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SOCIO-TECHNICAL PERSPECTIVE ON END-OF-LIFE VEHICLE RECOVERY FOR A SUSTAINABLE ENVIRONMENT

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ABSTRACT

End-of-life Vehicle (ELV) recovery is a promising strategy to minimize the environmental impact of automotives on environmental sustainability. This study aims to assess the community's knowledge from a socio-technical perspective on ELV. A survey was conducted in Japan and Malaysia to assess public perception on ELV recovery. The results showed that the communities in both countries have basic knowledge and a reasonably good level of awareness on environmental issues and recovery strategies such as recycling. However, there is a high level of uncertainty on the concept of ELV reuse and remanufacturing, as more than 50% of respondents were unsure of their willingness to participate in ELV initiatives. The respondents agreed that the industry and government should take the necessary steps to support the reuse strategy. The paper concludes with suggestions from a socio-technical perspective, which aim to ensure an effective implementation of ELV recovery through reuse and remanufacturing.

Keywords: ELV; Public knowledge; Recycling; Remanufacturing

1. INTRODUCTION

The United Nations (2011) noted the challenge of equilibrating the three main pillars (economic, social, and environmental) for finding ways to reach sustainable development and it has to be studied for the safety of the world. End-of-life recovery of products for environmental sustainability spans reuse, remanufacturing, and recycling. While reuse and remanufacturing have been identified as the highest level in the hierarchy of end-of-life recovery, recycling has been more successfully implemented in many countries through related laws or directives. In some countries, such as European Union (EU) countries, ELV directives have been passed to address environmental sustainability issues stemming from ELVs.

While the environmental and economic pillars can be strengthened through enactments and the development of infrastructure to support the market for reuse and remanufacturing, the societal pillar would require a different set of initiatives to ensure an integrated and harmonious growth of environmental sustainability. Few studies have focused on the societal pillar with regard to assessing public or community awareness of or readiness for ELV reuse and remanufacturing.

Watson (2008) highlighted the lack of inadequate research on public attitudes, perception, and

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behavior relating to remanufacturing, repair, and reuse. Rose (2009) reported on the current problems with the implementation of the End-of-life Directive (2000/53/EC), which has been in force since 2004. In addition, Amelia et al. (2009) noted that the lack of public confidence on the quality of reused products was among the major impediments to ELV recovery in Malaysia.

The automotive industry in Malaysia has grown tremendously since the establishment of Proton in 1985, followed by Perodua in 1993 as a part of the National Car Project (Go et al., 2010). The introduction of the National Car Project has boosted the development of automotive components and parts manufacturing in Malaysia. Despite fluctuations in production in the automotive industry, vehicle production in Malaysia has tended to increase, which is reflected by the rapid increase in domestic sales. As such, the automotive industry faces a number of serious challenges in vehicle disposal due to its impact on the environment throughout its entire life cycle.

In Japan, 3.5 million of 76 million in-use vehicles are treated as ELVs each year (Togawa, 2008). The Japanese ELV Recycling Law came into force in January 2005 and has set the standard for the recycling rate of Automobile Shredder Residue (ASR) to 30%, 50%, and 70% for the years 2005–2009, 2010–2014, and by the year 2015, respectively (Ogushi & Kandlikar, 2005). In order to ensure an effective implementation of ELV recovery, it is necessary to understand the community's level of knowledge of ELVs from a socio-technical perspective. The community's awareness and willingness to be involved in the related initiatives are equally important, and for this to happen, it is necessary for members of the community to understand the significance of their role.

To gauge the level of awareness and knowledge of the public community, this study aims to ascertain the public community's perceptions of ELV reuse among communities in two different nations, namely Japan and Malaysia. The findings from the study will enable Malaysia to learn from the Japanese who have enacted and implemented an ELV recycling law since 2005. The study focuses on the public community's knowledge, support, and willingness to be involved in recovery strategies and activities related to EL, and collects their views on how to ensure a successful ELV implementation.

2. METHODOLOGY

The study used a four-part questionnaire: Part A focused on the respondents' backgrounds, Part B focused on the respondents' level of knowledge, Part C on the respondents' support and willingness to be involved, and Part D on the respondents' view of ELV implementation. The respondents were asked to indicate their agreement with each of the given statements on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). To assist the respondents, we also provided the definition of remanufacturing.

Part A collects information related to gender, employment, and level of education.

Part B comprises the following nine statements: I know the concept of recycling of solid wastes (S1); Solid waste should be given due attention (S2); I know the concept of ELV (S3); I know the concept of reuse for ELVs (S4); Solid waste such as car components can be recycled into material at their end-of-life (S5); ELV components which have been tested to assure quality and durability can be reused in a new car (S6); ELV reuse can promote environmental sustainability (S7); ELV reuse can conserve energy (S8); and ELV reuse can reduce unnecessary consumption of new materials (S9).

Part C consists of three statements: I support the concept of remanufacturing for automotive components (S1); I am willing to be involved in the successful reuse of automotive components, e.g., using reused components for own consumption (S2); and, The government

needs to take further action on the management of ELV (S3).

Part D consists of seven statements: Recycling parts and components into materials is an appropriate way to dispose of old cars (S1); Reusing parts and components, which are still of good quality, is an appropriate way to dispose of old cars (S2); The automotive industry should design parts that are easy to uninstall or disassemble in order to support reuse (S3); The automotive industry should choose durable materials for long-term use in order to support reuse (S4); The government should promote remanufacturing of automotive components in the ELV Act (S5); The government should provide a suitable infrastructure for recovery of ELV (S6); and, The government should provide incentives for the public who are involved in recovery activities (S7).

A pilot study was conducted to ensure that the questionnaire was comprehensible and to check the reliability and validity of the results (Simon, 2011). The pilot study involved 10 Malaysian respondents comprising lecturers, postgraduate students, and staff at the Faculty of Engineering and the Built Environment, Universiti Kebangsaan Malaysia. Results of the pilot study were analyzed using the Statistical Package for Social Sciences (SPSS)© version 18. For the study in Japan, the questionnaire was translated into the Japanese language and checked by a research collaborator in Japan.

In Malaysia, the industrial city of Shah Alam in the state of Selangor was selected as the location of study, as it is an automotive city with the highest population in Malaysia (Department of Statistics Malaysia, 2010). We used the formula by Yamane (1967) to determine the optimal sample size:

$$n = \frac{N}{(1 + Ne^2)} \tag{1}$$

where, n = sample rate, N = population, e = significant rate = 0.05.

Therefore, the optimum sample number needed to represent the population of Shah Alam was determined as follows:

$$n = \frac{671282}{(1 + 671282 * 0.05^2)} = 399.8 = 400 \tag{2}$$

Four hundred questionnaires were distributed to respondents who agreed to participate in the study. The respondents were approached in public areas of Shah Alam such as public parks and shopping malls. The questionnaires were collected once the respondents had completed answering the questions.

For the Japanese respondents, the questionnaire was distributed using an Internet-based survey, as it was not possible for us to conduct a survey at public places in Japan. Because of the nature of an Internet-based survey, the number of respondents was dependent on the respondents' willingness to participate voluntarily; therefore, no optimum sample number was measured. The Internet survey collected a total of 254 responses. The main control parameter for the respondents in Malaysia was the citizenship of the respondents; that is, only Malaysian citizens were invited to participate. However, there was no specific condition for the respondents in Japan as it was an Internet-based survey.

3. RESULTS AND DISCUSSION

3.1. Results of Pilot Study

Referring to Table 1, all questions attained a Cronbach's alpha value of more than 0.7, indicating that the questions are comprehensible and need not be modified.

Table 1 Validity of survey questions in part B using Cronbach's alpha in SPSS

No.	Questions	Cronbach's alpha
1.	I know about the concept of solid waste recycling.	0.791
2.	Solid waste in Malaysia should be given due attention.	0.779
3.	I know about the concept of end-of-life vehicles (ELV).	0.786
4.	I know about the concept of reuse for end-of-life vehicles (ELV).	0.783
5.	Solid wastes such as car components can undergo end-of-life reuse process.	0.792
6.	End-of-life vehicle components that have been tested to assure quality and durability can be reused in a new car.	0.771
7.	The process of reuse can generate environmental sustainability.	0.775
8.	The process of reuse can conserve energy.	0.770
9.	The process of reuse can reduce material consumption.	0.775

3.2. Part A: Respondents' Backgrounds

This study aims to understand the community's knowledge and awareness of ELV recovery from a socio-technical perspective. The results show that, in both countries, more male respondents were willing to participate in this study than females, which could indicate a higher level of concern toward ELV issues among males.

Employment is divided into six categories: the public sector, the private sector, self-employed, students, unemployed or retired, and other. Figure 1 shows that the highest percentages of the respondents in Japan (40.2%) and in Malaysia (49.3%) worked in the private sector.

Figure 1 Employment sector of respondents

Likewise, Figure 2 shows that most respondents were educated to university or graduate school level, with 42.9% and 36% for Japan and Malaysia, respectively. This is a good sign since education is positively related to environmental knowledge (Aminrad et al., 2011); therefore, these educated respondents would provide reliable responses.

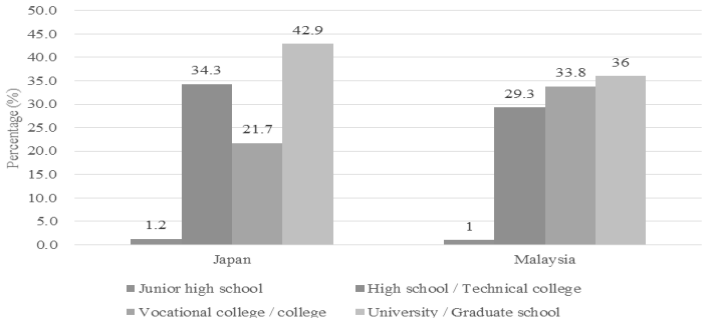

Figure 2 Respondents' education level

3.3. Part B: Respondents' Level of Knowledge

Figure 3 shows the percentages of respondents that "Agree" with the nine statements in Part B. The statements are related to the respondents' knowledge of recycling of solid waste and ELV recovery.

More than 40% of the respondents from both Japan and Malaysia agreed that they are aware of the concept of recycling of solid wastes. However, only 29.3% of Malaysian respondents agreed that solid waste should be given due attention, indicating that the environmental awareness of the Malaysian respondents is lower than that of the Japanese. According to Olmsted (2007), the Japanese are very efficient at recycling. Strict laws are in place, and the Japanese have a great sense of stewardship for the land. The Japanese Government introduced the ELV Recycling Law in 2002 to reduce waste generated from ELV (Ahmed et al., 2014).

More Malaysians were aware of the concepts and reuse of ELV than Japanese, as reflected by a higher percentage of Malaysian respondents who agree with statements S3 and S4. The percentages of respondents in Japan and Malaysia that either agreed or strongly agreed that solid waste such as car components can be recycled into material at their end-of-life is reasonably high at 67.7% and 76%, respectively. In Malaysia, the ELV concept is introduced in the National Automotive Policy (NAP) 2014. The Malaysia Automotive Remanufacturing Roadmap in NAP 2014 provides guidelines for the optimization of recyclability and recoverability levels of used components (Malaysia Ministry of International Trade and Industry, 2014), while Japan's Ministry of Environment has prioritized recycling rather than remanufacturing for solving the final dumping problem in the country. Japan's government unfortunately does not place emphasis on remanufacturing at all. While it has recognized this as an environmentally friendly economic activity, the industry size is much smaller than that of OEMs.

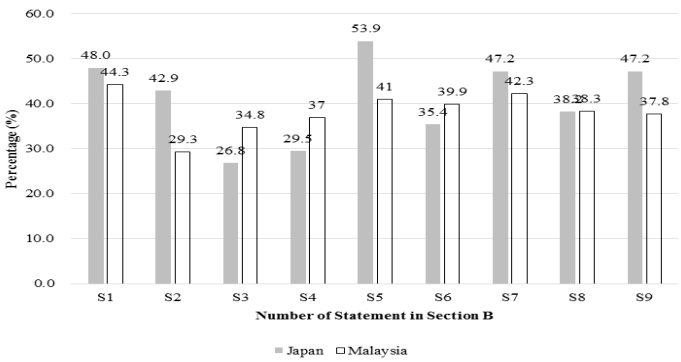

Figure 3 The percentages of respondents that "Agree" with the statements in Part B

Respondents from Japan and Malaysia who agreed that ELV components that have been tested to assure quality and durability can be reused in a new car recorded a similar percentage of approximately 38%. Watson (2008) pointed out issues of trust in remanufactured products—particularly complex remanufactured products of which the reliability cannot be assessed by the consumers—hence the need for a warranty.

The results indicated that 59.8% of Japanese and 91.3% of Malaysian respondents either agreed or strongly agreed that ELV reuse can promote environmental sustainability. Meanwhile, a similar percentage of approximately 38% of respondents from both countries agreed that ELV reuse can conserve energy. The findings from the study also show that the Japanese respondents are unsure whether ELV reuse can promote environmental sustainability and conserve energy. However, it is expected that the Japanese responded as such since they understood that, while ELV reuse reduces energy consumption in the manufacturing and recycling processes, it might

worsen energy efficiency in the use-phase; for example, when the reused component is much heavier than a brand-new component. Therefore, it is most appropriate for the Japanese to respond as "not sure" to the statement. The results also show that 60.6% of Japanese and 95.6% of Malaysian respondents either agreed or strongly agreed that ELV reuse can reduce unnecessary consumption of new materials. These significant results show that respondents agree on the promotion of ELV reuse to support environmental sustainability through reduction in energy and new materials consumption.

A high percentage of educated respondents with more years of formal schooling, contributed towards a higher incidence of pro-environmental behavior than did less educated and lower income respondents (Aminrad et al., 2011). It can be concluded that the respondents gave a significant positive response for knowledge on recycling of solid waste and ELV recovery.

3.4. Part C: Respondents' Support and Willingness to be Involved

Figure 4 shows the percentages of respondents that "Agree" with the three statements in Part C, which related to the support and willingness of respondents to be involved in ELV recovery. As Part C relates to a higher level of knowledge and commitment on remanufacturing, the number of questions is limited to three since it is a new concept in both countries.

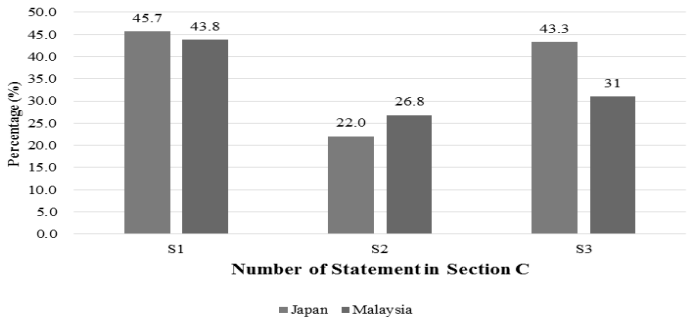

Figure 4 The percentages of respondents that "Agree" with the statements in Part C

Figure 4 shows that a significant percentage of Japanese (45.7%) and Malaysian (43.8%) respondents support the concept of remanufacturing for automotive components. However, the result also indicates a significant percentage of unsure answers among the Japanese respondents, approximately 33.9%. Additionally, the respondents in both countries were unsure of their willingness to become involved in ELV (Japan = 52.8%; Malaysia = 40.5%). Moreover, Amelia et al. (2009) indicated that reusing components or parts in newly manufactured vehicles has yet to be implemented in Malaysia. While the public and manufacturers may understand the need for environmental sustainability through remanufacturing as an ELV recovery strategy, they may not fully understand their role in the process of remanufacturing. The public may also have the impression that ELV efforts must come from the industry and government due to the technical complexity of the ELV implementation.

The Japanese agreed that the government needs to take further action on the management of ELV. However, the percentage of unsure answers is also high (37.4%). Similarly, most Malaysians either strongly agreed or agreed that the government should play their role in the management of ELV. In Japan, the ELV Recycling Law was based on a "shared responsibility" principle in which consumers in Japan have to pay a fee when they purchase a new car or, for cars sold before the enforcement of the law, at the time of mandated regular inspection. Environmental awareness on processes and systems play an important role in environmental education, and education that utilizes the findings of science and technology should play a leading role in creating awareness and a better understanding of environmental problems (Aminrad et al., 2011). Therefore, students should be educated from primary school level, and

the media should be used more intensively by the government to facilitate the transmission of environmental information and promote more positive environmental attitudes, such as using reused or remanufactured products. In other words, educational level is one of the most explanatory variables related to environmental awareness and attitudes (Aminrad et al., 2011).

3.5. Part D: Respondents' Views of ELV Implementation

Figure 5 shows the percentages of respondents that "Agree" with the seven statements in Part D, which indicate the respondents' views in relation to the disposal of old cars and steps to be taken by the industry and the government to support reuse.

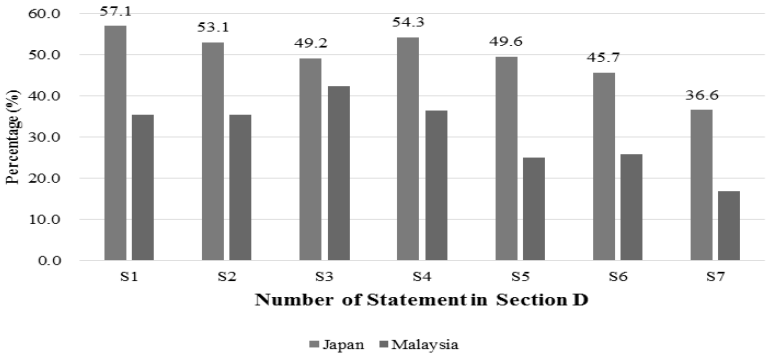

Figure 5 The percentages of respondents that "Agree" with the statements in Part D

Figure 5 shows that a high number of Japanese respondents agreed that recycling and reusing parts and components that are still of good quality is an appropriate way to dispose of old cars. Of the Japanese respondents, 49.2% agreed that the industry should design parts that are easy to uninstall or disassemble to support reuse. However, 31.1 % of them were unsure, which may reflect their misunderstanding of the term "disassemble." Furthermore, most respondents from both countries either agreed or strongly agreed that the industry should choose durable materials for long-term use to support reuse (Japan = 72%; Malaysia = 97.5%).

Environmental concern and government legislation has motivated manufacturers in many countries to consider product life cycle issues and deal with product recovery at the end of the product life cycle (Ahmed et al., 2014). As mentioned before, the Japanese respondents indicated significant responses of "agree" and "not sure" to the involvement of the government in promoting the remanufacturing of automotive components in the ELV Act, providing a suitable infrastructure for recovery of ELV, and developing incentives for the public who are involved in recovery activities. However, the Malaysian respondents indicated a high level of agreement on government involvement in promoting the remanufacturing of automotive components, providing a suitable infrastructure for the recovery of ELV, and developing incentives for the public who are involved in recovery activities. The Japanese may feel that incentives are unnecessary for the implementation of ELV recovery, since recycling has been successfully implemented in Japan without the need for incentives from the government.

3.6. Discussion

The automotive industry is one of the leading industries in this environmentally conscious manufacturing and product recovery (Ahmed et al. 2014). The findings shows that the authorities and automotive industries both play an important role in providing knowledge resources to the community, such as developing consciousness campaigns, workshops, and seminars on the concept of ELV reuse. It was also noted that disposing of vehicles at the end of their lifespan has been a global concern in which unregulated practices have resulted in environmental and health hazards, therefore indicating the need to initiate policies on reduce-reuse-recycle (3Rs), transform recycling activities to the remanufacturing industry, and regulate

the aftermarket towards the environment and the customer. These initiatives would require continuous and diligent education and promotion to achieve consumers' acceptance.

Community education through print and electronic media is also necessary to highlight the concept of the ELV. Disclosure of the ELV concept using the print media such as magazines, newspapers, and newsletters is also an effective way to educate the community since people nowadays have more interactions through electronic media. Therefore, the government authorities and industry must complement one another in their initiatives to educate the public and gain their support on ELV implementation.

In many countries, passing of laws and enactments is seen as a pushing factor for new concepts and implementation. In the EU countries, the directive is the pushing factor for establishing an environmentally conscious automotive industry (Amelia et al., 2009). For example, the EU's ELV Directive (2000/53/EC) has promoted recycling and provided incentives for environmentally friendly vehicle designs (U.S. Environmental Protection Agency, 2008).

While educational programs are necessary in the pursuit of environmental sustainability, it is also necessary to understand the culture and address other barriers such as social stigma on second-hand goods (Watson, 2008), which can be a deterrent to consumers' acceptance of reused and remanufactured products.

4. CONCLUSION

This study aimed to determine the community's level of knowledge, willingness to be involved, and views on ELV recovery in Malaysia and Japan. The results show that both communities have a good basic knowledge of recycling and environmental sustainability, as 42.5% of the Japan respondents and 56.5% of the Malaysia respondents confirmed their awareness of the concept of recycling in their country. Nevertheless, there were some significant differences in their opinions on specific issues such as ELV reuse and its impact, which reflects the actual understanding of the public based on their exposure to ELV issues. The findings from the study lead us to suggest the implementation of educational programs to enhance the community's awareness and readiness to support environmental sustainability. Additionally, the government and automotive industry should provide the proper infrastructure, and the success of ELV reuse should be accomplished through the collaboration and participation of the public community. Concerted efforts need to be undertaken by the various stakeholders to achieve the ELV goals.

5. ACKNOWLEDGEMENT

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