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Mitigating pollution of hazardous materials from WEEE of China: Portfolio selection for a sustainable future based on multi-criteria decision making

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ABSTRACT

In order to solve the environmental contaminations and human health problems caused by the inappropriate treatment of waste electrical and electronic equipment (WEEE) in China, sustainable e-waste treatment has emerged in China's WEEE recycling industry. This study aims to develop a multi-criteria decision making method by integrating interval Analytic Hierarchy Process and interval VIKOR method for China's stakeholders to select the most efficacious portfolio for solving the severe problems caused by the informal e-waste recycling and promote the development of China's WEEE recycling industry in a sustainable approach. An illustrative case in Guiyu has been studied by the developed method, and the results show that the portfolio of supporting the informal peddlers for legal transition, investing on infrastructure for WEEE recycling, training and education on China's residents, and restricting the foreign WEEE importation is the best one for Guiyu to solve the environmental problems caused by the informal treatment and recycling of WEEE.

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1. Introduction

A huge amount of waste electrical and electronic equipment (WEEE, so-called "e-wastes") were generated each year in China, and the inappropriate treatment of e-wastes could cause resource waste, serious environmental pollutions, and severe human health problems (Wen et al., 2006). China's e-wastes flow into two main channels: the informal collection channel, in which, the individual workshops, peddlers and hawkers recycle and resell the WEEE or the components and raw materials in an inappropriate way, and the official recycling sectors special for e-waste treatment that were established by the governmental agencies (Veenstra et al., 2010). Since a large part of WEEE in China was collected by the informal collection channel (Veenstra et al., 2010; Bo and Yamamoto, 2010), serious pollutions could occur due to the improper treatment of e-wastes by the informal sectors. For instance, in the city of Guiyu in Guangdong, the improper treatment of e-wastes, has caused many problems on aquatic systems, air, soils, human health, etc. (Robinson, 2009). Therefore, it is very urgent to develop a sustainable and environment-friendly e-waste treatment manner.

There are various barriers and factors that lead to the imperfect e-waste recycling system in China (Milovantseva and Fitzpatrick, 2015; Estrada-Ayub and Kahhat, 2014), e.g. lack of national management strategies (Liu et al., 2006), inadequacy of law and policies for e-waste governance (Zhang et al., 2012), China's special current situations – the conflict between economic development and environmental protection (Zhang, 2009; Tong, 2004), and governance and enforcement challenges (Yu et al., 2010). Although there are also various measures for overcoming these barriers and promoting the sustainable development, one measure can only overcome one barrier rather than all the barriers. The decision-makers usually adopt the portfolio that consists of multiple measures to overcome multiple barriers. Accordingly, it is of vital importance for the stakeholders to select the best portfolio for promoting the sustainable development of WEEE treatment. However, it is usually

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difficult to select the best portfolio among multiple alternatives as the decision-making process is a typical multi-criteria decision-making (MCDM) problem that has to consider multiple conflicting criteria.

A variety of studies have reported to use MCDM methods for portfolio selection concerning WEEE treatment. Queiruga et al. (2008) employed a PROMETHEE method for evaluating site location of WEEE recycling plans. Banar et al. (2014) studied plant site selection for WEEE recycling plants in turkey by using MCDM methods. Rousis et al. (2008) used multi-criteria analysis for determining the best scenario for WEEE management in Cyprus according to their performance and efficiency. Bereketli et al. (2011) developed a multidimensional analysis method for the evaluation of WEEE treatment strategies. Different from the previous studies, the aim of this study is to develop a MCDM method for decision-makers to determine the most appropriate portfolio that consists of multiple measures for overcoming the barriers and promoting the sustainable development of e-waste treatment under the conditions of uncertainty and incomplete information.

Besides the introduction section, the remainder of this study was organized as follows. The barriers for hindering the sustainable development of the e-waste recycling industry in China and the strategic measures for addressing these barriers were identified and summarized in Section 2; the MCDM method developed in this study was presented in Section 3; an illustrative case was studied by using the proposed method in Section 4; finally, this study was discussed and concluded in Section 5.

2. Barriers and measures

In this section, the barriers that hinder the sustainable development of WEEE treatment industry were firstly identified, then some measures for overcoming these barriers were proposed, and finally the feasible portfolios were constructed by combining several of these proposed measures.

It is well recognized that economic performance, environmental impact and social acceptability are the three pillars of sustainability (WCED, 1987). With the considerations of the influences of technological and political aspects on these three pillars, this study investigated the barriers of the sustainable e-waste treatment in China in four aspects, i.e. economic, environmental, technological, social–political aspects. A total of 13 barriers have been obtained based on literature review and a focus group meeting (Table 1).

2.1. Economic

2.1.1. Low economic incentive for formal recycling

Formal treatment plants in China have to invest a lot on the facilities/equipments for the e-waste treatment and worker protection, while the peddlers do not need to invest on these items as they recycle the components and metals of e-wastes in a crude way and at a very low cost. Consequently, the formal treatment plants cannot give an attractive price for e-waste collection compared with the individual workshops due to the restriction of high investments, in such case, the collection price between the formal and informal treatment plants is uncompetitive (Qu et al., 2013). For instance, an old computer can be sold to the curbside collector at 150–200 RMB while the formal recyclers can offer much less than this (MEP, 2008; Qu et al., 2013).

2.1.2. Insufficient subsidy and tax system

For collecting and disposing e-wastes in an environment-friendly way, a lot of money has to be invested for e-waste collection, logistics, and treatment equipments, etc. (Qu et al., 2013). The subsidies and tax exemption can effectively encourage more formal companies to participate in the e-waste recycling industry. Zhang et al. (2012) pointed out that it is easier for the small informal workshops to collect the e-wastes from the residents, because the high profits allow them to offer an attractive price to the sellers. On the contrary, the authorized businesses cannot collect enough e-wastes to sustain their normal operations, and the financial incentives like the subsidies and tax exemption can benefit them to collect more e-wastes in China (Zhang et al., 2012; Chi et al., 2011).

2.1.3. Low proportion of recycling by the formal companies

Low proportion of recycling by the formal companies means that the formal companies are not able to collect enough e-wastes due to the reasons like price disadvantage and incomplete industry chain compared with the informal sectors (Wei and Liu, 2012).

2.2. Environmental

2.2.1. Environmental contaminations

Improper treatment of e-wastes could release various hazard materials into the air, water, and soil, and China's primitive disposal of e-wastes has caused serious environmental contaminations and human health problems due to the emissions of several hundreds of hazard materials (Peng et al., 2009). Taking the largest e-waste recycling site in China-Guiyu as an example, the underground water and air in Guiyu was seriously polluted, a lot of adults suffered respiratory and renal diseases, and 81.1% of 1- to 6-year-old children suffered lead-poisoning problems (Peng et al., 2005). Many industrial workers face high risk of health problems as they usually

Table 1
Barriers of sustainable e-waste treatment in China.

Aspect	Barriers		References
Economic	Low economic incentive for formal recycling	EC_1	Qu et al. (2013)
	Insufficient subsidy and tax system	EC_2	Zhang et al. (2012), Chi et al. (2011)
	Low proportion of recycling by the formal companies	EC_3	Wei and Liu (2012)
Environmental	Environmental contaminations	EN_1	Peng et al. (2009)
	Equipment gaps	EN_2	Qu et al. (2013)
Technological	Technology gaps	T_1	Qu et al. (2013)
	Infrastructure gaps	T_2	Qu et al. (2013)
	Incomplete regulatory and legal system	T_3	Wei and Liu (2012), Liu et al. (2008)
	E-waste management and disposal system gaps	T_4	Liu et al. (2008)
	Lack of governance	T_5	Wei and Liu (2012), Liu et al. (2008)
Social–political	Weak awareness	SP_1	Liu et al. (2008)
	Unclear responsibilities	SP_2	Liu et al. (2008)
	Illegal treatment and recycling	SP_3	Wei and Liu (2012)

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