2015 4th International Conference on Informatics, Environment, Energy and Applications
Volume 82 of IPCBEE (2015)
DOI: 10.7763/IPCBEE. 2015.V82.18

Weighting Factors for LCA Impact Indicators by a Panel Approach for Thailand

Narnai Kuntachaianun [1], Thierry Tran [2] and Nanthiya Hansupalak [3+]

[1] M.Eng. in Advanced and Sustainable Environmental Engineering, Kasetsart University, Bangkok, Thailand

[2] Adjunct Prof., CIRAD-UMR Qualisud, Kasetsart University, Bangkok, Thailand

[3] Assistant Prof., Dep. of Chemical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand

Abstract. Unsustainable production and consumption are a major concern for the deterioration of the world environment such as climate change and global warming. On account of The United Nations Framework Convention on Climate Change (UNFCCC), business sectors are moving forward with more sustainable production practices. Life cycle assessment (LCA) is a quantitative tool to analyze the environmental footprint of products and services, and to identify hotspots of environmental impacts, in order to support decision makers to choose more sustainable production options. LCA typically presents a range of environmental impact categories, e.g. climate change, eutrophication, damage to the ozone layer, resources depletion, etc. To facilitate decision making, this study used a panel approach to generate weighting factors and rank the perceived importance of selected impact categories, with a view to aggregate LCA indicators into a single score. The study was conducted in Thailand. Three endpoint categories and twelve midpoint categories were investigated using a questionnaire in two parts. 500 respondents were interviewed by online and field surveys in Thailand. The endpoint's result pointed out Thai people concern for human health as the most important, followed by ecosystem quality and resources depletion, respectively. For midpoint categories, loss of habitat was the highest priority, while ionizing radiation the lowest. The nonparametric statistic test indicated that sex, age, and occupation were not significant factors explaining differences in answers, but that the type of survey and level of concern for environmental problems were. Further work will extend the study to Japan and Europe, to compare the priorities in environmental concerns in these regions.

Keywords: Life Cycle Assessment, LCA, Weighting factor, Sustainability.

1. Introduction

Environmental pollutions are a problem because of current unsustainable and unregulated patterns of production and consumption [1]. A report of major air pollutants and greenhouse gases from a regional emission inventory in Asia (REAS), illustrated that both China and India were the largest contributors to Asian emissions because of high energy consumption, economic activities and infrastructural development [2]. Therefore international organizations (e.g. The United Nations Framework Convention on Climate Change (UNFCCC)), national governments and the private sector have a responsibility to reduce environmental impacts, with the signature of international agreements such as the Kyoto Protocol. To this end, methods are needed to assess environmental impacts and monitor improvements. Life cycle assessment (LCA) is a useful method to do this because it can quantitatively analyze a range of environmental impacts caused by products or services. Moreover, LCA is increasingly used by government agencies and the private sector to support policies and investment decisions towards increased sustainability of production practices [3].

+ Corresponding author. Tel.: + 662-579-2083
E-mail address: fengnyh@ku.ac.th

Environmental impacts in LCA can be assessed via midpoint and endpoint categories; both have different names and numbers of categories among methods of LCA [4]. ReCiPe, a commonly used method [5], includes 18 impact categories (midpoint) and 3 damage categories (endpoint). In addition, ReCiPe method and Eco-indicator 99 [6] also suggest the way to calculate a single score via endpoint which follow the International Standard Organization (ISO) 14040 [7]. For the practical process summary of LCA is shown in Fig. 1. To calculate a single score indicator, weighting factors and normalization factors are required. For Eco-indicator 99, a panel approach was used to find weighting factors the three damage categories: Human health, Ecosystem quality and Resources, from which the results have been using until now [8]. The Eco-indicator 99 study was conducted with European respondents only and LIME method was conducted weighting factor survey in Japan [9]. Moreover, weighting factors for LCA damage categories were also investigated in North America (BEES 2.0). A panel of American citizens has been surveyed for 10 environmental impact categories [10]. These studies illustrated that weighting factors vary between regions, reflecting different opinions and priorities on environmental issues.

This research aims to determine weighting factors of midpoint and endpoint categories for Thailand and to compare the results with literatures [8], [10]. Additionally, sex, age, occupation, type of survey, and level of concern of environmental problems will be investigated to find relationship to weighting scores. However, the priorites of all categories are needed.

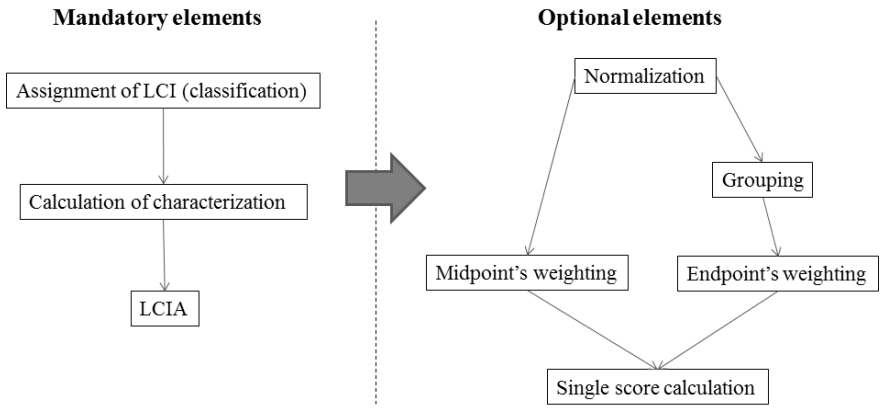

Fig. 1: Elements of the LCIA phase

2. Design of Survey and Its Analysis

A minimum of 400 respondents are needed to represent the Thai population, according to Yamane's equation [11]. Convenience sampling has been used to obtain respondents who are available and willing to participate in the survey. Two survey approaches were used, online using an internet-based questionnaire (Google Form^{TM}), and field survey using paper questionnaires to interview respondents in Kasetsart University (Bangkok). The online and paper versions of the questionnaire were identical in terms of content and questions.

The questionnaire was divided into two parts, firstly for endpoint categories and secondly for selected midpoint categories. Introduction and the goals of the survey were provided with explanations and definitions of the three endpoint categories Human health, Health of ecosystems and Resources depletion; and of the 12 midpoint categories: (1) climate change (2) ozone depletion (3) human toxicity (4) ionising radiation (5) formation of ground level organic compounds and particles (6) acidification (7) ecotoxicity (8) eutrophication (9) loss of habitat (10) fossil fuel depletion (11) mineral and metal resources depletion and (12) water depletion. Table 1 shows the characteristic of the respondents. A total of 500 respondents were derived from the two types of survey.

Hypotheses for this study are (1) sex, age, occupation, type of survey, and level of concern for environmental problems are not significant factors determining weighting scores (2) Among the three endpoint categories, human health is considered the most important concern, before health of ecosystems and resources depletion. (3) Among the twelve midpoint categories, human toxicity is considered the most important concern and ionising radiation the last concern. The data will be used Minitab^{TM} version 17 trial

version for statistical analysis. Wilcoxon rank sum test (Mann-Whitney) and Kruskal-Wallis test will be used for two independents samples and three or more means analysis, respectively.

Table 1: Characteristic of the respondents (n=500)

	Respondents	%		Respondents	%
Gender			Age		
Male	210	42.0	10-15	2	0.4
Female	288	57.6	16-20	144	28.8
Not filled in	2	0.4	21-25	172	34.4
Occupation			26-30	123	24.6
University's student	292	58.4	31-35	32	6.4
Employee	65	13.0	36-40	11	2.2
Engineer	8	1.6	41-45	2	0.4
Government Officer	53	10.6	46-50	6	1.2
Self-employed	26	5.2	51-55	5	1
Lecturer	24	4.8	56-60	1	0.2
ETC	7	1.4	>60	1	0.2
Not filled in	25	5.0	Not answered	1	0.2
			Levels of concern for environmental problems		
Types of survey			Very important	359	71.8
Online	251	50.2	Somewhat important	133	26.6
Field	249	49.8	Not very important	6	1.2
			Not filled in	2	0.4

3. Results

Five hundred respondents were collected from the surveys which were more than a minimum target. The characteristic of the respondents are shown in table 1. Approximately half of the data were not normally distributed. Consequently nonparametric statistic tests were proper used for the analysis. The Wilcoxon rank sum test (Mann-Whitney), which is used to compare two independent samples, was suitable to analyse the factors sex and type of survey. The Kruskal-Wallis test, which is used to compare three or more means, was suitable to analyse the factors age, occupation, and level of concern for environmental problems. For endpoint categories, sex, age, occupation, type of survey and level of concern for environmental problems were not significantly different from these three categories. The result was pointed out the same for all factors which indicated that everyone in Thailand possibly take this survey due to obtain weights especially for endpoint. For midpoint categories, sex, age, and occupation were not significantly different from most of midpoint categories. However, only ionising radiation was significantly different from sex. Women gave significantly higher weights than men to those categories. Ozone depletion and water depletion were both categories that were significantly different from different ages. Additionally, ozone depletion, ionising radiation, loss of habitat, mineral and metal resource depletion, and water depletion were found significant differences in occupation. There were significant differences between the types of survey: Scores given in the second part of the paper version (questions on midpoint categories) were higher and less dispersed than the online version, while scores given in the first part (questions on endpoint categories) were not significantly different. This may indicate that respondents to paper questionnaires, who were interviewed on the street (in a university campus) had less time available and completed the end of the questionnaire less in details in order to move on to their next activity. However, ozone depletion, ionising radiation, and water depletion were found significant differences in almost all of factors. It is quite clear that Thai people have diverse knowledge, understanding, and experiences about these issues. Finally, respondents who indicated a high level of concern for environmental issues gave more weights to almost all of categories on average. No significant differences found in the first part of questionnaires as endpoint categories and also climate change.

Weighting factors for endpoint categories were calculated by the means of each category as the results are shown in table 2. This table contributes the three different things of both studies. Firstly, 500 respondents from Thailand are reflected small number of standard deviation. It might point out that Thai people had relevant thoughts. In case of less respondents of Eco-indicator 99 (82 respondents), the standard deviation is quite large. Secondly, the ranking of both studies are different. Thai people gave the highest priority to human health and the least priority to ecosystems. These three weightings are very similar scores (range 32.93 to 34.11%). But resources depletion is the least priority for the other study. Thirdly, Eco-indicator 99 was conducted the surveys in Europe. Those differences of both studies indicates that different areas, different culture might reflect different thoughts. Weighting factors of midpoint categories were also derived the same as endpoint weights. It is difficult to directly compare the result with others methods which have different numbers and names of midpoint categories and also different method. However, priority of the environmental issues may be possible to see the relationship to BEE 2.0 method which has been studied these issues in North America (556 respondents). The result in table 3 reveals that the larger standard deviation of BEES 2.0, the more variance in weight as compares to Thailand. The ranking of both studies are totally different. This table also confirms that different areas might cause the differences in scores. In case of twelve midpoint categories of Thailand, the weighting scores are within a narrow range (7.87 to 8.98%), which indicates that overall of the respondents had similar level of concern for the categories. Midpoint categories of Thailand points to two groups: loss of habitat, water depletion, ecotoxicity, human toxicity, climate change with relatively higher weighting scores, and ozone depletion, eutrophication (...), ionising radiation with lower weighting scores. Categories in the first group tend to affect more directly humans and their surrounding environments, while categories in the second group are further from daily experiences.

Table 2: Endpoint category's weighting factors (WF) compare to Eco-indicator 99 [8].

Category	Thailand (n=500)			Eco-indicator 99 (n=82)	
	Mean	SD	%WF	SD	%WF
Human health	8.23	1.89	34.11%	20%	40%
Health of ecosystems	7.95	1.88	32.93%	20%	40%
Resources depletion	7.96	1.97	32.96%	15%	20%

Table 3: Midpoint category's weighting factors (WF) compare to BEES 2.0 survey [10].

Category	Thailand (n=500)			BEES 2.0 Survey (n=556)	
	Mean	SD	%WF	SD	%WF
Loss of habitat	8.36	1.91	8.98%		
Water depletion	8.35	2.17	8.97%		
Ecotoxicity	8.05	1.94	8.64%	4.1	10.0
Human toxicity	8.02	1.97	8.61%	2.4	7.0
Climate change	7.90	2.12	8.49%	12.5	21.2
Ozone depletion	7.58	2.05	8.14%	3.6	8.0
Eutrophication	7.58	2.02	8.14%	2.5	6.3
Acidification	7.55	1.97	8.11%	1.5	5.8
Fossil fuel depletion	7.53	2.15	8.09%		
Mineral and metal resource depletion	7.46	2.13	8.01%	4.3	14.2
Formation of ground level organic compounds and particles	7.41	2.06	7.95%	2.4	8.5
Ionising Radiation	7.33	2.13	7.87%		
Solid waste				2.4	7.0
Indoor Air Quality				8.9	12.0

4. Conclusion

As the first study of weighting factors for LCA midpoint and endpoint categories for Thailand, 500 Thai people were collected by online and field survey. The result of this study, sex, age, and occupation were found a few significant differences in weights which are not highly effect to the scores. But type of survey and level of concern for environmental problems had a great influence. Therefore, every people in Thailand are possible to involve themselves with this survey but type of survey and level of concerns for the problems should be considered. Endpoint categories received similar weights, with human health ranked as the highest priority, followed by health of ecosystems and resources depletion, respectively. Midpoint categories can be divided into two groups: In the first group, loss of habitat, water depletion, ecotoxicity, human toxicity, and climate change, these midpoint categories having more direct effects on humans received higher weights. In the second group, the rest midpoint categories further from daily experiences received lower weights. This result reveals that Thai people care about the environmental problems around themselves. The weightings of the endpoint and midpoint categories are different from Eco-indicator 99 and BEES 2.0, which may reflect different perceptions of environmental problems by the Thai society than in western societies, as well as changes in perceptions since the publication of Eco-indicator 99 and BEES 2.0. Thus, it is useful to determine weighting factors for specific regions, in order to understand regional differences in terms of environmental thoughts and priorities among human societies. For the business sector, these results can be used to focus on environmental problems identified as being of higher concern in their regions of operations. The study will be extended to Japan and Europe with the same questionnaires in order to further assess differences between regions.

5. Acknowledgements

Thank you for kind support from CIRAD-UMR Qualisud, Kasetsart University, Assoc.Prof.Dr.Naoya ABE, Tokyo Institute of Technology Japan, TAIST-Tokyo tech, NSTDA, department of Statistic and the graduate school, Kasetsart University.

6. References

[1] M. Tseng, S.F. Chiu, RR. Tan, and A.B. Siriban-Manalang. Sustainable consumption and production for Asia: sustainability through green design and practice. *Journal of Cleaner Production*. 2013.

[2] J. Kurokawa, T. Ohara, T. Morikawa, S. Hanayama, G. Janssens-Maenhout, T. Fukui, K. Kawashima and H. Akimoto. Emissions of air pollutants and greenhouse gases over Asian regions during 2000–2008: Regional Emission Inventory in ASia (REAS) Version 2. *Atmospheric Chemistry and Physics*. 2013,13 (21): 11019-11058.

[3] M.P. Cassiano, M.d.L. Leila, Z. Lidiana and C.d.F. Antonio. Life cycle assessment as entrepreneurial tool for business management and green innovations. *J. Technol. Manag. Innov*. 2013,8 (1):

[4] A. Carvalho, A.F. Mimoso, A.N. Mendes and H.A. Matos. From a literature review to a framework for environmental process impact assessment index. *Journal of Cleaner Production*. 2014,64 (0): 36-62.

[5] M. Goedkoop, R. Heijungs, M. Huijbregts, A.D. Schryver, J. Struijs and R.v. Zelm. ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. In: Report I: Characterisation. 2013. 4.

[6] M. Goedkoop and R. Spriensma. The Eco-indicator99: A damage oriented method for life cycle impact assessment: Methodology report. 2001,

[7] International Organization for Standardization 14040. Environmental Management — Life Cycle Assessment — Principles and Framework. 2006.

[8] T.M. Mettier and P. Hofstetter. Survey insights into weighting environmental damages: Influence of context and group. *Journal of Industrial Ecology*. 2004,8 (4): 189-209.

[9] N. Itsubo and A. Inaba. A new LCIA method: LIME has been completed.*Int. J. LCA*. 2003,8 (5): 305-305.

[10] P. Hofstetter, B.C. Lippiatt, J.C. Bare and A.S. Rushing. User preferences for life-cycle decision support tools: Evaluation of a survey of BEES users. US Department of Commerce, Technology Administration, National Institute of Standards and Technology, 2002.

[11] T. Yamane. *Statistics, An Introductory Analysis*. Harper and Row, New York. 1967.