

PAPER • OPEN ACCESS

## Assessing The Efficiency of Small and Medium Industry: An Application of Data Envelopment Analysis

To cite this article: S N W Pramono *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **598** 012043

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the **collection** - **download the first chapter of every title for free.**

# Assessing The Efficiency of Small and Medium Industry: An Application of Data Envelopment Analysis

S N W Pramono<sup>1</sup>, M M Ulkhaq<sup>1,2</sup>, D Pujotomo<sup>1</sup> and M A Ardhini<sup>1</sup>

<sup>1</sup>Department of Industrial Engineering, Diponegoro University, Semarang, Indonesia

<sup>2</sup>Jönköping International Business School, Jönköping University, Jönköping, Sweden

ulkhaq@live.undip.ac.id

**Abstract.** The educational toy business is one of the businesses with a good prospect and is expected to continuously grow. The estimated spending of educational toys in Central Java is 757,257 units per year. However, the local manufacturers can only fulfil 27% of the total needs, while the rest are filled by other manufacturers from Daerah Istimewa Yogyakarta or even from China. This is due to the high selling price, so it is less competitive compared to other competitors—according to the Chairman of “Asosiasi Penggiat Mainan Edukatif dan Tradisional Indonesia”. This high selling price is affected by high manufacturing cost caused by waste in resources usage; or in other words, low efficiency. This paper aims to investigate the relative efficiency of manufacturers’ education toys by employing the data envelopment analysis approach. Results show that three manufacturers are categorized as inefficient. Recommendations would be given so that the manufacturers could improve their efficiencies.

## 1. Introduction

Indonesia is one of the countries with the largest population in the world. The result of the 2010 population census showed that the population of children aged 0-14 years reached 68.6 million or 38% of the total population. The population of Indonesia increased to about 4.5 million people every year. This high birth rate becomes a potential market for children’s toys. There are many different types of toys that are circulating in the community, such as plastic toys, wooden toys, educational toys, and electronic toys. One type of toys that has a tremendous market potential is an educational toy.

The educational toy is a toy that is deliberately designed for the benefit of education. The goal is to optimize child development according to age and level of development, seen from the aspect of physical, cognitive, language, and social [1]. Unlike the gaming device in general, educational toys mostly found in early childhood education institute (ECEI).

According to the Central Agency on Statistics of Indonesia, the rate of growth of the population of Central Java Province increased 0.44% in the last ten years. A large number of ECEI, such as kindergartens, playgroups, and children’s daycare play a significant role in making the great needs of educational toys in Central Java Province. To support the learning activities, Ministry of Education and Culture each year provides funding of 10 million for each recipient for indoor educational toys.

With a great number of educational toys needed, manufacturers in Central Java Province was only able to produce 219,000 units per year or about 27% of 757,257 units in total demand. Based on the interviews with Chairman of “Asosiasi Penggiat Mainan Edukatif dan Tradisional Indonesia (APMETI)” of Central Java Province, because the price offered by the manufacturers is higher or less



competitive compared to the manufacturers of another area, such as Yogyakarta Province or even from foreign country, people prefer to buy from outside Central Java Province.

Expensive price of educational toys is caused by production inefficiencies that are shown in the waste of paint, waste of electricity workshop and the low level of labor productivity. The paint waste will have an impact on the cost of production because the paint is more expensive than regular paint as it contains a non-toxic material. Use of electricity is also quite significant to the costs of overhead due to various type of machines used, such as lathes, cutter machine, scroll saw, band saw, and planers. In addition, because the manufacturers are considered as a small and medium industry, they do not have formal organization rules, so the labors are often encountered idle in the middle of working hours. The low productivity of labor will certainly impede the production process. Machining process production is also hampered by events in the local area which resulted in the limited working hours and working days.

Based on the issues above, efficiency measurement of educational toys manufacturers in Central Java Province is required. It will determine whether they have been efficiently doing the production process or not. For measuring the efficiency, various methods have been proposed, for example parametric and non-parametric solution methods as well as ratio analysis. Among those methods, perhaps data envelopment analysis (DEA) proposed by [1] which is the non-parametric method has been widely applied. DEA, which is a linear programming-based method, is broadly utilized to determine the relative efficiencies of decision-making units (DMUs). It is used when inputs and outputs are a lot. DEA also might be implemented when the outputs have different measurement units [3][4]. Moreover, since it is a non-parametric method, DEA does not make any parametric assumptions related to the structure of the production function [5]. These flexibilities make DEA is preferable to other efficiency assessment methods (see [6][7][8] for the examples of the applications of DEA in various fields).

This paper aims to apply DEA to measure the relative efficiency of educational toys manufacturers. This method is used to compare and analyze the level of efficiency of the manufacturers by using their own inputs and outputs. After data processing, then it will be known which businesses are already efficient and which have not been efficient yet, as well as the evaluation of what should be adjusted refers to the business that is already efficient.

## 2. Research Design

DEA is a linear programming-based method for assessing the relative performance of organizational units (the units are regarded as DMUs) where there are numerous inputs and outputs that makes difficult to compare. DEA has no assumptions regarding to the distribution of inefficiencies or the functional form of the production function (though it enforces some technical restrictions such as monotonicity and convexity [9]). As a matter of fact, DEA utilises the input and output data to be calculated using linear programming method.

There are two basic approaches in DEA, namely, constant returns to scale (CRS) and variable returns to scale (VRS). The CRS model is regarded as the simplest form since there is no assumption that any positive or negative economies of scale exist. It is also well-known as CCR model, a name after Charnes, Cooper, and Rhodes, who was the first initiators [2]. The assumption used in this model is that a small unit should be able to operate as efficient as a large one. The second approach is closely related to the standard CRS approach as is evident in the dual of the VRS approach. This model is also known as BCC model, after Banker, Charnes, and Cooper [10]. The difference compared to the first is the introduction of the convexity condition. This additional constraint gives the frontiers piecewise linear and concave characteristics. This paper used the CCR model because the ratio of input and output addition is assumed to be equal.

Data collection is done by doing a direct observation into the field and interview with the owner of the small and medium industry of educational toys. The interview aims to dig information about the condition, problems faced by the manufacturers, turnover record last year, and input-output record for one month. Also collecting secondary data to support primary data information from the interview. Samples of this research were the small and medium industries which only produce educational toys (no

other wood processing industry, e.g., hand-crafted wood) and had a turnover with a range of IDR 100 million to 5 billion.

Data processing on this research will be conducted through several stages. First, determining the DMU, then identification of input and output, as well as the measurement of efficiency. DMU is unit which has operational characteristics in common. They became the object that will be measured. DMU which is referred to in this research was the small and medium industry which produce educational toys in Central Java Province.

The working principle of DEA is comparing the input and output of an organization. Input variables are the variables that affect output. In simply, efficiency measurement is stated with output/input. Input is resources used to produce educational toys, while the output is the final result of the production process. Based on the interview with the owners, the variables used in the research given in Table 1.

**Table 1.** Variables used in this research

	<b>Variables</b>	<b>Unit</b>
Inputs:	Wood ( $x_1$ )	Cubic
	Glue ( $x_2$ )	Kg
	Paint ( $x_3$ )	Kg
	Plastic ( $x_4$ )	Roll
	Electricity ( $x_5$ )	Kwh
	Labour ( $x_6$ )	Man hours
Output:	Production of educational toys ( $y$ )	Units

Each  $j$ th DMU ( $j = 1, 2, \dots, n$ ) is regarded to be a production unit that uses  $i$  inputs  $x_{ij}$  ( $i = 1, 2, \dots, m$ ) to produce an output  $y_j$  (note that there is only one output considered in this study). For a particular DMU  $j$ ,  $h_j$  is its efficiency;  $x_{ij}$  and  $y_j$  are its inputs and output; and  $v_j$  and  $u_{ij}$  are the calculated weights for the output and  $i$ th input. The model can be written in a linear programming problem (LPP) as the following:

$$\text{Maximize: } h_j = v_j y_j \quad (1)$$

$$\text{Subject to: } \sum_{i=1}^m u_i x_{ij} = 1 \quad (2)$$

$$v_j y_j - \sum_{i=1}^m u_i x_{ij} \leq 0 \quad (3)$$

$$v_j \geq 0, u_j \geq 0 \quad (4)$$

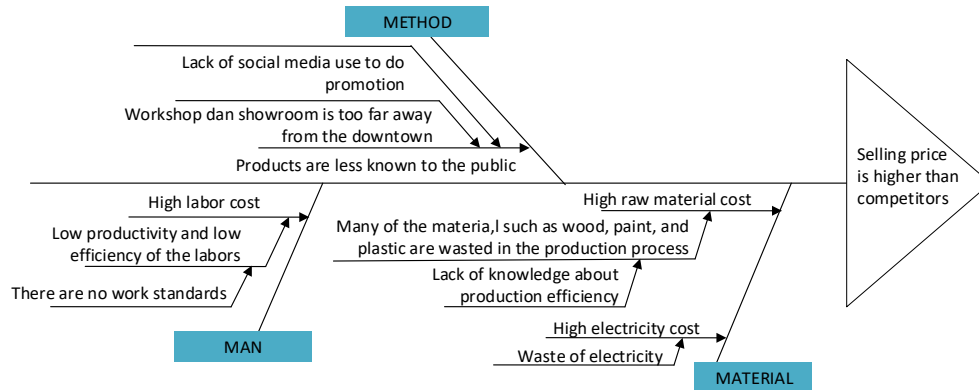
The LPP is solved for each DMU; thus, if there are  $n$  DMUs,  $n$  LPPs must be solved. Besides the efficiency index, DEA models yield the variables weights, benchmarks, and targets for the inefficient DMUs. The last two are decided from the values of the dual variables, that is, by the use of the complementary slack theorem or by solving the dual LPPs.

### 3. Case Study: Result and Discussion

To find out the problems in educational toys, an interview was conducted with the Chairman of APMETI of Central Java Province. Based on the interviews, we found the fact that the selling price of educational toys produced in Central Java Province is more expensive than the one produced in Yogyakarta Province or the one imported from countries like China. It makes them less competitive and this impact on the low interest in the public's buying. Consumers often switch on producers which are a lot cheaper although they are actually using paints that contain harmful substances. Problems that caused the product's price in Central Java higher than competitors described with fishbone, shown in Figure 1.

According to Figure 1, it can be concluded that the high price is due to the high cost of production, such as raw material costs, labor costs, and the cost of electricity. However, the output generated is not comparable to the high production cost. Meaning, there are inefficiencies in the production process

which are shown in the waste of raw materials and low productivity of the labors. After determining the DMUs, then identifying factors that affect the relative efficiency of educational toys manufacturers.



**Figure 1.** Problem Identification

**Table 2.** Recapitulation of Inputs and Output

DMU	Output		Inputs				
	Product (units)	Wood (cubic)	Glue (kg)	Paint (kg)	Plastic (roll)	Labor (man hours)	Electricity (Kwh)
1	750	1	0.3	0.25	2	1600	200
2	6000	5.36	60	0	3	768	306.69
3	700	3	1.5	5	0.3	1344	477
4	750	3	12	7	0.3	768	204.46
5	600	1	1.5	5	1	768	272.61
6	7500	5	20	25	3	3360	2403.7
7	1000	5	6	5	1	576	350
8	750	3	6	7	1	576	136.25
9	200	1	0.5	1	1	196	88.6

Through interviews with the owners of the small and medium industry, data was obtained which further grouped into input and output variable given in Table 2.

This research employed sistema integrado de apoio a decisão (SIAD) software v. 3.0. [11], a Portuguese version of an integrated system for decision support (ISYDS) to solve those LPPs. The software is capable of dealing with 150 DMUs, 20 variables (inputs or outputs), and works with a six decimals accuracy. Although for other research areas 150 units might be insufficient, this number is able to deal with the problem in this study. The software was used to measure technical efficiency of 9 small and medium industries in Central Java Province that manufacture educational toys. The results of the data processing showed the technical efficiency score for each DMU given in Table 3. It is the ability of economic units to produce up to the maximum level of output from inputs and constant technology.

Table 3 shows various type of level of efficiency attained by each DMU. There are 6 out of 9 DMU with  $TE_{CRS}$  score of 1, meaning the DMUs are already efficient. It indicates that the use of inputs in the production process to generate output has been already optimal. In the meantime, there are 3 DMUs that score less than 1, meaning they are inefficient: the use of inputs to generate output has not been optimal yet. They are Safari Toys, Creative, and Kesuma Toys. To achieve the perfect score of technical efficiency, Safari Toys and Kampung Creative should refer to Otak Atik Craft, UD Bangkit Jaya, and UD Sempulur. Meanwhile, Kesuma Toys refers to Rumah Puzzle and UD Sempulur. The selection of benchmark is based on proximity in the input and output indicators.

**Table 3.** Output of DEA

DMU	Small and Medium Industry	TE <sub>CRS</sub>	Benchmark
1	Rumah Puzzle	1	-
2	Otak Atik Craft	1	-
3	Freny Edu Toys	1	-
4	Salma Toys	1	-
5	UD Bangkit Jaya	1	-
6	UD Sempulur	1	-
7	Safari Toys	0.713222	2,5,6
8	Kampung Creative	0.710777	2,5,6
9	Kesuma Toys	0.856251	1,6

To improve efficiency, those 3 DMUs should follow recommendation based on the calculation by the software. Recommendations for improvements in terms of technically refers to improvements to the variables used in the data processing. The variables are the production factors that affect efficiency, referred to as inputs and output. Recommendations are made through calculation of slack results obtained by the software. Slack is the gap between the actual value of the use of inputs and output with a value of the target. In this study, DEA approach used input-oriented model so that improvements will be made by reducing the amount of use of the input variable as shown in Table 4.

**Table 4.** Recommendation for Improvements

DMU	Variable	Actual	Target	Slack	To reduced
Safari Toys	Wood	5	0.76	4.24	84.86%
	Glue	6	6.00	0.00	0.00%
	Paint	5	2.80	2.20	44.03%
	Plastic	1	0.47	0.53	52.69%
	Labor	576	576.00	0.00	0.00%
	Electricity	350	350.00	0.00	0.00%
Kampung Creative	Wood	3	0.78	2.22	74.00%
	Glue	6	6.00	0.00	0.00%
	Paint	7	2.50	4.50	64.30%
	Plastic	1	0.60	0.40	40.41%
	Labor	576	576.00	0.00	0.00%
	Electricity	136.25	136.25	0.00	0.00%
Kesuma Toys	Wood	1	0.16	0.84	83.57%
	Glue	0.5	0.50	0.00	0.00%
	Paint	1	0.53	0.47	47.26%
	Plastic	1	0.19	0.81	81.48%
	Labor	196	196.00	0.00	0.00%
	Electricity	88.6	61.60	27.00	30.47%

To achieve the target value and reduce the use of inputs, we compiled some recommendations for improvements that have been adapted to the real conditions in the field and can be applied by manufacturers of educational toys.

1. Wood. Before ordering, we recommend measuring the design pattern that will be created with the addition of cutting allowance so that the raw materials ordered are not too much or less. Then improve the cutting geometry. Try to set the spacing as best as you can so there are many empty sections. The distance between the pattern cut should be at least 4 mm because if it were less than 4 mm, then the delimiter will be very thin and will be gone in the finishing process. Also, try to reuse the residual of unused woods.

2. Paint. Before ordering, first, estimate the use of paint well so that the paint ordered are not too much or less. You may also replace brush paint with spray paint to make it more efficient and more evenly in the result. Another way to save on costs is to mix colors to produce new colors with the leftover paint. However, you should take note of the type of mixture and composition.
3. Plastics. Before doing the packing, measurements should be done and give the addition of allowance around 1 cm – 2 cm. The allowance will be shrinking in the shape of the toy when it's heated. For circular product, the circumference of the product divided by 2. It means that a product of 13 cm size will need plastic 6.5 cm or 8 cm width after the addition of allowance. For rectangular product, add width and height. For example, for product size 20 cm x 15 cm x 10 cm, then the width of the plastic required is 15 cm + 10 cm = 25 cm. Manufacturers can customize the purchase of plastic according to each toy. If not, keep using big-sized plastic (50 cm x 250 m) but set the cutting pattern to avoid a lot of waste. For big orders, they can hand the packaging to third parties. Another alternative is to replace the plastic with other substitution material, such as cardboard or container. Manufacturers can create their own container by using the excess woods.
4. Electricity. When you are finished using the tools, especially those that take a lot of electricity consumption like production machine, directly turn off and unplug the stop contact. Electronic tools still absorb electricity if stop contact is still connected.

#### 4. Conclusion

Relative efficiency measurement is performed using DEA approach to find out the efficiency score of educational toys manufacturers in Central Java Province. This research was conducted on 9 small and medium industry. The results show that there are 3 manufacturers in an inefficient category. They are Safari Toys with the score of 0.713222, Kampung Creative with the score of 0.710777, and Kesuma Toys with a score of 0.856251. The efficiency score is affected by the inputs and output of the production process. In this study, the inputs measured include the use of raw materials such as wood, paint, glue, and plastics. In addition, there is also the use of electricity and labor. The output of the process is the product of a puzzle and block. Improving performance may be done by following the slack calculation and refers to the benchmarks as the guideline. Because this study used input-oriented model, improvements will be made by reducing the use of input.

Relative efficiency measurement should be done periodically so that the manufacturers can do an evaluation of the company. This evaluation aims to keep the production process efficiently from a technical point of view. In addition, the manufacturers should pay attention to nontechnical things, such as developing the designing skill for product innovation and product promotions. The government also has an important role in helping open up opportunities through exhibits and restricting or limiting imported toys coming into Indonesia.

#### References

- [1] Tedjasaputra M S. 2007 *Bermain Mainan dan Permainan* (Jakarta: Grasindo) (in Bahasa Indonesia).
- [2] Charnes A, Cooper W W and Rhodes E. 1978 *Eur J. Oper. Res.* **2** 429-444.
- [3] Allen R and Thanassoulis E. 2004 *Eur. J. Oper. Res.* **154** 363-379.
- [4] Ramathan R. 2003 *An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement* (New Delhi: Sage Publications).
- [5] Reverte C and Guzman I. 2010 *Appl. Econ.* **42** 2751-2757.
- [6] Nabavi-Pelesaraei A, Abdi R, Rafiee S and Mobtaker H G. 2014 *J. Clean. Prod.* **65** 311-317.
- [7] Atici K B and Podinovski V V. 2015 *Omega* **54** 72-83.
- [8] Sari D P, Handayani N U, Ulkhaq M M, Budiawan W, Maharani D L and Ardi F. 2018 *MATEC Web of Conference* **204** 01015.
- [9] Färe R, Grosskopf S and Lovell C A K. 1994 *Production Frontiers* (Cambridge: Cambridge University Press).

- [10] Banker R D, Charnes A and Cooper W W. 1984 *Manage. Sci.* **30** 1078-1092.
- [11] Meza L A, Neto L B, de Mello J C C B S and Gomes E G. *Pesqui. Oper.* **25** 493-503.