The Significance of Public Involvement on Minimizing the Public Health and Environmental Impacts from Electronic Waste Recycling at the Community Level

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Abstract

To minimize the impact of electronic waste recycling at the community level on public health and the environment, careful planning and appropriate solutions are needed. The authors worked with the Khok Saat community in Kalasin Province as a case study and found that it is most effective to involve all the stakeholders during management of the problem solving process. Some of the most important stakeholders are national and local government, community members, and local recyclers. There are two phases to this study. In the first phase, four existing public participation models were used to develop a new and more suitable public participation model. This new model identifies and includes seven groups of stakeholders and five degrees of participation. In the second phase, the new model was used to identify problems and find solutions regarding e-waste recycling in the affected community.

To apply the new model, focus groups were created and their opinions and views were gathered and analyzed by applying the Appreciation Influence Control (AIC) technique. Face to face interviews were conducted with various representative stakeholders using both structured and unstructured questionnaires completed by all participants. The focus group technique was shown to be the most suitable and most efficient approach to gathering information, and for delivering and clarifying information to the participants. The resulting effective solutions were divided into three Solution Groups, namely 'Use of an effective business model', 'Delivery of knowledge, skill, and technology', and 'Development of local regulations and law enforcement'. All three Solution Groups must be implemented in order to successfully decrease environmental and health impacts in the Khok Saat community. The new problem solving approach as well as the action model developed should be applicable to any other community regardless of country or culture.

Keywords: Waste Electrical and Electronic Equipment, Environmental Impact, Public Health Impact, Waste Recycling, Community Level

Introduction

Electronic waste (e-waste) includes non-working, obsolete or expired electronic and electric equipment (EEE) which must be disposed of in some manner. E-waste items usually include numerous valuable materials such as Iron (Fe), Copper (Cu), aluminium (Al), lead (Pb) and nickel (Ni), and rare earth metals such as palladium (Pd), gold (Au) and silver (Ag) can also be recovered from some e-waste materials (Cui and Zhang, 2008). However, processing of the e-waste to recover these valuable products also produces hazardous materials which present significant public health and safety risks, and environmental pollution. The extent of the problem can be seen from a report (Baldé, Wang, Kuehr and Huisman, 2015) which estimates the total amount of e-waste generated in 2014 at 41 million tonnes (metric tonnes), and the predicted volume in 2018 is 50 million tonnes. The developed countries (e.g. Australia, Canada, European countries, Japan, South Korea, and United States) are the main producers of e-waste, and the developing

countries such as China, India and Pakistan are the major consumers and processors of that e-waste (Puckett et al., 2002). African countries are also destinations for e-waste.

China currently processes the majority of e-waste and several reports have shown high levels of associated pollutants in the water and soil which exceed acceptable quality standards. Guiya city in China hosts many small processing activities with manual processing methods, open burning of plastics from scrap electrical wiring, and metal separation from waste printed circuit boards by heating or with acid, and the storage and breakup of large volumes of old printer cartridges. Traces of copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), nickel (Ni), chromium (Cr), and aluminum (Al) traces in the soil near the recycling facilities were higher than recommended in both Chinese and European quality standards (Leung, Cai and Wong, 2006; Li, Duan and Shi, 2011). Studies in Tai Zhou city (Tang et al., 2010), and Long Tang city (Luo et al., 2011; Wu et al., 2015), where extensive e-waste processing is done, found that the quantity of toxic metals in the soil was also higher than accepted soil quality standards. It is therefore imperative for governments to establish e-waste management laws and to regulate the industry. To achieve proper and workable government intervention, by way of laws and regulations, and enforcement procedures, both community and industry involvement is essential. Voluntary industry Codes of Conduct are also necessary, although these would be more likely to be adhered to by larger recycling companies than small local community located recycling shops. This latter considerations implies greater local participation is necessary to place pressure on the local operators.

In Thailand, e-waste recycling has become a necessity and the demand is growing. However, it has often created negative public health and environmental impacts due to incorrect and inefficient recycling and disposal methods. Many recycling operations are located in residential and local areas, on private dwellings and often near public places such as schools and temples. Such locations had created conflict within the local and surrounding communities. These local recycling workshops constitute the informal recycling activities, as distinct from the formal recycling activities carried out by larger, better equipped recycling plants. The major differences between formal and informal categories are in the level of investment in equipment and facilities, recycling technology employed, number of employees, and regulation; formal recycling businesses require a recycling permit whereas the informal recycling shops do not.

It is the informal, community located recycling workshops were the focus of our research. These businesses are small operators, produce less recycled material and employ manual methods rather than using machinery. They normally operate without any significant regulatory oversight. The workers in the informal recycling activities do not wear or possess safety equipment, so are directly exposed to toxic e-waste. As a result, the informal recycling processing segment of the industry has a significantly greater impact on public health and the environment than the formal recycling industry (Fujimori et al., 2012).

The fact that these informal recycling are located within the community and may employ workers from the community, thereby having very much a 'community impact', makes it an important matter to be studied using an appropriate and comprehensive social impact model, which would better empower local communities and stakeholders to act on these issues. The causes of social and environmental problems in e-waste recycling in Thailand were the education and economic level, knowledge about existing e-waste-related laws and how to improve environmental condition (Liang and Sharp, 2017). An effective e-waste management system is not only concern about the well-established of policy, process, and practice but need to concern about well-conditioned enforcement and implement program (Liang and Sharp, 2016). The study by

Muenhor, Harrad, Ali and Covaci (2010), from which the concentration of brominated flame retardant (BFRs) in dust sample and indoor and outdoor air from 5 e-waste storage (3 in Ayutthaya, 1 in Nonthaburi, and 1 in Bangkok) lower than reported previous in China, Sweden, the U.S. concentration. The highest concentrations are in a room used to use discard TVs, stereo, and radio.

Communities identified for this study included: Sue Yai Utit Slum community in Bangkok, Khok Saat community in Kalasin province, Dang Yai community and Baanpho community in Buriram province. Khok Saat community was selected because there were several informal recycling processing businesses owned by local people who have operated their businesses for a long time. The recycling activity occurs within, and around the proximity of the residential areas. This had been done so over many years, meaning that the impacts of the informal recycling activities on public health and environment are clearly and easily identified. In 2014, we conducted a brief public survey in the Khok Saat community, over three time. We found that copper recovery from electrical wiring, and steel metal recycling from cathode ray tube (CRT) monitors, resulted in the most hazardous conditions. Specifically, when CRT monitors are broken up, polychlorinated dibenzodioxins /furans (PCDD/Fs) and lead contaminants leaked into the air, and the surrounding soil, surface and ground water. Our observations were very similar to those in a previous study in the same area which had found concentrations of copper, mercury and manganese in leachate above the regulatory standards. In soils collected from the dumping area and in informal recycling activity areas, the levels of copper, lead and zinc contaminations were high. However, these concentrations of mercury, lead, cadmium, copper and nickel in surface water and rice paddy adjacent to the dumping area and in informal recycling activity areas, the levels of copper, lead and zinc contaminations were high (Saetung, 2009).

This study had developed a new social action model with effective participatory methods and activities, based on extensions to existing models of social participation. The characteristic of group of stakeholder and degree of participation were analyzed by two hypothesis: 1. the stakeholders' understanding of the model, communication with other stakeholders' groups, and managing participation within the group do not have influence within the group of stakeholders (or degree of participation), in all participation models (H_0), and 2. the stakeholders' understanding of the model, communication with other stakeholders' groups, and managing participation within the group do have influence within the group of stakeholders (or degree of participation), in all participation models (H_1). We also apply a new model to the identification, elicitation and analysis of the problems and solutions by adding inputs from participating communities.

Methods and Materials

There are two phases to analyze the new public participation model as showed in Figure 1.

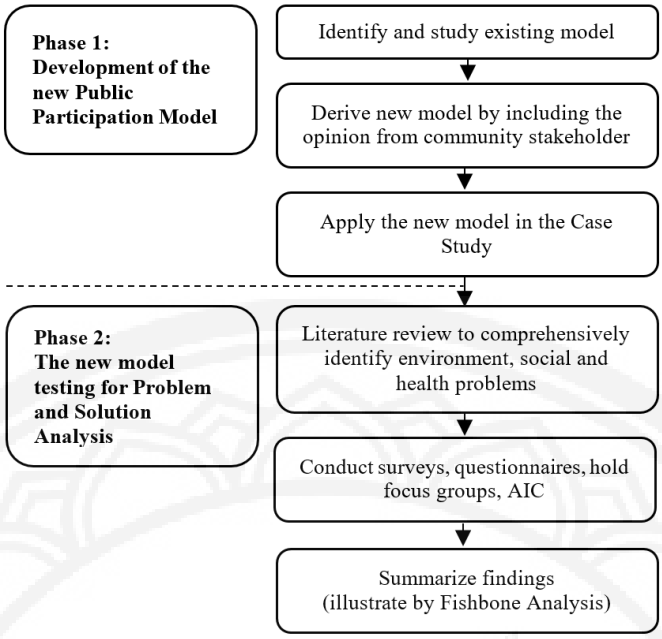

Figure 1 Methodology Approach

Phase 1: Development of the New Public Participation Model

First, an extensive study of the existing models of social participation was undertaken. The four models identified include: ONEP model (Office of Natural Resources and Environmental Policy and Planning (ONEP), 2006); Det model (Wattanachaiyingcharoen, 2010); Netherlands Environmental Assessment Agency model (Hage and Leroy, 2008); State of Victoria model (State of Victoria, Australia, 2005). The parameters 'Group of stakeholders' and 'Degree of participation' of each model were identified and included in our questionnaire to allow us to gain information on 'public' understanding of these. For example, the ONEP model identifies and lists seven groups of stakeholders: 1. Non-beneficiaries and Beneficiaries, 2. Consultant and project owner, 3. Government agencies who give a license, 4. Central, provincial and local government, 5. Environmental NGO, NGO, Education institute and Independent academician, 6. Mass media, and 7. Public at large. The questionnaire respondents were requested to state whether they understood these groupings, at what level of understanding, on a Likert scale from 0 to 5. This scale is widely used to 'assess respondents' attitude such as to measure waste management satisfaction and evaluate respondents' willing to participate in waste separation and payment, and the future waste management scenarios (Xian, Zhang, Zhu and Lin, 2017)', 'measure knowledge and experience with wind energy and perception of infrasound on energy project (Langer, Decker and Manrad, 2017)', and 'consider the acceptation of urban renewal plan (Wang, Hu, Li and Liu, 2016). Before the questionnaires were used, they were examined by three environmental experts, one environmental institute, and one big waste recycling plant. All of examiner have experience in environmental management and public participation activities.

Similarly, for the parameter 'degree of Participation', the Det model listed six categories of participation: 1. Public information available, 2. Public consultation, 3. Public meetings/forums, 4. Public decision making, 5. Participation by legal mechanisms, and 6. Participation in control. Again, the participants were asked to indicate if they understood this classification of community participation, and their level of understanding of what each implied for their involvement in a social or community participation program.

We then distributed the questionnaires to eight representative members of the communities in the study,

and from local government and any other interested parties, to assist in defining the new model of participation appropriate to a study of informal e-waste recycling in those study sites. In our study, we coded 'How well do the stakeholders understand the model?' as (U), and the 'How well can the stakeholders communicate with each other?' as (C), and 'How easily can stakeholder participation be gained and managed?' as (P). The scoring of the questions on this questionnaires were set up as a Likert Scale from 0 to 5; 5 being 'highly feasible' down to 0 which was 'not feasible'. The results from the responses to the questionnaire were evaluated by a χ^2 test for an independent sample with 95% confidence interval. Two hypotheses were developed.

For the group of stakeholders (or degree of participation) tested;

H_o: Stakeholders' understanding, communication, and managing stakeholder participation dimension and the characteristics of the group of stakeholders (or degree of participation) in each participation model are independent.

This means that the stakeholders' understanding of the model, communication with other stakeholders' groups, and managing participation within the group do not have influence within the group of stakeholders (or degree of participation), in all participation models.

H_1: Stakeholders' understanding, communication, and managing stakeholder participation dimension and the characteristics of the group of stakeholders (or degree of participation) in each participation model are not independent.

This means that the stakeholders' understanding of the model, communication with other stakeholders' groups, and managing participation within the group do have influence within the group of stakeholders (or degree of participation), in all participation models.

The conclusion derived from the questionnaire and the analysis of the responses was the creation of this new model of social participation, which included the various parameters from the four models which, based on the responses from the questionnaire, we considered were most appropriate for inclusion, and excluding those which had been least understood by the respondents. The new model was then applied to the particular problem under consideration that of e-waste processing in the community selected for this study, Khok Saat.

Phase 2: The New Model Testing for Problem and Solution Analysis

The new participation model was employed to identify significant causes of problems and feasible solutions. Several public participation tools were used such as the information from our literature review of related studies, the survey which we undertook, and the questionnaires and from public meeting attended by e-waste recycle, related people and other related agencies. The Appreciation Influence Control (AIC) technique was applied in the public meeting. The significant problems and solution results from every steps were analyzed and classified using Fishbone technique with six different influencing factors, including machinery (technology), methods (process), materials, manpower, measurement and environment. After that summary them as the clearly and easily diagram.

Results

Phase 1: Development of the New Public Participation model

Four models of public participation were compared. Two out of the four models applied in this study were from Thailand. The factors considered in each model are shown in Table 1 and Table 2 After model classification, the scoring process to rate the components relating to public health and environmental factors affected by e-waste recycling was undertaken using the three dimensions of U (How well do the stakeholders understand the model?), C (How well can the stakeholders communicate with each other?), P (How easily can stakeholder participation be gained and managed?).

Scores were assessed using the questionnaires initially provided to the eight respondents from seven groups of stakeholders associated with e-waste recycling activities in the study area. The seven groups of stakeholders participating in the scoring process included the community leaders (R1), Sub-district administrative organization (R2), the public health center (R3), primary school (R4), environmental institute NO.1 (R5), environmental institute NO.2 (R6), the recycling shop (R7), and the university (R8). The results were statistically tested using χ^2 test for independent samples. This technique was utilized to determine the relationship between the type of participation model associated with all of three dimension of 'U', 'C', and 'P'.

The results from the statistical analysis between the public participation model and the degree of difficulty in the participating stakeholders' understanding, communication and managing participation for all respondents supported the acceptance of H_o and rejection of H_1. This result indicated that the four different participating models can be implemented in the e-waste recycling processes at the community level in order to overcome the important problems related to public health and the environment. Given this, in this study the group of stakeholder's model proposed by ONEP and the degree of participation from Victoria's study were utilized

Phase 2: The New Model Testing for Problem and Solution Analysis

In order to identify significant causes of problems and solutions, 3 analysis steps were performed. These 3 approaches included a review of existing studies related to public health and the environment from many sources, then the performance of new studies, as shown in this study and, finally, public hearings with people and organizations related to e-waste recycling activities. This was done on July 16, 2014, using Appreciation Influence Control (AIC) techniques. The 93 participants from the recycling shop and 14 participations from related agencies were participated as the one group. The problems and solutions from AIC technique were classified by Fishbone technique into six different categories, including Machine (technology), Method (Process), Materials, Manpower, Measurement and Environment. After that the significant 16 problems such as 'economic and financial problem', 'separators don't have knowledge about efficiency and safely of e-waste separator technique', and 'no marketing promotion system from e-waste separation product' were grouped into seven different influencing groups, including 'lack of basic human need', 'lack of knowledge', 'lack of skill', 'lack of technology and management', 'lack of funding and organization', 'lack of law and regulation', and 'lack of enforcement'. From public participation process with the new model, the eight individual significant solutions were grouped into three groups including 1. 'Effective business model' consist of three individual solutions: 1) to expand the irrigation, if people have enough water for agriculture, inappropriate e-waste separation activities will decrease, 2) to site visit in successful e-waste separation shop, and 3) to set up workshop and training activities about appropriate technology that can solve three groups of problems: 'lack of human need', 'lack of knowledge', and 'lack of technology and management', 2. 'Package of knowledge, skill, technology' consists of two individual solutions that can solve six groups of problems, and 3. 'Develop of local regulation and enforcement law' consist of three individual solutions that can solve two groups of problems (see in Figure 2).

The three groups of effective solution in Figure 2 can be classified into (i) solutions requiring financial support from central government and (ii) solutions requiring little or no financial budget or funding support, with any support coming from local government and community groups. Involvement of the central government usually takes time and administrative effort over a long period, but when 'local' solutions are sought, the local government or community group is more able to act quickly and more can immediately be accomplished by

the local government and local people. This latter approach is considered to be the more successful for attaining sustainable solutions, which was demonstrated in our study.

Table 1 Existing Participation Models of Stakeholder

Existing Model	Group of Stakeholder
ONEP model (Office of Natural Resources and Environmental Policy and Planning (ONEP), 2006)	Seven specific groups of stakeholder 1. Non-beneficiaries and Beneficiaries 2. Consultant and project owner 3. Government agencies who give a license 4. Central, provincial and local government 5. Environmental NGO, NGO, Education institute and Independent academician 6. Mass media 7. Public at large
Det model (Wattanachaiyingcharoen, 2010)	Five specific groups of stakeholder 1. Project proponents 2. Community 3. Government unit 4. Consultant 5. Public at large
Netherlands Environmental Assessment Agency model (Hage and Leroy, 2008)	Four general groups of stakeholder 1. Government 2. Expert system 3. Industry 4. Interest groups * use mind map to determine specific groups of stakeholder
State of Victoria model (State of Victoria, Australia, 2005)	Four general groups of stakeholder 1. Social 2. Environmental 3. Culture 4. Economic * use mind map to determine specific groups of stakeholder

Table 2 Existing Participation Models of Degree of Participation

Existing Model	Degree of Participation
ONEP model (Office of Natural Resources and Environmental Policy and Planning (ONEP), 2006)	Four principles of participation (don't define the degree of participation) 1. Start early 2. Stakeholders 3. Sincerity 4. Suitable method
Det model (Wattanachaiyingcharoen, 2010)	Six degrees of participation (Low -> high) 1. Public information 2. Public consultation 3. Public meeting/forum 4. Public decision making 5. Participation by legal mechanisms 6. Participation in control

Table 2 (Cont.)

Existing Model	Degree of Participation
Netherlands Environmental Assessment Agency model (Hage and Leroy, 2008)	Eight degrees of participation (Low -> high) 1. Use no participation 2. Inform 3. Study 4. Listen 5. Consult 6. Take advice 7. Co-produce, 8. Co-decide
State of Victoria model (State of Victoria, Australia, 2005)	Five degrees of participation (Low -> high) 1. Inform 2. Consult 3. Involve 4. Collaborate 5. Empower

Discussion

The new public participation model was derived from four previously published models. Representative from stakeholder groups, and individuals in the community, who participated in the study, were requested to complete a survey questionnaire. The results were then analyzed using χ^2 tests for independent samples. The χ^2 test results indicated that all four participation models used in this study were applicable to the matters of public health and the environment, and were therefore appropriate analysis methods to apply in an e-waste recycling study. In this study, the new model consist of seven groups of stakeholders (Office of Natural Resources and Environmental Policy and Planning (ONEP), 2006) and categorized the degree of participation into 5 different classes (State of Victoria, Australia, 2005). Seven groups of stakeholders were categorized based upon the impact levels and degree of association combined with their responsibility for public health and environmental problems and protection.

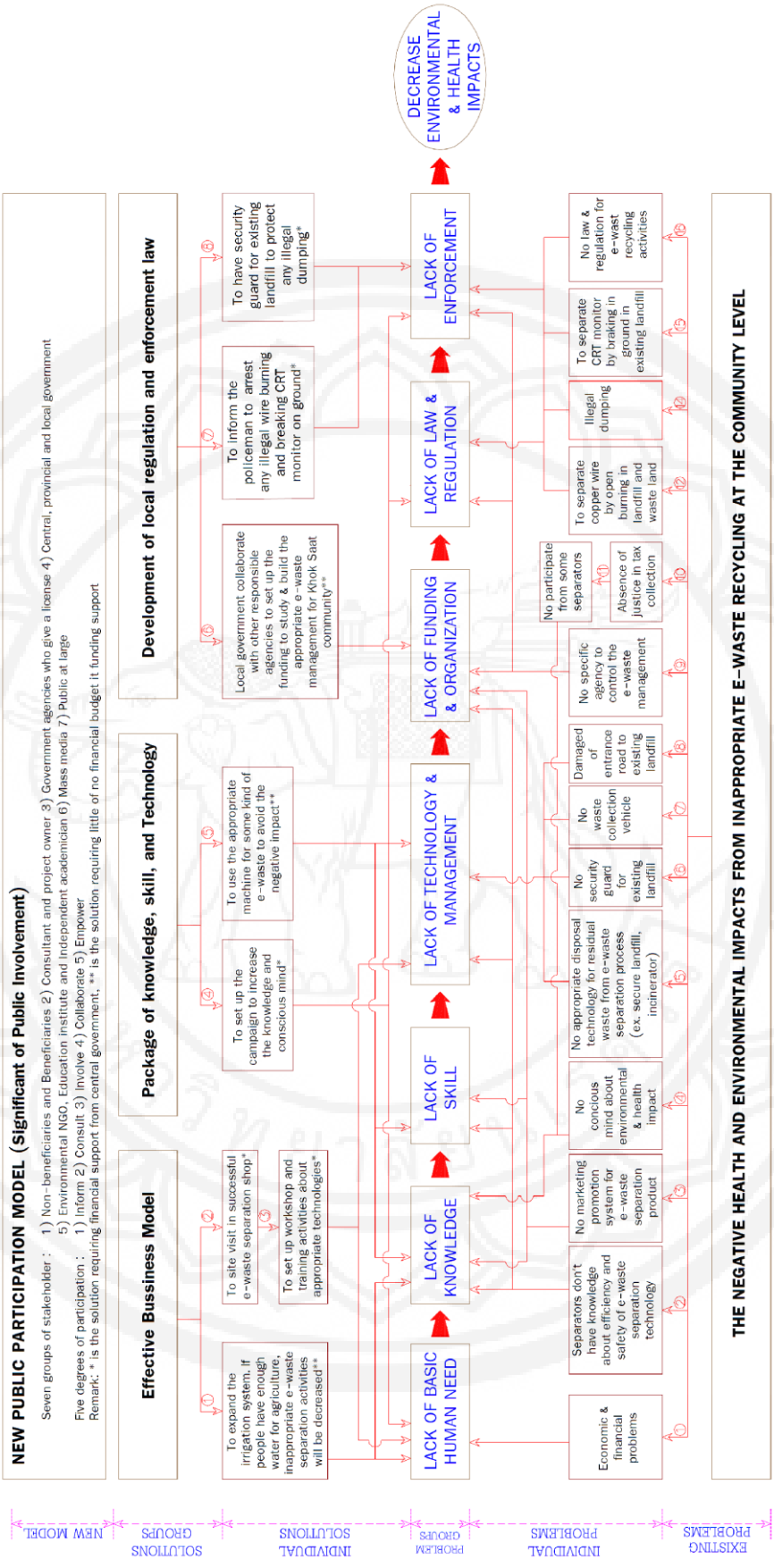

Figure 2 The Significant of Public Involvement on Minimizing the Public Health and Environmental Impacts

The study by Estrada-Ayub and Kahhat (2014), from which we derived our stakeholder classifications, classified stakeholders into three different groups, entailing micro, meso and macro levels, divided into 20 different subgroups based on their activities and involvement in the situation. Other models showed different approaches, which we did not adopt, although our model achieved similar outcomes. (Keramitsoglou and Tsagarakis, 2013; Charnley and Engelbert, 2005) for example, did not classify or group stakeholders into many classes, and scored associated people and agencies equally. Surveying is a usual approach in social research studies (Estrada-Ayub and Kahhat, 2014; Keramitsoglou and Tsagarakis, 2013; Charnley and Engelbert, 2005). Questionnaires are the major tool used to carry out surveys, either alone or as a basis for further information gathering, such as face-to-face interviewing. The questions in a questionnaire are prepared based upon the research objectives. Estrada-Ayub and Kahhat (2014) used both structured and unstructured interviews, whereas Keramitsoglou and Tsagarakis (2013) and Charnley and Engelbert (2005) utilized solely structured interviews. The previous survey methods from Estrada-Ayub and Kahhat (2014) and Keramitsoglou and Tsagarakis (2013) employed the face to face interview, but Charnley and Engelbert (2005) used a postal survey, a telephone survey and target groups. Charnley and Engelbert (2005) claimed that the postal survey was the most effective method which minimized time and budgets. In our study we used all these acknowledged survey approaches, but we also used focus groups and held public meetings as information gathering approaches, and applied the Content Analysis technique to deriving appropriate information from the recorded discussions in these meetings. We found that the focus group concept was effective. The participants at a focus group meeting are able to present more of their opinions, more personal information, a better understanding of their beliefs and viewpoints in the atmosphere of the focus group than was possible from pre-prepared questionnaires and survey instruments. More project information, additional knowledge relating to problem significance and awareness, and information on the benefits arising from the stakeholders' participation in the study could be ascertained, or promulgated and distributed in the focus groups. As well as in the focus groups, a greater level of trust amongst the various stakeholders was formed when face-to-face interviews were carried out. Generally, the focus group is considered to be the best two-way mode of communication associated with the Appreciation Influence Control (AIC) technique applied to the analysis of the problem and for determining solutions that do arise from personal participation.

The new participation model from our study showed high promise when applied to stakeholder understanding, stakeholder communication and stakeholder practice. One important aspect of identifying stakeholders which was relevant to the areas studied, and also for other regions in Thailand, and other countries within the Asian region, is that the people in those areas are socially, culturally and traditionally homogenous and have very similar knowledge and viewpoints. The problems and solution of e-waste separation in community level that finding from our study can be applied in the same way with the new participation model.

Conclusion

To solve or prevent long-term environmental and public health problems caused by the e-waste recycling process, it is necessary to involve all affected parties in developing a sustainable solution. The authors developed a social collaboration model to enable comprehensive stakeholder involvement.

The three criteria discussed with stakeholders in order to understand the existing model and develop the new model were: 'How well do the stakeholders understand the model?', 'How well can the stakeholders

communicate with each other?', and 'How easily can stakeholder participation be gained and managed?'. These three criteria were useful for extracting stakeholders' opinions of the existing models and developing the new model. Furthermore the effectiveness of the new model for understanding problems and developing solutions in turn confirmed the sound design of the three fundamental criteria. The new model was developed with seven groups of stakeholders and five degrees of participation. To select the most appropriate public participation tools (e.g. focus groups, questionnaires, face-to-face interviews, etc.), the following important characteristics of each community member were considered: their education, knowledge, local culture, traditions, occupation, and community standing. The results showed that questionnaires, focus groups and public meetings were the most effective tools to collect information from the stakeholders about problems and solutions. This study's new model as well as the model's results regarding problems and solutions can be applied to other regions in Thailand and other countries in Asia, since these people share many similar social and cultural characteristics as well as related knowledge and viewpoints.

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