3$. Therefore generally PDAMs in Indonesia operated a cost inefficient. There were 63.6% of PDAMs classified as inefficient, or just about 120 (36.4%) were classified as efficient. The relative number of PDAMs still had potential to increase the capacity and reach efficiency were 221 PDAMs, or about 67%. The other hands, a total of 109 PDAMs, which the production were above the average national production capacity, and about 33% PDAMs, will face diseconomies of scale conditions that are less favorable.*

***Keywords:*** *cost curve, benchmark, capacity of production, economies of scale.*

## Introduction

Local Government Water Supply Company (PDAM) is a company owned by the local government engaged in providing of drinking water to urban areas in Indonesia. As a business unit, the company manages asset separated from the government budget. The production mission is providing drinking water services and the business mission is PDAM is become one of local government revenue sources. However, the performance of PDAMs is generally low. The data in 2010 showed that from 341 PDAMs in Indonesia, there were only 34% categorized as healthy, while others are categorized as sick or unhealthy. It will threaten the sustainability of public access to drinking water and on the other hand to burden on local government budgets with the additional capital for PDAMs operational cost. Among the problems that cause unhealthy performance is the setting of drinking water fare which not in accordance with the laws of economics. Approximately 91% PDAMs, the average of water fare was set lower than the cost of production. This means that most of PDAMs have been loss due selling the water of production. This condition appears to be less well understood by the executive and the legislative as the owner and the supervisor, thus the PDAMs generally have difficulty adjusting to the cost of production rates. On the basis of these conditions, it is necessary estimates the basic cost of drinking water production that can be used as a benchmark of PDAMs in Indonesia to set the fares according to the capacity of each production.

## Problem Formulation

Because generally PDAMs in Indonesia set the average price lower than the cost of production, then the situation could threaten the sustainability of the public drinking water services and local government finances. The problem is that among the PDAMs did not have a reference or a benchmark of the production cost which appropriate to the each of production scale, so that the executive (as the owner) and legislative did not understand the situation and condition very well. To answer these problems, it will be developed a model to estimate the benchmark of production cost using cost theory approach. This production cost was the result of calculations based on data audit by BPKP (Financial and Development Supervisory Agency) in the form of cost production (full cost recovery). Estimation result of the production cost model was assumed as a benchmark level of efficiency based on empirical data. Because the result was a general pattern, then the analysis did not consider the uniqueness of each PDAM which can distinguish the efficiency of one another.

## Literature Review

### 1) Theory of Cost and Average Cost

Fare by theoretically is the price of a product (goods/services). For a company, the price is a signal of potential profit. At a certain price level, if market is competitive, then the company will try to streamline the cost of production so that the difference (margin) at a price is higher than the price of the product on the market. The more efficient a company to carry out the production, then the potential to take profits is greater too. According Lipczynski and Wilson (2004:44-51) were meant by the cost is:

*"costs refer to the payments or rewards made by firms to the suppliers of factors of production. It is important to note that costs simply reflect what is happening in production."*

In the cost analysis, there are three common approaches, namely (1) cost allocation analysis (2) cost-effectiveness analysis and cost-benefit analysis. In this research will be used cost allocation analysis approach. As disclosed in Sewell and Marczak (without year):

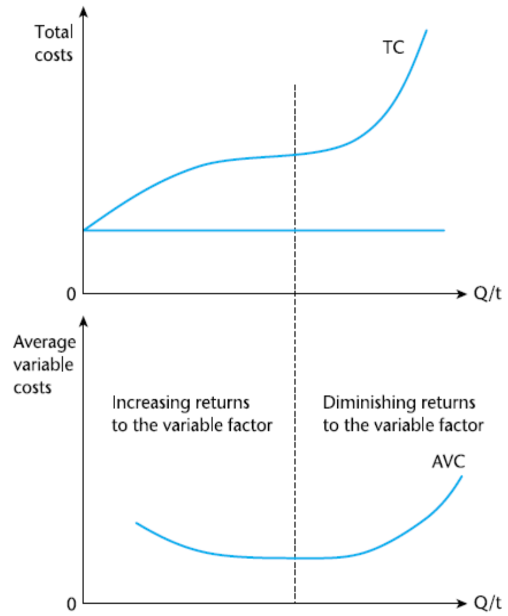
*"it basically means setting up a budgeting and accounting systems in a way that Allows program managers to Determine a unit cost or cost per unit of service. This information is primarily a management tool."*

The next stage in the analysis of cost is to convert it into the average cost, the total cost divided by the quantity of production. According Lipczynski and Wilson (2004:44-51), which is the average cost, the pattern changes and the implications are:

*"From this total cost curve we can derive an average variable cost curve. Average variable costs are calculated by dividing total costs by the units of the variable factor. Increasing returns to the variable factors mean that total costs are rising at a slow rate and thus average variable costs are falling. The firm is enjoying increasing efficiency by adding more of the variable factor. However, once diminishing returns to the variable factor sets in, the total cost curve begins to rise at a faster rate, roommates leads the average variable cost curve to rise. The firm begins to suffer from an inefficient combination of its variable factors with its fixed factors. If average cost becomes very high, the firm may have to consider increasing the other factors, such as plant and machinery."*

Average cost is very important for a company and practically is often known as the cost of production. The average cost is a basic component in determining the selling price of goods / services. The high average cost is not profitable for a company in a competitive market. Graphically, the process to obtain the average cost curve is taken from the total production cost curve. At low levels of production, the average cost is relatively large, and then decreases along with the increasing of production to the lowest point or it called the most efficient point. After that, if production continues to increase, gradually the average cost of production will continue to increase. See the following figure:

**Figure 1. Curve of Average Cost**




Traditional total cost curve and average variable cost curve

### 2) Water Fare

Water can be traced substantially from upstream to downstream. On the upstream side or raw water, the substance is classified as public or semi-public goods. Along with the processing and distribution that require investment and operational costs, the water that had been turned into clean water or drinking water is classified as private goods, which the utilization are exclusive and competitive. For private goods, the production cost of drinking water should be taken into account and set it rates. The price level of drinking water as well as other products should be set by considering the level of efficiency.

Furthermore, studies in China say water pricing policies that more consider on multiple aspects. The study in China is very important for drinking water fare in the system of water supply by PDAM in Indonesia. Regulations related to drinking water fares in China from the World Bank study (2007) are as follows:

*"The Administrative Regulation on Urban Water Supply Pricing, Introduced in 1998, provides a legal basis for water supply pricing in China. The regulation states that: 1) the general principles of setting water fares are "cost recovery, reasonable revenue, water conservation and social equity", 2) municipalities are responsible for approving water fares; 3) fares should cover operation and*

*maintenance, depreciation, and interest costs; 4) fares should allow for an 8 to 10 percent return on the net value of fixed assets, Depending on the sources of funds; 5) fares should be appropriate to local social characteristics and affordability; 6) a two-part fare consisting of a fixed demand charge and a volumetric charge or increasing block fare (IBT) should be Gradually Adopted; 7) the first block of IBT should meet the basic need of residents living; and 8) public hearings and notices should be conducted in the decision making process of setting water fares. To meet the objective of cost recovery, regular fare increases may be Necessary in many Chinese cities."*

Based on these considerations, the fare or price of water should be well defined as it relates to the broad aspects. In terms of fare setting is too low or even lower than the average cost of production, and then in the long term will have a negative impact on piped drinking water services and further threats to the quality of natural resources.

## Research Methods

### 1) Research Variable

There were two principal research variables, namely;

- **AC**: Average Cost, the average cost is taken from the Cost of Production for producing and distributing 1 $m^3$ of drinking water by PDAM.
- **Q** : Quantity of production, it is the effective production in accord with drinking water production capacity by PDAM in liters / sec.

### 2) Model

The structure models of both variables was using the theory of cost, with the following basic formula:

$$AC = f(Q)$$

This means that the average cost of production would be affected by the number or quantity of production. Operationalization of the model can be done in a variety of alternative forms. But if based on the cost theory, particularly average cost, it will be U-shaped. Therefore the possibility of the transformation model will be a quadratic form as following:

$$AC = b_0 + b_1Q \quad \text{.......................... (1) or}$$

$$AC = b_0 + b_1Q + b_2Q^2 \quad \text{............... (2)}$$

There were several techniques for obtaining estimates the average cost curve, namely Engineering Cost Estimates, Statistical Cost, Survivor technique, and Rate of Return. Further cost statistical method described as in Lipczynski and Wilson (2004:35-44):

*"This approach does not use the data hypothetical but actual data. A sample of firms in an industry is selected and an average cost for each firm as well as its size is calculated and plotted on a graph. One then draws a curve of best fit by regression analysis."*

This method was chosen by the following considerations:

1. Can be done using secondary data based on actual data.
2. Available data about 355 PDAMs, so that available in many options of production capacity with cross section data analysis.
3. The results can be used as a PDAMs benchmark in Indonesia based on the position of the yield curve studies.

However, several weaknesses in this study are (1) these were not distinguish more deep on the characteristics of each PDAM, such as the sources of raw water are from rivers, wells or springs (2) the use of term efficiency was not considered as actual trait or technical engineering opportunities.

### 3) Research Design

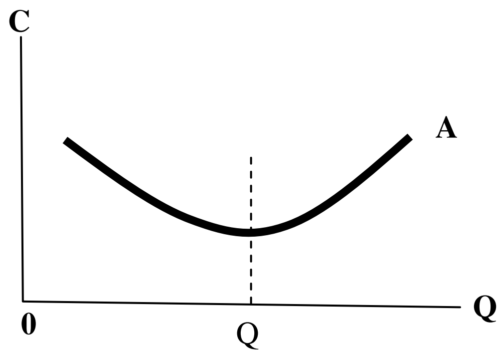
a. Data Collection Techniques

Data of this study consists of secondary data and primary data. Secondary data were obtained from all of PDAMs data in Indonesia from Support Agency of Water Supply System Development (BPPSPAM), Indonesian Ministry of Public Works in 2011. In addition to secondary data, also it will be interviewed the advisor at the agency, which aimed to obtain empirical and technical information relating to the cost of production and the fare of drinking water on PDAMs in Indonesia.

b. Data Analysis

The analysis will be based on a cross section of 341 PDAMs in Indonesia. The technique used to process the data was regression technique. Linearity and complexity of the regression will be suspected based on existing data. The chances are multiple linear or non-linear and simple regressions with only one variable or multiple regressions with the same variables, but the pattern was different. Beforehand, the existing data will be conducted by econometric tests such as tests of multicollinearity, heteroscedasticity and autoregresi. These tests were intended to eliminate the factors that can make biased regression. After econometric test, then the obtained regression model was tested by applying (1) t-test: to test the significance of the independent variables partially (2) F-test: to test the significance of the independent variables simultaneously and (3) to determine the coefficient of determination relationships or correlations based on the variation between the independent variables and the dependent variable. Thereafter, the obtained models were relatively fit and then can be interpreted the results. Models that fit then assumed to be the most efficient pattern in producing and distributing drinking water based on empirical data. From the equation obtained, it can be interpreted in four important areas, as shown in the following figure:

**Figure 2. Interpretation of Efficiency According to Area**




Explanation of the four areas are:

1. Areas above the regression line, showing PDAMs are relatively less efficient at the cost of potable water production. The number of PDAMs in this position can be calculated, so it can be known how many percent of PDAMs in Indonesia which are less efficient at producing.
2. The area under the regression line, showing PDAMs are relatively more efficient at the cost of potable water production. The number of PDAMs in this position can be calculated, so it can be known how many percent of PDAM in Indonesia are efficient at producing.
3. The left areas at the minimum point of the AC curve, showing that PDAMs can increase economies of scale, as the increase in the production of potable water. This applies when the curve AC is nonlinear.
4. The right areas at the right of the minimum point of the AC curve, showing PDAMS can feel the reduction in economies of scale, as the increase in the production of drinking water. This is true when the non-linear curve AC.

Based on those four areas, the policy implications of PDAMs will be more obvious, especially in terms of production cost efficiency and drinking water fare that has been set. In analysis of each area will be strengthened by an unstructured interview with BPPSPAM advisor at the Ministry of Public Works, including to explore the potential to make differentiations and cost reductions, which eventually will change the positions of average cost curve.

## Discussion

### 1) Production and Production Costs of The PDAMs

Local government Water Supplies Company (PDAM) is a company owned by local governments (cities) which produces drinking water or clean water. As a government owned enterprises in the provision of basic needs: water, PDAMs are always guided by the (central) government through various agencies, including the Ministry of Public Works as a technical advisor. Ministry of Public Works through the Support Agency of Water Supply System Development (BPPSPAM) always measures the health performance of PDAMs in Indonesia. PDAMs in Indonesia in 2011 were totally 391. From all of PDAMs, a number of 335 have been assessed its performance by the Ministry of Public Works (BPPSPAM) in 2011, based on data from Finance and Development Supervisory Agency (BPKP) audit in 2010. “Health” level of PDAMs was calculated based on the financial aspects, operation, service and human resources. The most distribution of PDAMs was in Java Island, which were 107 taps or approximately 31.9% of PDAMs in Indonesia. Those PDAMs served approximately 4.5 million subscribers or 57.5% of all customer connections in Indonesia. This was understandable, since the population centers are also on Java Island. The ratio of number of customer connections to the large number of PDAMs only occurs in Java. The ratio of the service in other areas was generally lower. The next highest number of PDAMs after Java Island was in Sumatra Island. The details can be seen in the following table:

**Table 1. The number of PDAMs and Total Customer Connections in 2010**

| Areas | Number of PDAM | % | Number of Customer Connections | % |
|---|---|---|---|---|
| Sumatera | 87 | 26,0 | 1.450.429 | 18,5 |
| Java | 107 | 31,9 | 4.512.143 | 57,5 |
| Bali-Nusa Tenggara | 29 | 8,7 | 501.793 | 6,4 |
| Borneo | 49 | 14,6 | 775.434 | 9,9 |
| Celebes | 46 | 13,7 | 504.561 | 6,4 |
| Moluccas-Papua | 17 | 5,1 | 97.144 | 1,2 |
| **TOTAL** | **335** | **100** | **7.841.505** | **100** |

*Source : BPPSPAM 2011 (data processed)*

Based on the level of performance, in 2002, there were only 9% PDAMs were “healthy”. Later in 2007, the "healthy" PDAMs were increased to 26% (of 306 companies) and then in 2010 reached 43% (of 335 companies). In the context of PDAMs as a company is formed to gain profit and have other function for providing clean water to the community, thus the fare are managed to have not a high profit margin, but it is enough to cover the investment and operational costs (full cost recovery). However, in reality many PDAMs did not applied a full cost recovery rates. In 2009, a total of 88.3% of PDAMs in Indonesia set a lower fare than the cost of production. In 2010, the percentage slightly dropped to 79.6%. It can be said that by 2010, these PDAMs mostly sell at a loss or set the water fare lower than the cost of production. Generally, Losses are closed by equity participation from local government or in the form of loans. This indicates that the level of sustainability of national water supply was experiencing a horrible threat.

### 2) Production Capacity and Cost of Production

Two variables studied were drinking water production (capacity) and cost of production (average cost of production). By using statistical methods, PDAMs can be classified into 10 classes of production groups. Classification results show that the disparity among the PDAMs production capacity in Indonesia is very large. Approximately 97.4% of PDAMs in Indonesia, its production capacity was small. This difference was related to the level of investment and service capabilities. Large production capacity will require greater investment and also have the opportunity to reach a wider range of services. The next is cost of production or average cost of production. Disparity in cost of production among PDAMs was not too large compared to the disparity in production capacity. For both of these can be seen from the following two tables:

**Table 2. Classification of PDAM by Total Production Capacity in 2010**

| Class | Production (liter/second) | Number of PDAM | % |
|---|---|---|---|
| 1 | < 1.789 | 332 | 97,4 |
| 2 | 1.790 - 3.576 | 5 | 1,5 |
| 3 | 3.577 - 5.364 | 1 | 0,3 |
| 4 | 5.365 - 7.151 | 1 | 0,3 |
| 5 | 7.152 - 8.938 | - | - |
| 6 | 8.939 - 10.725 | 1 | 0,3 |
| 7 | 10.726 - 12.512 | - | - |
| 8 | 12.513 - 14.300 | - | - |
| 9 | 14.301 - 16.087 | - | - |
| 10 | 16.088 - 17.874 | 1 | 0,3 |
| | **Total** | **341** | **100** |

*Source : BPPSPAM 2011 (data processed)*

**Table 3. PDAM Classification by Production Cost in 2010**

| Class | Cost of Production ($Rp/m^3$) | Number of PDAM | % |
|---|---|---|---|
| 1 | 434 - 3.080 | 161 | 47,2 |
| 2 | 3.081 - 5.727 | 142 | 41,6 |
| 3 | 5.728 - 8.374 | 26 | 7,6 |
| 4 | 8.375 - 11.021 | 5 | 1,5 |
| 5 | 11.022 - 13.668 | 1 | 0,3 |
| 6 | 13.669 - 16.315 | 4 | 1,2 |
| 7 | 16.316 - 18.962 | 1 | 0,3 |
| 8 | 18.963 - 21.610 | - | - |
| 9 | 21.611 - 24.257 | - | - |
| 10 | 24.258 - 26.904 | 1 | 0,3 |
| | **Total** | **341** | **100** |

*Source : BPPSPAM 2011 (data processed)*

Based on these data, when the disparity between the data was too large, then for the purposes of data analysis needs to be selected. The data will be used in the first models, the outliers data must be removed first. The difference was too large (exceeds the outliers), indicates the need of a different approach. From both of these data, the tendency of biggest outliers was on production capacity data, when compared to the variable of production cost. Therefore the production capacity data will be used as a variable to be cleaned from the outliers. By eliminating the outliers data, it became 330 data of PDAMs were ready to processed. PDAMs that classified as outliers and were not included in the calculation process as follows:

**Table 4. PDAMs Outlier in 2010**

| No | Province | PDAM City / Regency | Production Capacity (liter/ second) |
|---|---|---|---|
| 1 | East Borneo | Samarinda City | 1.573 |
| 2 | West Java | Bekasi Regency | 1.643 |
| 3 | West Java | Bogor Regency | 1.802 |
| 4 | South Celebes | Makassar City | 2.340 |
| 5 | West Java | Bandung City | 2.487 |
| 6 | Mid Java | Semarang City | 2.574 |
| 7 | South Sumatera | Palembang | 3.202 |
| 8 | Banten | Tanggerang Regency | 4.572 |
| 9 | South Sumatera | Medan City | 5.891 |
| 10 | East Java | Surabaya City | 8.283 |
| 11 | DKI Jakarta | DKI Jakarta | 17.875 |

*Source : BPPSPAM 2011 (data processed)*

### 3) Production Cost Curve of The PDAMs

Based on the model-I was processed by using the data as many as 330 PDAMs in Indonesia, after eliminating the outliers data (11 PDAMs), the results of these calculations:

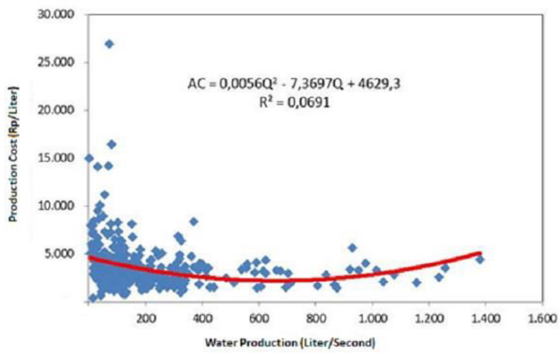
$$AC = 4027 - 1.90\ Q$$
$$(22.05)^{**}(-3.24)^{**}$$
$$R^2 = 0.031$$

From that model, the constants and the regression coefficient was highly significant in the average cost. The results of t-test show the numbers that beyond the table or the p-value was lower than 0.05. The regression coefficient indicates a negative sign. This means that the greater production capacity of drinking water in PDAMs, the average cost was getting smaller. Although the model was significant, but it did not shown the general pattern of the average cost curve. Therefore it needs to be calculated again on the average cost of the quadratic model-II following:

$$AC = 4629 – 7.37\ Q + 0.0056\ Q + Q^2$$
$$(19.0)\ {**}\ (-4.60)\ {**}\ (3.65)\ {**}$$
$$R^2 = 0.069$$
$$F = (12.1)\ {**}$$

When the equation in model-II was plotted into the image, it will be showed a general pattern of the average cost as appear as follows:

**Figure 3. Average Cost Curve of Water Production at PDAMs in Indonesia**




Model-II (quadratic) showed a pattern more in line with the Cost Curve and has a coefficient of determination ($R^2$) was higher than the model-I (linear). The coefficient of determination of models-I is 0.031, while model-II was 0.069 or more than doubled. This means that the second model more fit to the data distribution. Furthermore, partially, the constants and all the regression coefficients were also significant at a higher level. The constants of 4629 showed that the average fixed cost of water production in PDAMs connected to the customers in Indonesia was amounted Rp.4,629/$m^3$. Regression coefficient for Q and $Q^2$ was also very significant at a higher level, respectively -4.60 and 3.65. If there was additional production capacity of 1 liter/second, then the average cost will decline by Rp.7,26/$m^3$ of water. After production capacity reached 209 liters per second (average production capacity of 330 PDAMs), then slowly the average cost will increased. The characteristics of cost decrease after increase on production capacity was more powerful than the tendency of increased costs. These conditions indicate the better direction of efficiency on many PDAMs in Indonesia. Only from the aspect of the production, without considering other aspects such as technical efficiency, human resources, fixing water loss rate, etc., the PDAMs are still have opportunities to increase production capacity to serve the customer while enjoying an average reduction of production costs (economies of scale). From 330 PDAMs, a number of PDAMs which likely to increase capacity while enjoying efficiency were 221 PDAMs, or about 67%. A total of other 109 PDAMs, which the production was above the national average of production capacity, about 33% PDAMs, face the diseconomies of scale, and it was less favorable condition. Additional of production capacity, even will increased more the average cost of production, so the price of potential production was more expensive. On the type of PDAMs like this, focusing on other efficiency measures was very important. In general it can be said that the big PDAMs should make bigger efforts to improve the efficiency, or make additional investments on long-term production capacity. The additional on large production capacity in the long term will facilitate to achieve economies of scale or production efficiency also in the long term.

**Table 7. Benchmarking of Production Cost Average by Production Rate**

| Category of PDAM | Capacity (liter/ second) | Benchmark (Rp/$m^3$) | Actual [Production Cost] (Rp/$m^3$) |
|---|---|---|---|
| Q = average | 209 | 3,332 | 3,629 |
| Q < average | 93 | 3,990 | 3,958 |
| Q> average | 444 | 2,458 | 2,961 |

*Source : BPPSPAM 2011 (data processed)*

Based on categories above, then it can be arranged four group of PDAMs based on the position of the production number to the average position of the benchmark and the actual product cost. The best group position of PDAMs was position-1, which the PDAMs have a chance to enjoy economies of scale and also operating efficiently. Next was the toughest position, the position-4, where the PDAMs were not likely to enjoy economies of scale as well as not efficiently operating. A total number of PDAMs in best position (1) was 152 PDAMs or approximately 46.1%, while in the toughest position (4) there was 51 PDAMs or approximately 15.5%.

**Table 8. Group Category of PDAMs**

| Group Posi-tion | Category | Sum | % |
|---|---|---|---|
| 1 | Lower number of production * Efficient (Production Cost<Benchmark) | 152 | 46.1 |
| 2 | Bigger number of production * Efficient (Production | 58 | 17.6 |

| | | | |
|---|---|---|---|
| | Cost<Benchmark) | | |
| 3 | Lower number of production * Inefficient (Production Cost>Benchmark) | 69 | 20.9 |
| 4 | Bigger number of production * Inefficient (Production Cost>Benchmark) | 51 | 15.5 |
| | **Total** | **330** | **100** |

*Source : BPPSPAM 2011 (data processed)*
Note: (*) = in comparison with the average of national production number.

## Conclusions

1. Total production capacity of drinking water at PDAMs in Indonesia was very varied, which was many of them at low production capacity. Conversely, PDAMs at large production capacity was relatively few.
2. Quadratic Curve Cost Model was more appropriate in describing the pattern of the average cost of production of drinking water in 330 PDAMs in Indonesia, so it can be used as a benchmark.
3. The benchmark of average water production cost was Rp.3,332/$m^3$, while the actual cost was Rp.3,629/$m^3$. It means generally PDAMs in Indonesia operated a cost inefficient, which the benchmark was lower than the actual. There were 63.6% of PDAMs in Indonesia by comparison with the benchmark was considered inefficient, or just about 120 (36.4%) were classified as efficient as the average cost of production was lower than the average production cost of benchmark.
4. The number of PDAMs which likely to increase the production capacity while enjoying efficiency was 221 PDAMs, or about 67%. Another 109 PDAMs which the production was above the average of national production capacity, about 33% PDAMs were facing diseconomies of scale conditions that were less favorable.

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