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The quantitative eco-efficiency measurement for small and medium enterprise: a case study of wooden toy industry

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Abstract Eco-efficiency is a tool for the analysis of the sustainability of industries, which indicates the economic relationship and environmental impact. This research presents the development of eco-efficiency indicators for quantitative measurement of the wooden toy industry, as well as the raw material suppliers who are a part of the supply chain. The eco-efficiency of the wooden toy industry was measured by using the key indicators of the three axes of sustainable development, which are (i) economic indicator: net sale and gross margin, (ii) environmental indicator: material, energy, water consumption, waste disposal, and (iii) social indicator: frequency rate of accidents, local employment, and corporate social responsibility. Moreover, the combined eco-efficiency evaluation of the supplier and company showed that the company's eco-efficiency has likely increased during 2 years of observation, while the eco-efficiency of the supplier-company combination has decreased. The evaluation of socio-eco-efficiency results showed that the company has acquired a socially supportive management system at the company level, community level, and social level. This research can contribute to the improvement of the resource and process efficiencies in economic, environmental, and social dimensions. It can also provide a basic framework on eco-efficiency evaluation for the small and medium enterprises in Thailand, which will feed into policy and strategic development.

Keywords Eco-efficiency · Socio-eco-efficiency · Small and medium enterprise · Economic indicator · Environmental indicator · Social indicator · Supplier

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Introduction

Currently, capitalism under globalization has played an important role in the strategic development of countries, including Thailand. The invention of manufacturing processes and competition in production responding to human needs have caused the deterioration of natural resources and environment (Charmondusit and Keartpakpraek 2011). The economic development, growth of industry, and urban development have occurred all over the world. In the future, these situations are likely to increase as a result of technological developments and economic growth in the industry. The consequential impact is unavoidable, and it will take effect directly on the ecosystem. The impact on one system will have a chain reaction-type effect on other systems, because every system is linked. Pollution results from the consumption of materials in production and transportation, including waste emissions from industrial processes. These are a main cause of the environmental problems. Therefore, multiple parties have jointly attempted to resolve the issue. In the past, the proposed solutions to pollution problems, such as using new technology to treat the waste before emitting it into ecological and environmental systems, etc., did not hit the mark. On the contrary, those "solutions" adversely increased the production costs and product prices. Meanwhile, companies of

all sizes wanted to focus on profitability; thus, the environmental problems have continued to their current critical levels (Huppes and Ishikawa 2007).

The environmental conservation and prevention of possible pollution have become an emphasized issue and are of large concern among many countries around the world in which environmental contaminating pollutants are diligently avoided. There is a concept of waste reduction proposed on the principle of increasing the amount of finished products by reducing the production materials used in the manufacturing process. This concept helps to solve this core environmental problem by limiting the cost of waste disposal, which is due to the reduction in production materials used. Therefore, corporate environmental management is used to prevent and reduce those environmental impacts. As a result, the retention of profitable and social responsibilities would lead to sustainable development (Welford 1998).

The concept of sustainable development is related to the creation of triangular balance between the economic, environmental, and social dimensions. The World Commission on Environment and Development, also known as the Brundtland Commission, coined the most widely used definition of sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, WBCSD 1987).

Sustainable development of the industrial sector can create a balance between the economic and environmental dimensions, which allows free competition in the global market. This balance can produce profit for the organizations along with the prevention of environmental deterioration. These balancing acts are applied to be a theoretical principle called eco-efficiency (Sikdar 2007; Charmondusit 2008). The basic idea of this theoretical principle is to produce more with less impact on nature, and is measured as reduced emissions or reduced raw material consumption, or both. (Michelsen and Fet 2010)

Eco-efficiency is an important concept that can help governments, companies, or organizations attain better economic and environmental efficiency. The economic growth must be in line with the efficient utilization of resources and the reduction of pollution emissions to the environment. Eco-efficiency implementations are applied in the industrial sector, which can be useful as tools of management analysis and indicators leading to changes at the technical and policy levels. Eco-efficiency can be used at the industrial level in the industrial sector and industrial estates (Charmondusit 2009; Panyathanakun et al. 2013). In addition, in order to make the supply chain more efficient, eco-efficiency is evaluated in the supply chain, which can cover the whole system, not only the manufacturing process but also any point along the supply chain affecting the quality of products (Michelsen et al. 2006).

The concept of environmental management through the supply chain is widely applied when organizations utilize the environmental management standard framework, such as ISO 14001, to improve the environmental performance (Nawrocka et al. 2009). The processes in the supply chain are part of production costs. If these activities are managed efficiently, the production costs will be lower. If companies or organizations use eco-efficiency in their supply chain, their operating system, in terms of both economics and environmental protection, will be more efficient (Seuring et al. 2008).

This research aims to develop the eco-efficiency indicators, which can be used as an environmental tool for measuring wooden toy companies' status and further trends, for the evaluation of the wooden toy industry. It is a concept that may be utilized to meet current sustainable business development and measures in international trade, which opens major export markets for the company and focuses on reducing environmental impact. The expected results from this research can contribute to the improvement of the process efficiency in economic and environmental dimensions. Moreover, implementation of eco-efficiency concepts could be applied to evaluate industrial supply chains. It can also be utilized to help guide other small and medium enterprises (SMEs) similar to the wooden toy industry and can be used as assessment data for policy makers and management strategy of companies in the future.

Methodology

System boundary and data collection

The wooden toy manufacturing plant of the Plan Creations Co., Ltd., which is located in Thailand's southern Trang Province, was selected for the case study. The system boundary, which focused on the entire life cycle of wooden toy products, was then specified. Data collection was mainly done by field site investigation. The research form was based on primary and secondary data. Primary data were acquired by the scientific measurement in the manufacturing plant of the Plan Creations Co., Ltd. Secondary data were gathered from the monitoring reports and data of suppliers in the supply chain. The eco-efficiency evaluation was based on the data collection over the period from 2006 to 2008.

Indicators

In order to measure the sustainability, progress of the company, economic, environmental, and social indicators

were developed. SMEs in Thailand are required to submit annual reports of their basic financial data, such as net sales and gross margin, to the Ministry of Commerce. However, they are not required to report value added, and as such, this is not a well-reported or easily attainable financial data. Therefore, net sales and gross margin were selected as economic indicators. Net sale is defined as the total recorded sales. Gross margin is defined as the net sales minus costs of goods and services sold. The general indicators (based on the input–output of a system), such as material consumption, energy consumption, water consumption, and waste generation, were employed as environmental indicators.

The social indicators at various levels (company, community, and social) were developed. It was noted that many social indicators are subjective and qualitative (Hutchins and Sutherland 2008). The social indicators, which are safety, health, equity, and philanthropy, have been proposed and can be effectively utilized in decision-making related to supply chains (Hutchins and Sutherland 2008; Tsuda and Takaoka 2006). At the company level, the importance to safety for workers was a main focus, especially within the manufacturing industry. Without careful safety and adequate prevention, there would be damage to workers, raw materials and production machines, which would produce negative effects as a whole (Clift 2003). In addition, international trade employs the work safety issue as a commercial barrier because work safety is fundamental to increase the production quality. In this study, accident frequency rate was selected as a social indicator at the company level. The measurement of safety in the operation of workers referred to 1,000,000 working hours.

Community development is a critical government policy to improve the quality of life in both urban and rural areas. Community development problems could be resolved by way of well-being, equality, community self-reliance, employment, and wiping out the poverty in the community. Thus, supporting community employment increases the likelihood of public revenue, distribution of income into the community, and a better economic community. Therefore, the local employment was selected as a social indicator at the community level of this study.

Businesses are managed with the aim of creating profits and economic growth. The business sustainability not only means benefits or profit of organizations but returns of profits to society. Currently, businesses must operate in conjunction with corporate social responsibility (CSR) in order to provide benefits to people and society. Therefore, CSR was selected as a social indicator at the social level, which can identify business effectiveness and sustainability. The summarization of all indicators, including economic, environment and social, is illustrated in Fig. 1.

Eco-efficiency measurement

The measurement of eco-efficiency in this research was based on The World Business Council for Sustainable Development (WBCSD) guidelines and previous literature (Lehni 1998; World Business Council for Sustainable Development, WBCSD 2000; Kharel and Charmondusit 2008; Thant and Charmondusit 2010) on a ratio relationship to compare the economic values and environmental impact. The equation is as follows:

$$\mathrm{EE}\ (\mathrm{n}) = \frac{\mathrm{EV}}{\mathrm{EN_m}} \tag{1}$$

where EE is Eco-efficiency, and "n" is type of eco-efficiency indicators.

EV is an economic performance indicator in units of baht (B), and the environmental performance indicator is referred to by $\mathrm{EN_m}$. "m" is type of environmental influences of the wooden toy industry. Net sales and gross margin in units of baht (B) were used as indicators for economic performance. Material consumption in tons (T),

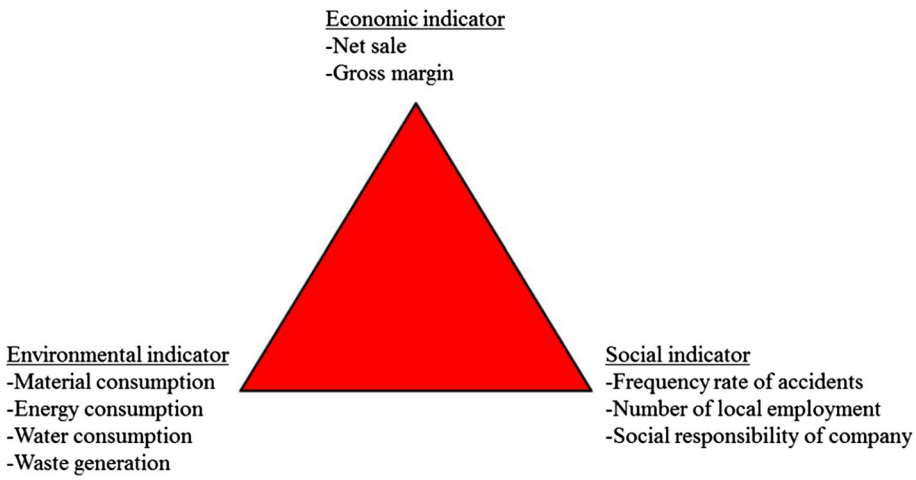

Fig. 1 The summarization of all indicators including economic, environment and social

energy consumption in mega joules (MJ), water consumption in cubic meters (m^3), and waste in tons (T) were used as indicators for environmental performance as illustrated in Table 1.

Eco-efficiency evaluation in suppliers and company

In this research, the combined eco-efficiency evaluation of suppliers and company was considered. The raw materials injected by the suppliers into the production process are important because if they are of bad quality and not environmentally friendly, even if they are manufactured with innovative machines and tools, the product quality and production cost would be adversely affected. In order to examine the effects of supplier on the company performance, the eco-efficiency of the suppliers-company combination was evaluated and can be expressed as the following equation:

$$EE_{SC}(n) = EE_S(n) + EE_C(n) \quad (2)$$

where EE_{SC} is the eco-efficiency values of the suppliers-company combination in "n" type of eco-efficiency indicators; $EE_S$is the eco-efficiency values of the suppliers in "n" type of eco-efficiency indicators; EE_C is the eco-efficiency values of the company in "n" type of eco-efficiency indicators

Socio-eco-efficiency

We know that eco-efficiency is fundamentally a ratio of some measure of economic value to some measure of environmental impact, which is the ability to combine performance along two of the three axes of sustainable development. However, a third axes, the social dimension, is needed for a complete measurement of sustainable development. Therefore, the socio-eco-efficiency, which includes the issue concerning social property, was proposed as follows:

$$\begin{aligned}&\text{Socio - eco - efficiency}\\ &= \left(\frac{\text{Economic value}}{\text{Sum of weighted environmental values}}\right)\\ &\quad \times \text{Sum of weighted social values}\end{aligned} \quad (3)$$

The input values for this equation need to represent the total value of economic, environment, and social indicators of all categories in each year. So, the methodology for calculation of the total values was then adopted from the normalization method for eco-efficiency analysis by BASF (Saling et al. 2002). The environmental and social indicators were normalized by using the weighting values as summarized in Table 2.

Finally, the factor, which is a ratio of the comparison between the socio-eco-efficiency of the evaluated year and the socio-eco-efficiency of the reference year, was applied to measure the improvement of the company.

Results and discussion

Economic measurement of the company

In calculating eco-efficiency, economic indicators involved the net sale and gross margin. The economic measurement, by using net sale and gross margin as indicators, explained that the gross margin value was lower than the net sale value as shown in Fig. 2. In addition, the differences between net sales and gross margin were due to the fact that the gross margin term does include fluctuating material costs, and thus, does not vary as much. Therefore, the gross margin can better reflect the true economic situation of the company.

The economic data over the 2006–2008 period in Fig. 2 showed that the net sales values rose by 54.65 % from 2006 to 2007, and 23.64 % from 2007 to 2008. At the same time, the gross margin rose by 61.34 % from 2006 to 2007 and by 57.67 % from 2007 to 2008. Therefore, it is apparent that the economic indicators likely increased from

Table 1 Calculation of the proposed environmental indicators

Indicator	Equation	Terms
Material	$EE(M) = \frac{EV}{\sum_{t=1}^{r} M_t} = \frac{EV}{(M_1 x CF_1 + M_2 x CF_2 + \cdots + M_n x CF_r)}$	(M_1, M_2, …, M_n) represents various materials and (CF_1, CF_2 … CF_r) means relevant conversion factors used to convert all the materials into common unit of Ton (T).
Energy	$EE(E) = \frac{EV}{\sum_{t=1}^{r} E_t} = \frac{EV}{(E_1 x CF_1 + E_2 x CF_2 + \cdots + E_n x CF_r)}$	(E_1, E_2, …, E_n) represents energy used in process and (CF_1, CF_2, …, CF_r) means relevant conversion factors utilized to convert all the energy sources into common unit of mega joules (MJ)
Water	$EE(W) = \frac{EV}{\sum_{t=1}^{r} W_t} = \frac{EV}{(W_1 + W_2 + \cdots + W_n)}$	(W_1, W_2, …, W_n) represents water used in process evaluated in cubic meter (m^3)
Waste	$EE(W_s) = \frac{EV}{\sum_{t=1}^{r} W_{s_t}} = \frac{EV}{(W_{s_1} + W_{s_2} + \cdots + W_{sn})}$	(W_{s_1}, W_{s_2}, …, W_{s_n}) represents various wastes generation evaluated in Ton (T)

Table 2 Weighting values

Indicators	Weighting value (%)
Environmental indicators	
Material consumption	0.25
Energy consumption	0.25
Water consumption	0.25
Waste generation	0.25
Social indicators	
Accident frequency rate	0.33
The number of local employment	0.33
CSR	0.33

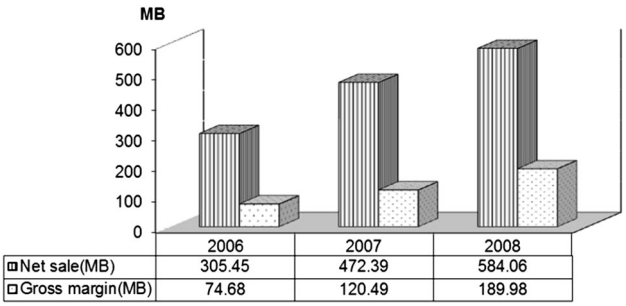

Fig. 2 The economic indicators (net sale and gross margin) over the period of year 2006–2008

2006 to 2008 as a result of the rising product sales in alignment with consumers' demands. However, as the company's main products were exported to foreign markets, the fluctuation of the foreign exchange rates affected the change in economic indicators of the company.

Eco-efficiency measurement of the company and the suppliers-company combination

Material eco-efficiency indicator

The evaluation of the material eco-efficiency indicator is to assess the ratio of economic value in millions of baht (MB) and materials utilized in tons (T). Figure 3 illustrates that the material eco-efficiencies in the net sales term increased by 16.22 % in 2006–2007 and 26.74 % in 2007–2008 with increased productions. The tendency of the material eco-efficiency in the gross margin was the same as that of the material eco-efficiency in the net sales. It increased by 22.22 % from 2006 to 2007 and 59.09 % from 2007 to 2008 as illustrated in Fig. 4. The material consumption and economic value of products increased from 2006 to 2008 because of the increasing market demand. The increasing material consumption was consistent with continuously increasing production. Overall, the tendency of both eco-efficiency indicators was in the ascending approach.

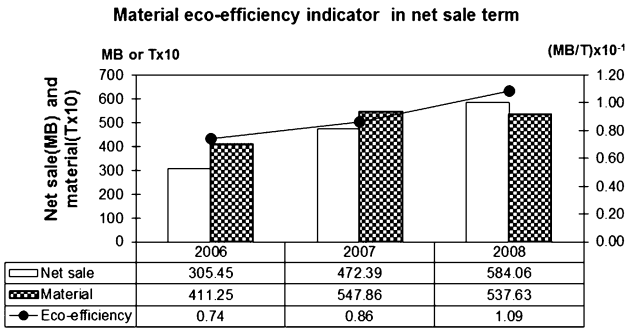

Fig. 3 Material eco-efficiency indicator in term of net sale value

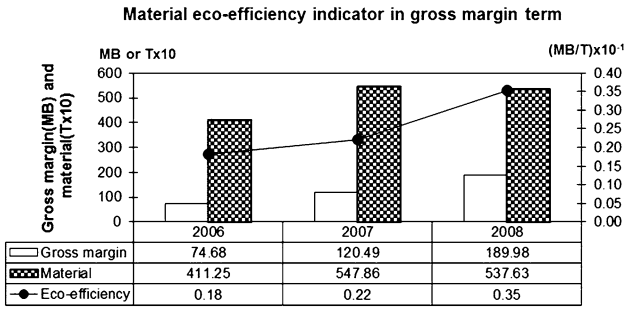

Fig. 4 Material eco-efficiency indicator in term of gross margin value

Figure 5 illustrates the material eco-efficiencies in net sales of the supplier-company combination. The analysis results of the material eco-efficiency indicator showed an increase in the 2006–2007 period of 38.23 %, but a decrease by 28.08 % from 2007 to 2008. In a comparison of material eco-efficiencies of the company and the supplier-company combination, the material eco-efficiency of the company increased from 0.74 to 1.09 MB/T and rose by 47.30 % during the 2006–2008 period, whereas the material eco-efficiency of the supplier-company combination decreased from 4.73 to 4.76 MB/T, which was <1 % during the same period.

Energy eco-efficiency indicator

The energy eco-efficiency indicator was defined as the ratio of economic value in millions of baht (MB) and a consumption of energy sources entering into the manufacturing processes boundary, including purchased electricity, self-generated electricity from boilers (thermal energy), and internal transportation (fossil fuels such as diesel oil and gasoline) in mega joules (MJ).

Figure 6 illustrates the evaluation of the energy eco-efficiency in terms of net sales, which increased by 16.66 % from 2006 to 2007 and 14.29 % from 2007 to 2008. Although, the values of the energy eco-efficiency have increased at a slightly less rate (from a 16.66 % increase to a 14.29 % increase), the overall tendency of the

energy eco-efficiency indicator has been to gradually increase. The increasing energy eco-efficiency was also observed at the gross margin indicator, which is shown in Fig. 7. The eco-efficiencies in terms of gross margin increased by 25.86 % from 2006 to 2007 and 42.47 % from 2007 to 2008.

The energy eco-efficiencies of the company and the suppliers-company combination are illustrated in Fig. 8. The comparison of energy eco-efficiencies between the company and the supplier-company combination showed negative signs, representing decreases of eco-efficiency by 35.39 % from 2006 to 2007, 11.48 % from 2007 to 2008, and 42.81 % in an overall comparison of the 2006–2008 period. Reverse trends of the energy eco-efficiencies in millions of baht per mega joules (MB/MJ) of the company and supplier-company combination were observed. The company's energy eco-efficiency was rising, while the suppliers-company combination was falling as depicted in Fig. 8. The company's energy eco-efficiency rose from 0.0024 to 0.0032 MB/MJ, which accounted for a 33.33 % rise during the 2006–2008 period. Energy eco-efficiencies of the supply chain dropped from 26.84 to 15.35 MB/MJ, which accounted for 42.81 % drop during the same period.

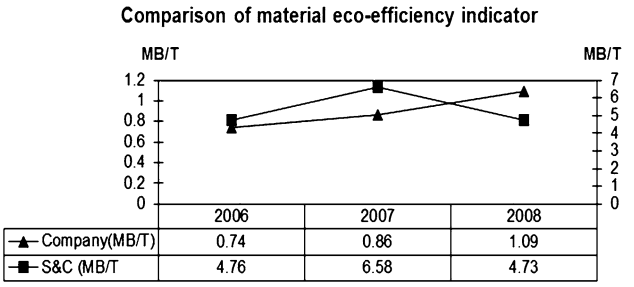

Fig. 5 Comparison of material eco-efficiencies between the company and the supplier-company combination in term of net sale value

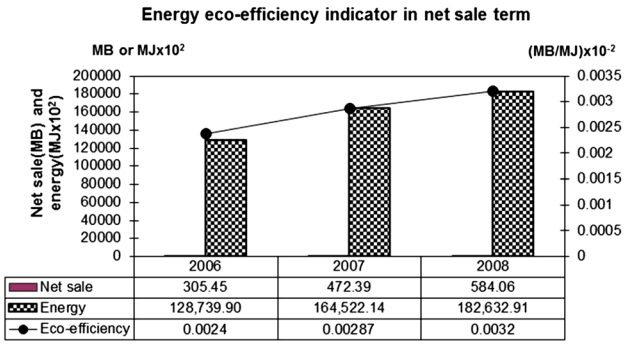

Fig. 6 Energy eco-efficiency indicator in term of net sale value

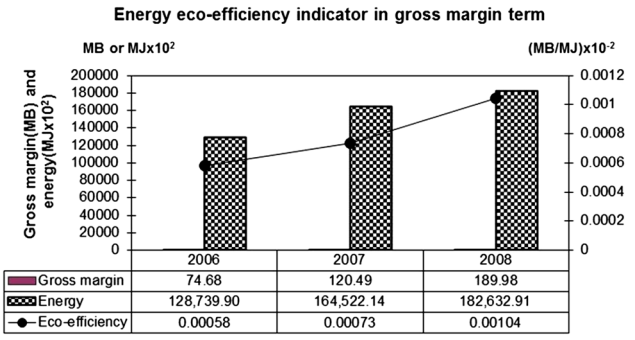

Fig. 7 Energy eco-efficiency indicator in term of gross margin value

Water eco-efficiency indicator

The water eco-efficiency indicator is the ratio of economic value (net sales and gross margin) in millions of baht (MB) to water consumption in units of cubic meters (m^3). The evaluations of water eco-efficiency are illustrated in Figs. 9 and 10. A comparison of water eco-efficiency values during the 2006–2007 period and the 2007–2008 period shows that the values unevenly increased by 57.77 and 22.72 %, respectively. A specific comparison of 2006 with 2008 shows a drastic increase in water eco-efficiency. Contrarily, a comparison of years 2007 and 2008 reveals a slow increase. The evaluation of water eco-efficiency in gross margin is illustrated in Fig. 10. A comparison of eco-efficiencies between 2006–2007 and 2007–2008 showed an increase of 65.57 and 56.44 %, respectively. The increase of water eco-efficiency came from the proper arrangement of water collection tanks, water channels, pumps, pipes and a 3R (reduce, reuse, recycle) strategy of water management, which can save the water consumption in the process.

Water eco-efficiencies in millions of baht per cubic meter (MB/m^3) of both the company and the supplier-company combination were rising, as shown in Fig. 11. Water eco-efficiencies of the company rose from 2.51 to 4.86 MB/m^3 or grew by 93.63 %, from 2006 to 2008. During the same period, water eco-efficiencies of the supplier-company combination also increased from 2.52 to 4.87 MB/m^3 or grew by 93.25 %.

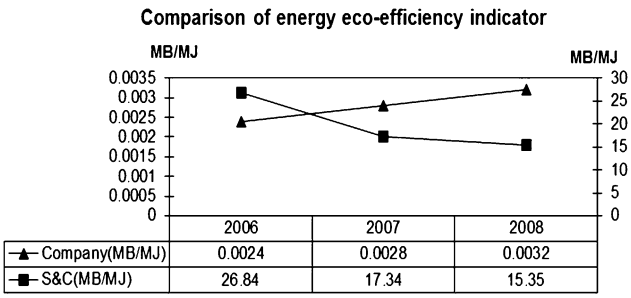

Fig. 8 Comparison of energy eco-efficiencies between the company and the supplier-company combination in term of net sale value

A comparison between the water eco-efficiency of the company and the supplier-company combination suggests that it is likely that the eco-efficiency of both the company and the supplier-company combination would be higher as a result of water reuse, reduction of water consumption, and good management.

Waste eco-efficiency indicator

The waste eco-efficiency indicator is the ratio of economic values, net sales, and gross margin in millions of baht (MB) to waste generation during the manufacturing processes from such materials as sliver, sawdust, residue color used, lacquer, and waste water converted in tones (T). Evaluated waste eco-efficiencies, which are illustrated in Fig. 12, showed that the waste eco-efficiencies in the 2006–2007 and 2007–2008 periods increased by 50 and 33.33 %, respectively. Likewise, waste eco-efficiencies in the gross margin (Fig. 13) show an increase of 52.63 % in the 2006–2007 period and 59.77 % in the 2007–2008 period.

Similarly, economic values (MB) of production were also increasing continuously per T of waste generation within the same duration. In accordance with the analysis, the waste eco-efficiency indicator was consistent with increasing material consumption and water utilized for all reporting periods from 2006 to 2008.

The waste eco-efficiencies of the company and the supplier-company combination were rising, as presented in Fig. 14. The eco-efficiencies of the company were up 100 % from 0.02 to 0.04 MB/T during the 2006–2008 period. In a similar way, waste eco-efficiencies of the supplier-company combination were up from 37.89 to 39.84 MB/T, which were 5.15 % in the reporting periods of 2006–2008, except the waste eco-efficiency in 2008, which declined from the previous year. However, the overall tendency was to rise. The comparison of waste eco-efficiency indicators within the 2006–2007 period showed that their values increased by 47.60 %. A comparison of such indicators in the 2007–2008 period revealed that the value of the waste eco-efficiency indicator decreased by 28.74 %.

The results of comparing the eco-efficiencies between the company and the supplier-company combination showed a different tendency of eco-efficiency in almost

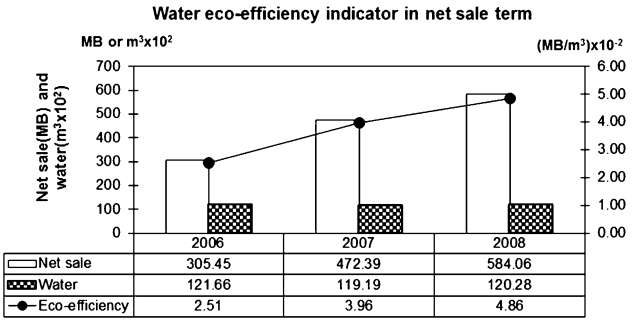

Fig. 9 Water eco-efficiency indicator in term of net sale value

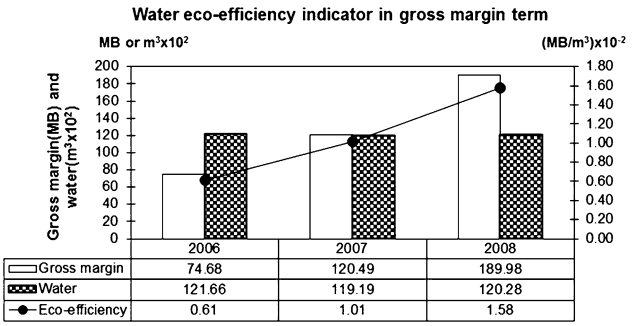

Fig. 10 Water eco-efficiency indicator in term of gross margin value

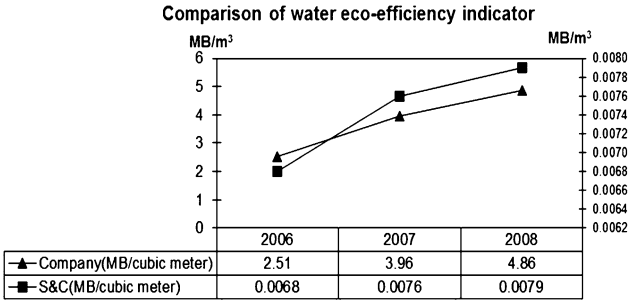

Fig. 11 Comparison of water eco-efficiencies between the company and the supplier-company combination in term of net sale value

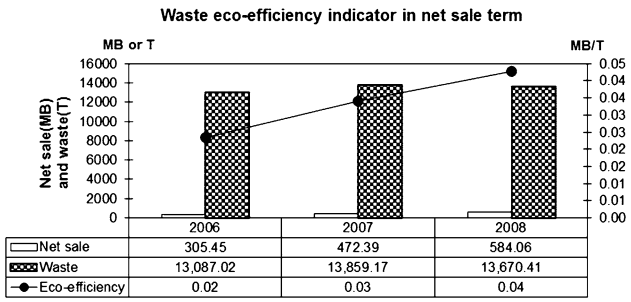

Fig. 12 Waste eco-efficiency indicator in term of net sale value

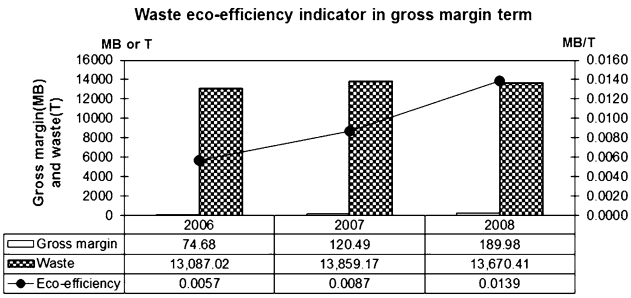

Fig. 13 Waste eco-efficiency indicator in term of gross margin value

every indicator. That is, the eco-efficiency of the company was likely to be increasing. On the contrary, the eco-efficiency of the supplier-company combination was likely to be decreasing, except the water eco-efficiency, which was likely to move in the same direction. Therefore, although the company is managed efficiently, if there is no concern about the suppliers who deal with the company directly, the sustainable development may be impossible. To increase the eco-efficiency of the supply chain, companies must be concerned about and pay attention to suppliers. The company should purchase the raw materials from the environmentally friendly suppliers, which will have a positive effect on company profits and provide more incentive and reward to environmentally conscious suppliers.

Social measurement of the company

Internal level

The results in Fig. 15 showed that accident frequency rate of the company was at 10.48 per million hours worked in 2006, 10.23 per million hours worked in 2007 and 7.04 per million hours worked in 2008. The comparison of accident frequency rates of the company revealed that the rates decreased by 2.39 % from 2006 to 2007, 31.18 % from 2007 to 2008, and decreased throughout the period of 2006–2008. The accident frequency rate of the company over the period of 2006–2008 likely decreased, which reflected the increases in work safety.

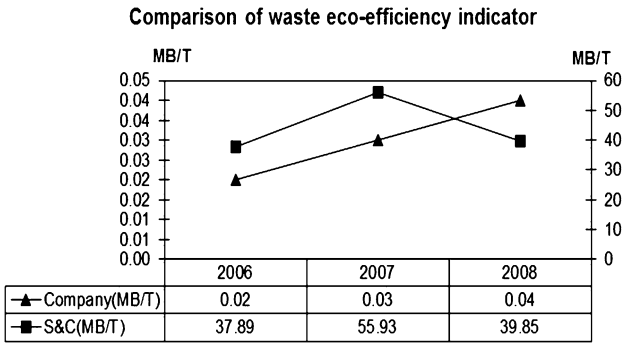

Fig. 14 Comparison of waste eco-efficiencies between the company and the supplier-company combination in term of net sale value

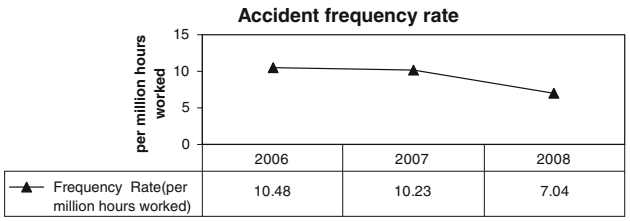

Fig. 15 Accident frequency rate of the company over the period of year 2006–2008

These circumstances indicated that the company had been concerned and strict about work safety, as well as focusing on a reduction in the accident frequency rate.

Community level

Employment by the company over the period of 2006–2008 is shown in Fig. 16 and presents both local employees and non-local employees of Trang Province. The percentage of local employees increased continuously from 92.60 % in 2006, 94.30 % in 2007, and 95.12 % in 2008, respectively. On the other hand, the number of non-local employees continually decreased from 7.40 % in 2006, 5.70 % in 2007, and 4.88 % in 2008. This showed the proportional employment in the community rather than employment outside the community. This means that the company has recognized the importance and profits of the community; so it intends to engage local employees to generate the income for local people in Trang Province. This appears to be a return to the community and a kind of participation in the community development.

Social level

The amount of CSR projects and investment money of the company over the period of 2006–2008 are illustrated in Fig. 17. There were 7 CSR projects in 2006, 9 projects in 2007, and 12 projects in 2008. According to a comparison, the number of CSR projects during 2006–2007 and 2007–2008 periods increased by 28.57 and 33.33 %, respectively. A comparison of investment money in the company's projects shows that the investment amount decreased by 7.69 % in 2006–2007, but increased by 83.33 % in 2007–2008.

Moreover, the ratio of the amount of money for CSR projects in millions of baht (MB) and net sales in millions of baht (MB) are illustrated in Fig. 18. The results showed that the ratio of the amount of money in net sales and the number of CSR projects decreased by 40 % from 2006 to 2007 but increased 47.06 % from 2007 to 2008.

Likewise, the ratio of the amount of money for CSR projects in millions of baht (MB) and gross margin in millions of baht (MB) are shown in Fig. 19. A comparison

Fig. 16 Employment of the company over the period of year 2006–2008

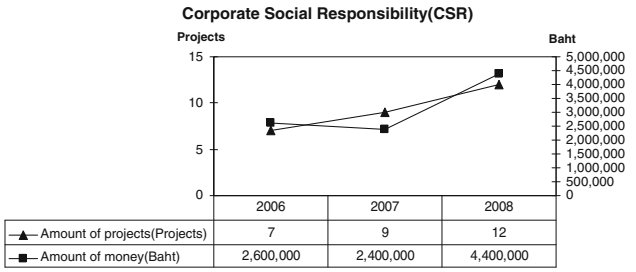

Fig. 17 The amount of CSR projects and investment money of the company over the period of 2006–2008

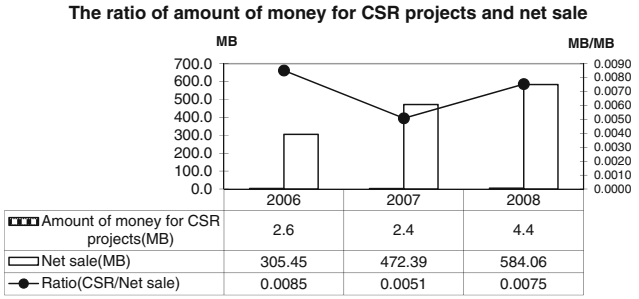

Fig. 18 The ratio of amount of money for CSR projects and net sale

of the ratio of the amount of money for CSR projects in gross margin shows that it decreased by 42.82 % in 2006–2007, but increased by 16.58 % in 2007–2008. These results showed that the company has adhered to CSR; thus, it has regularly supported the creation of activities and projects benefiting both community and society.

Socio-eco-efficiency measurement

Socio-eco-efficiency indicators were calculated by multiplying total eco-efficiency indicators and total social indicators together. The socio-eco-efficiency measurement of the company over the period of 2006–2008 is illustrated in Fig. 20. It can be seen that socio-eco-efficiency indicator increased by 56.22 % from 2006 to 2007 and 36.29 % from 2007 to 2008, and rose by 112.92 % during the 2006–2008 period. This rising tendency of socio-eco-efficiency indicators of the company occurred in three dimensions: economic and environmental dimensions in eco-efficiency, and the social dimension. Eco-efficiency relates to the improvement of process, reduction of resources, and good management, while the social dimension values humans and communities.

Discussions and feedbacks

The findings indicated that material consumptions were based on the production according to market demand and increasing prices of materials, which affected the

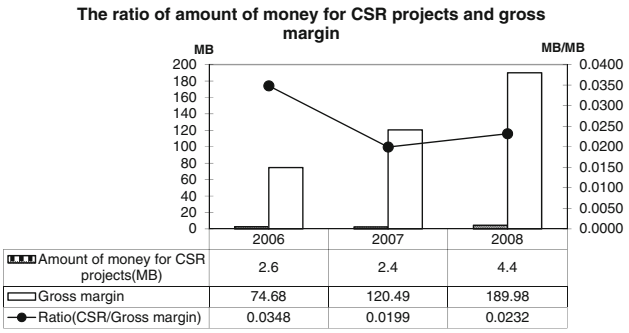

Fig. 19 The ratio of amount of money for CSR projects and gross margin

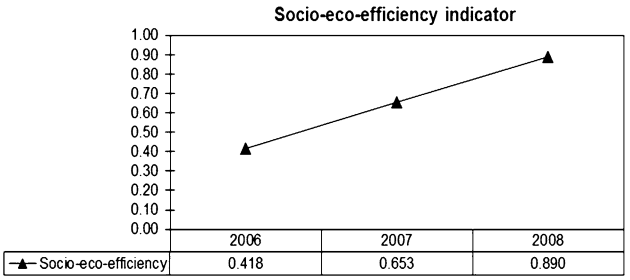

Fig. 20 The socio-eco-efficiency measurement of the company over the period of year 2006–2008

increasing eco-efficiency indicators value during three years. In order to maintain the rise of material eco-efficiency, the factory has to produce the maximum power of machine efficiency using the least amount of raw material. As such, the efficiency of each machine in the production process needs to be regularly checked. The rejected products or material from one model of wooden toy must be considered for recycle in order to decrease the material consumption and waste generation.

The conclusion showed that the company's eco-efficiency indicator regarding energy consumption continuously rose from 2006 to 2008. The higher energy consumption was compensated by better economic performance, which drove the tendency of eco-efficiency higher. The increasing energy consumption was mainly due to the production capacity increase and the consumption of fuel for internal transportation. Further, energy was lost due to the shutdown of routine preventive maintenance and unforeseen factors such as frequent irregular machine break downs, power failures, and the loss of power to restart and operate to its normal operating load. In order to increase the energy efficiency, the company has to reduce the energy consumption by decreasing the losses of energy through supervision and preventive measures to avoid unnecessary losses of energy from the aforementioned factors. The change of the internal transportation system from trucks to motorcycles with sidecars, which was an

example of good company management, will help reduce fuel consumption. Moreover, the alternative energy should be utilized to retain the company's production capacities to serve market demands; therefore, the eco-efficiency value will rise.

Similarly, the company was able to increase their water eco-efficiency each year as the company consumed less water and reused some water. Therefore, the eco-efficiency indicator, in respect to water consumption, likely improved over the period of 2006–2008. In order to maintain the increase of water eco-efficiency, reduction of water consumption must be achieved by decreasing the water losses through preventive maintenance of pipelines to avoid leakages and optimize the water recycling system.

The evaluation of the waste eco-efficiency indicator of the company was concluded based on the analysis findings. That is, the amount of waste has increased during the reporting period of 2006–2008. Since this increase of waste quantity came from a higher production volume of the company, if the amount of waste was reduced, while the resources were efficiently used, the company's eco-efficiency would increase. As such, the application of eco-design in order to reduce materials and receive the benefits of reusing scrap rather than making new purchases was recommended.

The eco-efficiency evaluation of an extended supply chain included all major suppliers. It can be seen that eco-efficiency indicators of the company have increased, while eco-efficiency indicators of the suppliers-company combination have decreased. It showed that when considering the supply chain, it is apparent that the suppliers occupy an important role because the eco-efficiency value of the suppliers-company combination moved in the same direction of that of the eco-efficiency of suppliers, which was likely to be a decreasing trend, and which is different from the eco-efficiency of the company. Although, eco-efficiency indicators of the company seemed better, it did not necessarily mean that the eco-efficiency of the suppliers-company combination would be good. If we cooperated with the suppliers who are not good, or not environmentally friendly, then the eco-efficiency would not be effective and might affect the overall system, because the eco-efficiency of product is not only focused on companies, but also on the entire supply chain.

According to the evaluation of social indicators in the past 3 years, the wooden toy company has produced some development and has continuously focused on the social dimension; either work safety or environment to enrich its working efficiency, community employment, and CSR, which mirror the company's involvement in giving benefits back to the community and society. Supplementary studies on the social dimension should be further conducted to develop social indicators that are especially concerned with humans and community in order to support the social policy of the wooden toy industry.

Finally, an eco-efficiency evaluation should be established as an industrial policy that all companies should be aware of and utilize as a tool to help indicate the status of industry (Cote et al. 2006). Eco-efficiency would be more advantageous if coupled with creating cooperative learning opportunities with industries and through its legislative enforcement. If the concept of eco-efficiency evaluation is widely accepted in Thailand, it will create more benefits in the international trade, including database, which is important for the industry in Thailand. In addition, eco-efficiency should be extended to suppliers to be linked through a network for additional benefits.

Conclusions

Eco-efficiency is a key concept of proper indicators which can help a company reach more sustainable development. This research presents the development of eco-efficiency indicators for sustainability analysis of the wooden toy industry. Choosing the eco-efficiency indicators can identify the status of the economic and environmental dimensions. The eco-efficiency of the wooden toy industry was measured by using the key economic and environmental indicators, such as net sales, gross margin, material, energy, water consumption, and waste disposal. Moreover, eco-efficiency evaluation of the suppliers and company, a process which is a part of the supply chain, was included in this study. Eco-efficiency evaluation in the supply chain can ensure that there would be sustainable and environmentally conscious manufacturing. In addition, the social indicators, which are the frequency rate of accidents at the internal level, local employment at the community level and CSR in the social level, were developed. Social indicators are important as they enable optimal company stability; thus, they ensure greater competitive and business sustainability.

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