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Environmental problems indicator under environmental modeling toward sustainable development

[1*]P. Sutthichaimethee; [2]W. Tanoamchard; [1]P. Sawangwong; [3]P. Pachana; [4]N. Witit-Anun

[1]Department of Environmental Science, Faculty of Science, Burapha University, Chonburi, 20131, Thailand

[2]Department of Human resource management, Faculty of Management and Tourism, Burapha University, Chonburi, 20131, Thailand

[3]Department of Chemistry, Faculty of Science, Burapha University, Chonburi, 20131, Thailand

[4]Department of Physics, Faculty of Science, Burapha University, Chonburi, 20131, Thailand

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ABSTRACT: This research aims to apply a model to the study and analysis of environmental and natural resource costs created in supply chains of goods and services produced in Thailand, and propose indicators for environmental problem management, caused by goods and services production, based on concepts of sustainable production and consumer behavior. The research showed that the highest environmental cost in terms of Natural Resource Materials was from pipelines and gas distribution**,** while the lowest was for farming coconuts**.** The highest environmental cost in terms of Energy and Transportation was for iron and steel**.** The highest environmental cost in the category of Fertilizer and Pesticides was for oil palm**.** For Sanitation Services, the highest environmental cost was movie theaters**.** Overall, the lowest environmental cost for all categories, except Natural Resource Materials, was for petroleum and refineries**.** Based on the cost index, coconut farming gained the highest Real Benefit to the farm owner, while pipelines and gas distribution had the lowest Real Benefit. If Thailand were to use a similar environmental problem indicator, it could be applied to formulate efficient policy and strategy for the country in three areas, namely social, economic, and environmental development.

Keywords: *Energy and transportation; Environment cost; Fertilizer and pesticides; Indicator; Natural resources materials; Real benefit; Sanitary and similar services*

INTRODUCTION

The environment and natural resources are important factors to consider in the development of a country (Chen, 2003; TDRI, 2007; Asian Development Bank, 2014). However, the social and economic changes within Thailand have caused the deterioration of the environment and natural resources, i.e. loss of forests and wild animals, mangrove forests (TDRI, 2007), water resources (Bodini *et al.*, 2002) and increased waste. Besides, the amount of natural resources is limited (Hammond *et al.*, 1995), whereas the consumption of natural resources is unlimited (Chen *et al.*, 2010), and this can cause the environmental and natural resources to decrease rapidly (Harwick and Olewiler, 1998) and continuously. The Thai government has foreseen this issue, leading them to announce the sustainable development policy that is to increase economic growth together with social and environmental development (TDRI, 2006). The environmental and natural resource degradation should be the first concern for Thai society in developing a plan together (ADB, 2014), and the plan must correspond with the economic and social development strategy of the Ministry of Natural Resources and Environment (NESDB, 2015).

*Corresponding Author Email: *pruethsan@gmail.com*
Tel.: (+66) 831 978 764; Fax: (+66) 2560 1870

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Policy principles of the country must address the problems outlined below (Hammond *et al.*, 1995; Marull *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015). Previous policy did not focus sufficiently on environmental issues, leading to ineffective management of environmental problems (Simpson, 1996; Marull *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015). The Index of Sustainable Economic Welfare (ISEW) is an indicator to specify sustainable development of the country and economic welfare measurement (Hammond *et al.*, 1995; Bodini, 2002; McMullan, 2013; Yigitcanlar *et al.*, 2015). ISEW does not only consider consumption value, but also incorporates unsustainable environmental costs and social costs (Brent, 2006). Comparing ISEW per capita and GDP per capita of Thailand during 1977 to 2003 shows that ISEW per capita before 1977 was consistent with GDP per capita, during which time the growth rate was positive (ADB, 2014). However, after 2003 both indices diverged and the growth rate decreased (NESDB, 2015). ISEW per capita decreased by 6.70% whereas GDP per capita –fell by 0.89%. Before 1977 ISEW per capita was higher than GDP per capita, but from 2003 to the present ISEW per capita was lower than GDP per capita because of the increasing foreign investment in Thailand (NESDB, 2015). This is the main factor related to the degradation of environmental and natural resources, and leading to the decrease of ISEW per capita (TDRI, 2007). The Thailand Development Research Institute (TDRI) reported that the degradation of environmental and natural resources in Thailand has occurred primarily in the following areas:

1. Deforestation, leading to environmental problems,
2. Inefficient water resource management, causing floods and drought,
3. Overfishing, causing degradation of fishery resources,
4. Increasing air pollution, waste pollution, and water pollution.

Businesses and consumers are the major players in the economic system (Kennedy *et al.*, 2007; Liang and Zhang, 2009; Li *et al.*, 2012). Consumers want to gain high utilization under limited budgets, whereas businesses aim to maximize their profit and reduce expenditures (Lenzen, 1998; Hugo and Pistikopoulos, 2005; Pantavisid, 2012). Neither party pays attention to the environmental cost, causing over-consumption and over-production (Duchin, 2008; Benoit, 2009; Chen *et al.*, 2010; ADB, 2014). However, the sustainable development of the country should develop in three dimensions, collectively (Adams, 2009; Ukaga *et al.*, 2010; Yigitcanlar and Dizdaroglu, 2015), namely economic, social, and environment. Previously, nonetheless, Thailand has given priority to developing only the economic growth. Moreover, the National Economic and Social Development Board (2015) stated that firms did not consider the environmental costs from natural resource materials, energy and transportation, fertilizer and pesticides, and sanitary and similar services. As a result, Thailand did not achieve sustainable development because economic growth goes together with higher environmental cost (Brent *et al.*, 2006; Grossmann, 2009; Duque *et al.*, 2010).

Accordingly, the formulation of policy and strategy to develop the country must concern real benefits and environmental costs in the three areas mentioned above (Bodini, 2002; TDRI, 2005; Ness *et al.*, 2007; Salema *et al.*, 2010; Ukaga *et al.*, 2010; ADB, 2014; NESDB, 2015). In addition, prioritizing environmental problem should be clearly defined (ADB, 2014). Including all these factors in an index could help identify environmental problems and lead to sustainable solutions in the future, which is the main concern of this research.

Objectives

1. Apply a model to study and analyze environmental and natural resource costs of goods and service production in the supply chain.
2. Propose an indicator to help manage environmental problems caused by the production of goods and service, leading to more sustainable consumption and production.

Scope of Study

1. The results are calculated from 180 production lines categorized by their environmental and natural resource costs as depicted in Thailand's Input-Output Table (NESDB, 2015). The calculation considers input data consisting of natural resource materials, energy and transportation, fertilizer and pesticides, and sanitary and similar services. It does not cover environmental effects from consumption.
2. The main calculation from this study uses data from the Input-Output Table of Thailand 2015 (NESDB, 2015), which is the most current data. The accuracy of calculations made from Input-Output Table data is limited by economic and social description.

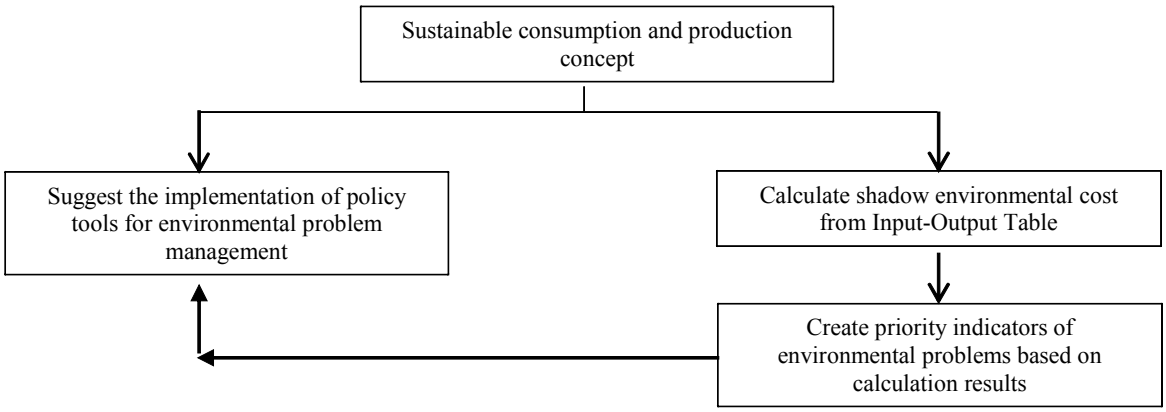

Fig. 1: Conceptual Framework.

Table 1: Matrix used to create the Input-Output table of production sectors.

Producing Sector \ Using Sector		Processing Sectors 1	2	Final demand				Total Outputs (X)
Processing Sectors	1	x_{11}	x_{12}	c_1	i_1	g_1	e_1	x_1
	2	x_{21}	x_{22}	c_2	i_2	g_2	e_2	x_2
Payments Sectors	Value added	l_1	l_2	l_c	l_1	l_g	l_e	L
		n_1	n_2	n_c	n_1	n_g	n_e	N
	Imports	m_1	m_2	m_c	m_1	m_g	m_e	M
Total Outlays (X')		x_1	x_2	C	I	G	E	X

Conceptual Framework

The conceptual framework (Fig. 1) for selection of product sectors for evaluating their Shadow Environmental Cost is based on aims and concepts of sustainable development (NESDB, 2015). Three supporting concepts are Welfare Economics of A.C. Pigou (Pigou, 1960; Zhang, 2012; ADB, 2014), Natural Resource Economics, and Ecology Economics (Yigitcanlar and Dizdaroglu, 2015; Zhang, 2012).

MATERIALS AND METHODS

The model in this study is related to the Input-Output Table, in which the relationship of the data are categorized by rows and columns as follows in Table 1 (Leontief, 1986; Karna and Engstrom , 1994; Lee *et al.*, 2009).

Rows present output distribution of product sector i for n product sectors and the Gross product of product sector i can be defined, for $1 \leq i \leq n$, by

$$= \sum_{j=1}^{n} X_{ij} + F_i \quad (1)$$

Where

X_i refers to Gross product of product sector i, X_{ij} refers to product distribution of product sector i of goods and services production for product sector j, and Fi refers to the final demand of product sector i. X_i

Columns show the structure of expense or cost of goods production for product sector j (Xi) that can be defined, for $1 \leq j \leq n$, by

$$X_i = \sum_{j=1}^{n} X_{ij} + V_j \quad (2)$$

Where

V_j refers to value added of product sector j, only if input value is directly proportional to output value. Then X_{ij} can be defined by the relationship of output (X), input coefficient (A) and final demand (F) of production structure for an economic system that can be defined by

$$X = AX + F \quad (3)$$

$$= [I - A]^{-1} F \quad (4)$$

$[I - A]^{-1}$ is the Leontief Inverse Matrix (or inverse matrix) (Leontief, 1936) , which is important for economic system analysis when using the Input-Output Table. The inverse matrix acts as a direct and indirect input coefficient of a production supply chain that can be

used for supply chain length and intensity calculation. Environmental Cost of the production of each good or service can be calculated using the multiplication of the Environmental Cost coefficient and the inverse matrix. Finally, the result represents the total effect of a supply chain by giving the accumulated Environmental Cost of each good produced. The result also shows intensity of backward environmental effects of direct and indirect inputs and outputs. Furthermore, the result presents names, sectors and intensities of Environmental Costs that are useful to formulate an efficient policy and in environmental problem solving (Lave *et al.*, 1995).

Relationships in the Input-Output Table affects the output of each product sector (ΔF), which is called the Multiplier for Final goods and services. Equation 5 presents the calculation of the Multiplier.

$$\Delta X = [I - A]^{-1} \Delta F \quad (5)$$

If final demand (ΔF) increases, Environmental Cost will increase (ΔE). Equation 6 calculates the increase of Environmental Cost.

$$\Delta E = R[I - A]^{-1} \Delta F \quad (6)$$

RESULTS AND DISCUSSION

The results of the Environmental Costs, Real Benefit, and Multiplier are classified by each category of the production. This research can be summarized as following Table.

Table 2 lists the top ten industries in terms of Multiplier, Real Benefit, and each category of environmental cost. Real Benefit is the revenue for a sector, minus the environmental costs. The average Real Benefit was 0.709. If the Real Benefit for a given industry is lower than the average, it can be considered to represent a loss, while values higher than the average represent profit. The average values for environmental cost in Natural Resource Materials was 0.0276; for Energy and Transportation, 0.119; for Fertilizer and Pesticides, 0.006; and for Sanitary and Similar Services, 0.001. If the cost for a particular industry is lower than the average, there is further capacity for production. Environmental cost values that are higher than the average signify that there is no further capacity for production.

Highlights from the findings include the following:
1. Overall environmental cost was lowest for coconut farming (sector 010), and this sector has the capacity for further production.
2. Iron and steel (105) had the highest environmental cost in terms of Energy and Transportation. It was even higher than the average for industries that do not have the capacity for further production. The lowest environmental cost for this category and having capacity for production was petroleum refineries (093).
3. The highest environmental cost in terms of Fertilizer and Pesticide use was oil palm (011), while the lowest environmental cost was petroleum refineries. The industries with highest environmental cost in this category do not have capacity for production, whereas those with lowest environmental cost have further capacity.
4. Movie theatres (073) showed the highest environmental cost of the Sanitary and Similar Services, and this sector does not have capacity for production. In contrast, petroleum refineries had the lowest environmental cost of this category and it still has capacity to produce.
5. The highest Real Benefit in the production sector was for coconut farming, while the lowest Real Benefit was for pipeline and gas distribution (136). The lowest Real Benefit could represent loss in profit.
6. The highest Multiplier in the production sector was for iron and steel production, while the lowest Multiplier was for petroleum refineries. Thus, iron and steel had the highest indication of environmental concerns.

This research is a pilot study of environmental cost of production of goods and services in the economic system of Thailand, using a database to account for differences among sectors. Environmental Cost contributes damage to the environment and is affected by the behavior and decisions of producers, consumers, and government (Bailey *et al.*, 2004; Benoit, 2009; Xu, 2010; ADB, 2014; TDRI, 2015). The environmental cost cannot be estimated from the activities occurring in the market alone. Instead, the estimation of the environmental cost of each production sector in Thailand needs to incorporate Shadow Environmental Cost, which is the economic database showing environmental cost (Pantavisid, 2012). The information can be used to compare the environmental cost of production sectors, which could help to create an environmental problem management indicator (McMullan, 2013; ADB, 2014). The Shadow Environmental Cost modeled in this study relies on four groups of economic data, including costs of Natural Resources Materials, Energy and Transportation, Fertilizer and Pesticides, and Sanitary and Similar Services (TDRI, 2005; Pantavisid, 2012).

Table 2: Analysis in top 10 of each production sector

Multiplier		Real Benefit		Natural Resources Materials Cost		Energy and Transportation Cost		Fertilizer and Pesticides Cost		Sanitary and Similar Services Cost	
value	Sectors	Value	Sectors	Value	Sectors	value	Sectors	Value	sectors	value	sectors
3.230	105: Iron and steel	0.941	010: Coconut	0.730	136: Pipe line and gas distribution	0.492	105: Iron and steel	0.165	011: Oil palm	0.012	173: Movie theatres
2.614	043: Canning and preserving of meat	0.921	066: Tobacco products	0.318	087: Paints	0.489	057: Ice	0.098	047: Coconut and palm oil	0.009	148: Hotels and places of loading
2.532	042: Slaughtering	0.903	163: Real-estate	0.228	078: Saw mills	0.464	036: Fluorite	0.094	015: Coffee and tea	0.008	176: Amusement and recreation
2.427	050: Tapioca milling	0.901	152: Land transport support service	0.177	102: Cement	0.416	156: Air transport	0.054	004: Cassava	0.008	152: Land transport support service
2.401	047: Coconut and palm oil	0.890	162: Other Insurance Service	0.176	101: Structural clay products	0.356	151: Road freight transport	0.053	005: Other root crops	0.007	033: Tin ore
2.302	173: Movie theatres	0.886	146: Retail trade	0.173	104: Other non-metallic products	0.326	148: Hotels and places of loading	0.051	017: Other agricultural product	0.007	137: Water work and supply
2.292	180: Unclassified	0.886	038: Salt	0.161	103: Concrete and cement products	0.318	030: Coal and lignite	0.050	014: Tobacco	0.007	163: Real-estate
2.290	019: Swine	0.883	018: Cattle and buffalo	0.136	099: Ceramic and earthen ware	0.312	135: Electricity	0.040	007: Vegetable	0.007	155: Water transport services
2.281	054: Noodles and similar products	0.880	161: Life insurance services	0.135	141: Non-agriculture public works	0.301	041: Other mining and quarrying	0.040	012: Kenaf and jute	0.006	099: Ceramic and earthen ware
2.272	059: Coffee and tea	0.878	025: Logging	0.125	079: wood and cork products	0.301	150: Road passenger transport	0.038	002: Maize	0.006	161: Life insurance services

This research calculates the Multiplier of goods and services production by adding in one unit resulting from changing of GDP and the Green Sector Products (Grossmann, 2009; Espinosa and Walker, 2011; Su et al., 2009). The result from this calculation portrays economic connectivity of each product sector resulting from the economic growth and economic net income (Ness *et al.*, 2007; Pantavisid, 2012; ADB, 2014). The purpose of environmental problem management is to reduce negative impacts from the environmental costs to the economic system. Production sectors have been systematically studied and significant environmental costs of production have been identified already (TDRI, 2007; Yu, 2008). However, the production size has a very large impact on the scale of the resulting environmental harm. Therefore, other necessary economic data could support environmental problem management prioritization (TDRI, 2007; Xu, 2010; Zhang, 2012; ADB, 2014). The database was created to factor in the Multiplier and Green Value Added.

The results of this examination of environmental costs by each sector is consistent with the research of Zhang, Y. (2010), Pantavisid, S. (2012), and the results of the Real Benefit analysis is also consistent with the research of Sa-nguanwongthong, N. (2013), which they used the average value to create the environmental costs index. From the research found that when comparing the average and the result from the comparison, there are 33 sectors in Environmental costs of natural resource material has higher value than the cost of average criteria. Likewise, 62 sectors of energy and transportation, 33 sectors of fertilizer and pesticide, and 120 sectors of sanitary and similar service found that the result from the research are higher than the average. Thus, from the past, Thailand did not take an interest in such environmental costs indicator, which led to damage of the environmental and natural resources because of used over carry capacity.

However, the results of this research could also be applied to the environmental problem management under the sustainable production concept with a limitation of administrative resources. It leads to efficient environmental consumption by the society (TDRI, 2007). The classification of natural resources and environmental capital of the whole system can be implemented at the micro level (ADB, 2014), while the classification from Green Value Added and the Multiplier is for decision making at a macro level (Zhang, 2012; ADB, 2014). Consequently, using the correct data allows for effecient environmental problem-solving (TDRI, 2007). Thailand and other ASEAN countries do not create an environmental problem indicator from the analysis of real benefit, environmental cost, and environmental problems, and this leads them to formulate ineffective policies and plans for the country (ADB, 2014). More developed countries, in contrast, like Japan and European countries, give an importance to environmental problems, and the GDP of these countries are shown in Green GDP format. This methodology will help the country formulate efficient policy and forecast a future situation more accurately. Hence, the developed countries can deal with the crisis arising from those environmental problems (TDRI, 2007; Sanguanwongthong, 2013).

CONCLUSION

Thailand has adopted predominantly state policies that focused on economic growth and prosperity from very early in its history. The State was fixated on improving the GDP without taking into consideration the consequences of such policies on Thailand (TDRI, 2007; NESB, 2015). This mismanagement has led to subsequent instability and crisis in the country (ADB, 2014). The rapid economic development of Thailand came at the cost of environmental degradation and the depletion of its natural resources. This calls for proactive measures that address the complex nature of the issues and create environmental indicators that can be effectively used to set state policies and strategies in the future.

The research found that Thailand has many environmental issues that hinder the country's future development. Environmental costs were found to be higher in all sectors, specifically 33 sectors for natural resource material, 62 sectors for energy and transportation, 33 sectors for fertilizers and pesticides, and 120 for sanitation and related services. 51 sectors had higher values than the average benefit indicator. The top three production sectors in need of immediate intervention are the Iron and steel sector, canning and preservation of meat, and Slaughtering. Thailand's economic development plan must integrate environmental indicators from this research to set the most efficient strategies and policies for sustainable development. In the past, Thailand did not incorporate environmental indicators in policy planning, and as a result of such an oversight, environmental and natural resources have been mismanaged to beyond sustainable capacity. The indicators in this research will greatly improve state policies addressing environmental sustainability.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interests regarding the publication of this manuscript.

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AUTHOR (S) BIOSKETCHES

Sutthichaimethee, P., Ph.D.; Instructor; Department of Environmental Science, Faculty of Science, Burapha University, Chonburi, 20131, Thailand. Email: *pruethsan@gmail.com*

Tanoamchard, W., Ph.D.; Instructor; Department of Human resource management, Faculty of Management and Tourism, Burapha University, Chonburi, 20131, Thailand. Email: *wanvice@buu.ac.th*

Sawangwong, P., Ph.D. ; Assistant Professor; Department of Environmental Science, Faculty of Science, Burapha University, Chonburi, 20131, Thailand. Email: *pichan@buu.ac.th*

Pachana, P., Ph.D.; Assistant Professor; Department of Chemistry, Faculty of Science, Burapha University, Chonburi, 20131, Thailand. Email: *pumipat@buu.ac.th*

Witit-anun, N., Ph.D.; Assistant Professor; Department of Physics, Faculty of Science, Burapha University, Chonburi, 20131, Thailand. Email: *nirun@buu.ac.th*

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