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Developing a Household IoT E-waste Management Guideline: Analyzing Data with Atlas.ti 8

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Abstract*: The Internet of Things (IoT) plays a huge part in the current Fourth Industrial Revolution which turned out to be one of the fastest contributors towards technological development around the world including Malaysia. As good as it sounds, an emergence of new technology means increases in the number of digital devices which later contribute towards the rise of E-Waste or the possibility of "IoT E-waste" generation if they are not managed properly. Hence, this paper aims to investigate the stakeholders involved in managing a sustainable household IoT E-waste collection processes as well as the elements involved in developing a sustainable system to manage those wastes. The research adopts case study research method where three cases were studied and a total of six participants were interviewed, with two participants per case. Outcomes from the interview were transcribed and analyzed using an Atlas.ti software. The identified stakeholders involved and the elements for a sustainable waste system will contribute towards the development of a Sustainable Household IoT E-waste Management Guideline which particularly enables the policymakers to strategize on the planning, development, and implementation of IoT initiatives for the future of Malaysia household IoT E-waste management.

Keywords: Atlas.ti 8, E-waste, IoT E-waste, stakeholders, waste system elements

I. INTRODUCTION

The term "Internet of Things (IoT)" was actually used by Kevin Ashton, a British technology pioneer in 1999 which he described "a system in which objects in the physical world could be connected to the internet by sensors" [1]. The impacts of IoT can be observed from three dimensions of Sustainable Development such as environment, economic and social. In this 21st century, devices connected to the internet is increasing in number [2] and is at an alarming rate. According to Statista, the statistics portal, and Gardiner, the number of connected devices will be increasing up to 30 billion by the year 2020 [3]. However, according to i-Scoop and Juniper Research, the number of connected IoT is estimated to increase to over 46 Billion the year after [4][5]. Cisco predicted that the number of objects connected to the Internet will reach up to 50 billion by 2020 [6] with IoT's value at USD14.4 trillion, forecasted between year 2013 to 2022 [7]. Thus, it is expected that connected devices outnumber the humans with ratio of 2:1 [8]. With the millions of IoT sensors and devices are utilized with billions of connected devices, IoT has greater environmental impacts than expected and one of them is extreme E-waste generation. On top of that, there are still lack of clear guidelines for managing household E-waste in Malaysia especially from the consumers' side which happens to be the ultimate source of most of the E-waste produced. Thus, it is crucial to consider a planning for managing the possible increase in E-waste number as the impact from IoT emergence in the country. In the context of this study, "IoT E-waste" is E-waste produced from unwanted or end-of-life of IoT embedded devices that include all the hardware parts, electronic circuits and the sensors used. "IoT E-waste" is a term used to reflect the phenomenon of the increase in E-waste in par with emergence and increase of IoT embedded devices.

Although IoT has the potential to achieve energy saving, and carbon compliance, however, for every connected IoT devices, the arising concerns are: (1) How IoT could negatively impact the environmental sustainability especially in terms of household IoT E-waste in Malaysia? and (2) How to encourage a sustainable IoT E-waste management among households in Malaysia?. Therefore, the objectives of this paper are: (1) To investigate the stakeholders involved in managing a sustainable household IoT E-waste collection processes and (2) To investigate the elements involved in a sustainable system to manage those waste in Malaysia. This research adopts case study research method where three cases were studied and a total of six participants were interviewed, with two participants per case. Outcomes from the interview were transcribed and analyzed using an Atlas.ti 8 software. The identified stakeholders involved and the elements for a sustainable waste system will contribute towards the development of a Sustainable Household IoT E-waste Management Guideline which particularly enables the policymakers to strategize on the planning, development, and implementation of IoT initiatives for Malaysia.

Malaysia is purposely chosen for the study region due to the Industrial Revolution 4.0 (IR4.0) that was recently introduced in the country.

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The IR4.0 is driving industry towards automation and robotics through the use of IoT, along with other emerging technologies such as big data analytics (BDA) and artificial intelligence (AI) [9].

Thus, expecting that Malaysia will move towards a greater implementation of IoT in daily lives, considering a sustainable approach on the waste system is a proper move towards a sustainable and better future.

II. HOW IS IOT EMERGENCE A CONCERN TOWARDS E-WASTE IN MALAYSIA?

A. Internet of Things (IoT) on IoT E-waste Generation

Synonymously, IoT has also been delivered as "Internet of Everything"; "Internet of Objects"; and "Industrial Internet" [10]. Currently, there are more than 15 billion interactive devices are exchanging information, and with IoT advancement, it is expected that more than 200 billion devices to be actively used by year 2020, and very soon, the world will be surrounded with more than 1 trillion interactive devices [11]. Cisco predicted that the number of objects connected to the Internet will reach up to 25 billion by 2015 and 50 billion by 2020 [6] with IoT's value is at USD14.4 trillion (equals to more than RM59 trillion) forecasted between year 2013 to 2022 [7]. Gardiner also projected that almost 30 billion of connected devices around the globe by year 2020. Thus, it is expected that connected devices outnumber the humans with ratio of 2:1 [8]. While IoT focuses on the functionality and the technological aspects, Green Internet of Things (G-IoT) targets a sustainable smart world and aim to reduce energy consumption of the IoT [12] as well as to reduce carbon emission [13]. The National Intelligence Council (NIC) of U.S. has included IoT as one of the six "Innovative Civil Technologies" that will impact U.S. power grids. The impact on U.S. will certainly give insights towards the impact on other developed and developing countries including Malaysia as Malaysia is approaching the IR4.0 [14], which IoT plays a huge role in the technological development. In order to enable a sustainable smart world, IoT should be characterized by energy efficiency [15] since all devices in the world are beginning to be equipped with sensors and thus require more energy [12].

However, as good as it sounds, new technology means increase in the number of digital devices which later contribute towards the rise of E-Waste or the possibility of "IoT E-waste" generation if they are not managed properly. This is the effect from technology transition where former devices are being replaced with a more interactive application and thus resulting towards a disposal of the unused devices. On top of that, rapid innovation of phones for example, has reduced their usage span which results in increase in the number of waste mobile phones (WMPs) [16], also called as E-waste around the world.

B. Concern of IoT Emergence towards E-waste Generation

IoT has been a great use to researchers and indeed it gives huge advantage to the environment. IoT has contributed in several sectors across countries. In Southern Spain, a species of Iberian Lynx which are in the edge of extinction are tracked with location collars that implement the same concept as other existing IoT asset management systems would [17]. On top of that, IoT sensors are used to detect harmful chemicals as well as providing accurate information for parents of breathing problems infants and act as a real time environmental data. IoT has also contributed towards agriculture sectors, specifically with the development of Smart Farming. Smart sensors are used to measure data of soil thermal conductivity, soil temperature gradients, as well as photosynthetically active radiation. These mean of purpose assist ecologist and scientist to as well, measure the impact of climate change [18]

In Malaysia, several pilot projects are being conducted with collaborations between Malaysian Communications and Multimedia Commission (MCMC) and strategic organizations that focuses on five key verticals including Track and Trace, Healthcare, Transportation, Retail and Payment, and Agriculture [19]. On top of that, MIMOS Berhad has also launched their pilot projects including Aquaculture Traceability Application for Agriculture and Aquaculture sector, Continuous Health Monitoring Application in Healthcare sector, Smart Village Application for the Government, and Intelligent Landfill Management Application for the Environment [20].

The urbanization will continue to accelerate with an estimated that two-thirds of the world's population living in cities by year 2050 that contribute to a 70% increase in Greenhouse Gases (GhG) emission and energy use [21]. Apart from that, a bigger concern is the E-waste generated once the IoT devices reached the end of life. In year 2016, approximately 54 million tons (49 million metric tons) of used electrical and electronic products are produced. The Solving the E-waste Problem (StEP) predicted the world is producing about 33 percent more E-waste, or 72 million tons (65 million metric tons) by year 2017, which weigh about 11 times as much as the Great Pyramid of Giza (Lewis, 2013). Asia is one of the biggest market for electrical and electronics industry which contributes to nearly half of global sales by volume and produces the most E-waste. Similar to the global concern, the waste from discarded electronic gadgets and electrical appliances has reached severe levels in East Asia, posing a growing threat to health and the environment.

On average, electronic waste in the 12 countries in the study had increased by nearly two thirds in the five years, totaling 12.3 million tons in 2015 alone [23]. Malaysia produced an approximately 10-15% of total generated scheduled waste in 2012 and expected to increase when the collection of household E-waste is fully implemented [24]. The Global E-waste Monitor 2017 Report by the United Nations University, Malaysia generated approximately 8.8kg of E-waste per person in 2016 [25]. In 2017, it is reported that Malaysians throw away one million tons of E-waste every year [26]. Apart from that, based on studies conducted in selected areas, Malaysian households generate an estimated 53 million pieces of E-waste in 2020 which is 3.5 times higher than in 1995 [27].

C. Existing Policies and Guidelines

KeTTHA has come out with a National Green Technology Policy in 2009. The Green Technology Policy describes several elements including energy, environment, economy, and social. It seeks to attain energy independence and to promote efficient utilization, conserve and minimise the impact on environment, enhance the national economic development through the use of technology, as well as improve quality of life for all [28]. E-wastes were listed in the First Schedule of Environmental Quality (Scheduled Wastes) Regulations 2005 [29] and categorized to three different codes which are SW 103 for batteries waste containing cadmium and nickel, SW 109 for waste containing mercury and it's compound and SW110 for other e-waste assemblies including printed circuit board, electronic components and wires [30].

Besides, Department of Environment (DoE) has come out with a report on Management of Household E-wastes in Malaysia on April 2018. They presented the reporting by collectors, transporters and recycling facilities using Manifest system, reporting by manufacturers, importers, and reporting from E-waste recycling facilities [31]. Although report on household E-waste has been produced by the Department of Environment (DOE) in Malaysia, it is a fact that most E-waste goes to landfills and incinerators [26] which will end up contributing harm to the land and environment. This indirectly shows that a proper and improved guideline is needed by the policymakers and thus, suggestions shall be made in this research.

D. Model and Theory

"Three pillars model" or also known as "three circles model" or "Triple Bottom Line" is globally known model of sustainable development where it takes three dimensions to be labelled as requirements for sustainable development [32]. The three dimensions are "environmental, economic, and social resources" [32], [33]. The idea of this model constructs the dependability of each dimension to support one another. For this study, a model developed for an Integrated Sustainable Waste Management (ISWM) [34] as illustrated in Figure 1 is adopted for the process of data collection. The dimensions include "Waste System Elements", "Stakeholders", and "Aspects" where the model conclude generally of the important elements to be considered for managing waste sustainably. In this study, a model was proposed in Fig. 3 as the result from data collection and a modification from the ISWM.

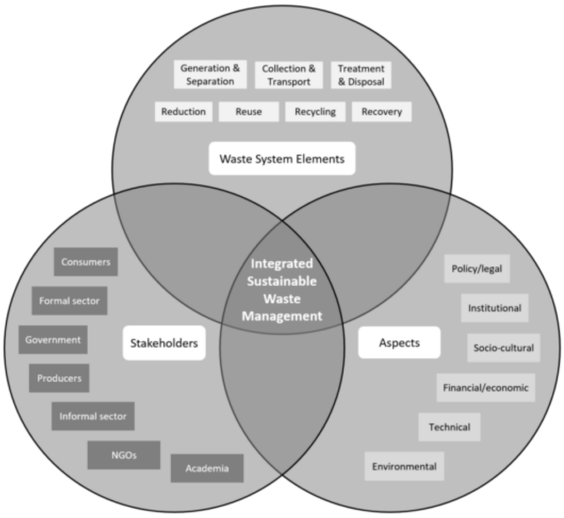

Fig. 1. Integrated Sustainable Waste Management (ISWM) model [34].

"Stakeholders" dimension indicate that multiple stakeholders are involved, to certain extent and contribute in the cycle of waste from the production stage until the final disposal. Every stakeholder affects the waste management process differently with different responsibilities. In this research, stakeholders for an effective E-waste collection were identified which later contributes towards the development of Sustainable IoT E-waste Management Guideline.

"Waste System Elements" dimension is the elements that represents the technical constituents and measures of the waste management system. They show how E-wastes are being handled and where it remains at the end of the process [34]. Several categorization and prioritization have been developed in the form of waste management hierarchy where it aims at reversing the traditional approach of waste disposal. This is done by strategically putting prevention, minimization, recycling, and recovery before even approaching the disposal phase. This dimension helps the development of the guideline in term of the crucial action of every stakeholder must take to achieve a sustainable IoT E-waste management among households.

The third dimension is the "Aspects" where it provides different factors that are necessary in developing a viable waste management system. These contributing factors include political environment, the legislative and institutional framework, socio-cultural conditions, environmental and health aspects, as well as financial and economic factors. The aspects are interdependent and not stand-alone criteria which allow for a comprehensive assessment of the Sustainable Household IoT E-waste Management Guideline.

To support the element of "environmental" of the Aspects dimension, the International Relations Theory presents a Green Theory, written by Hugh C. Dyer. Green Theory belongs to the critical theory tradition, in which it means that environmental issues evoke questions on relations between and among individuals as well as with others, also in the context of community and collective decision-making [35]. Green theory puts nature before people for which it is called Eco-centrism. Eco-centrism includes those within a wider ecological perspective and prioritizes healthy ecosystems as they are essential to human health and wellbeing. This theory definitely aligns with the three pillars model where it is impossible to separate human development from environmental development due to the fact that majority of resources that human use come from nature in the form of ecosystem services [36]. Also, it aligns with the concerns highlighted in this research where E-waste problem is considered as a long-term effect for technological development which Green Theory highly values that concern.

III. METHODOLOGY

This research adopt multiple case study method, which is particularly appropriate for exploratory studies [37]. Experience of participants and context of actions are critical as well as to understand complex, temporal processes (why and how of a phenomenon) rather than factors or causes (what) [38]. Upon uncovering a significant finding from a single case, the finding is later replicated by conducting a second, third or more cases. The replications are dynamic which can either be the exact conditions of the original case or altered considering varies of conditions from the previous findings [39]. In this study, the case study replications are altered accordingly to achieve a robust finding and thus, three cases were selected to achieve a literal replication.

A. Data Collection

In this research, the consumers of IoT embedded devices are the case being studied. IoT consumers came from various different backgrounds and thus, the "consumer" is the primary unit of analysis. The cases are divided into three categories based on the consumers' background. Individuals with basic knowledge on the study were chosen to participate as interviewees and to gain their perspective as a consumer of IoT. This include those with the background of: (1) household E-waste collection, (2) handling IoT, and (3) IT consulting.

Next, the interview instruments and protocols are established for data gathering with the three categories of respondents. A semi-structured interview protocol is used for all visits of the selected respondents. The interview covered a number of topics relating to IoT products (hardware), IoT applications (software), IoT benefits and risks to the environment in terms of E-waste as well as the relation significance of elements from the model. The interview protocol also includes the descriptive information of the respondents and site at which the interview was carried out. The development of interview questions is based on the literature reviews, model constructed, observation of previous research and national policies.

A preliminary study or a pilot study is then conducted. The preliminary study is useful for testing several aspects of the research including the research process, interview questions, observation techniques, as well as the researchers themselves [40]. This process allows the research topic itself to be revised in term of the research statement, plans, interview questions and the interviewing presentations before conducting the actual data collection.

The primary data collection is using semi-structured interviews in a field setting. The interview is carried out with respondents holding a top managerial position in their field of expertise. Upon obtaining the consent, the interview sessions are electronically recorded along with notes taking and observation of the comments, which later transcribed verbatim into a text document for analysis. The data from each interview is analyzed before the next interview take place. As mentioned, replication on case condition is dynamic which lead to alteration to the interview protocol, along with any issues raised during the earlier interview session before replication of the interview protocol to other cases. In addition, company tour or plant tour is carried out, and relevant company publications are analyzed.

B. Data Analysis

The data analysis is carried out in two stages which are (1) within-case analysis, and (2) cross-case analysis. Within-case data analysis is the examination of the emergent concepts at each case site and identify the patterns between the concepts to generate an initial theory of the problem. The within-case analysis is done separately for each case due to the difference in background of specific group of consumers in Case 1, 2 and 3. Next, cross-case analysis is conducted to identify the similar concepts and patterns between different case sites. The patterns were then used to validate the initial model or to refine the model into a more inclusive and generalizable model. The result of data analysis is constructed in par with the Sustainable Household IoT E-waste guideline development. Apart from that, an Atlas.ti 8 software (data analysis software) is used to assist the data analysis process.

The transcribed interviews went through data analysis process that involved several steps suggested by Erlingsson and Brysiewicz [41]. The steps include (1) Meaning Unit & Condensed Meaning Unit; (2) Code; (3) Category; and (4) Theme. This technique allows codification of qualitative information into pre-defined categories to derive relevant patterns or themes that occur most frequently in terms of contexts and relatedness. The steps is presented in Figure 2.

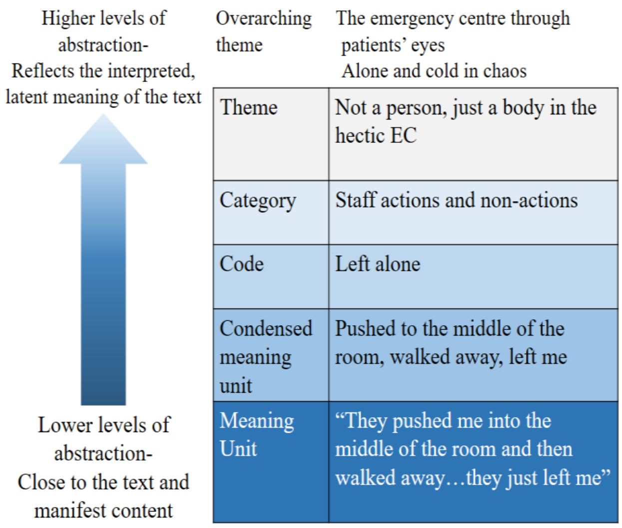

Fig. 2. Abstraction level of analysis.

Coding is heuristic. It **is** an exploratory problem-solving technique without specific formula to follow and it is only the initial step toward a more complicated analysis of a transcript [42]. Quotations from the interview transcript are open coded with proper code phrases which were guided by the ISWM model. These codes were then categorized according to the elements of the model and further grouped into themes of dimensions.

Atlas.ti 8 was used to assist in the documentation, extraction, and organization of data gathered from the actual data collection. The quotations of respondents from the transcript were open coded, then categorized accordingly as listed in Table I. Example of coding is as illustrated in Figure 3 where a respondent was asked on a stakeholder's responsibility for managing E-waste. The right side of the figure displays all the codes assigned to selected quotations.

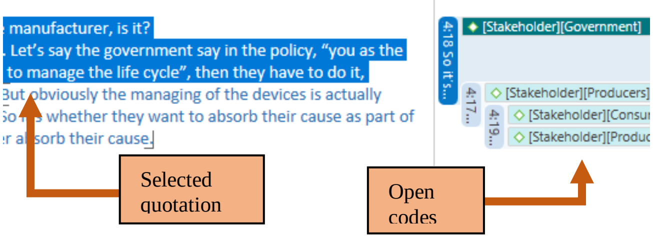

Fig. 3. Open coding.

Every code consists of code ID assigned to specific quotation. Figure 4 illustrates the "ID" and quotations being assigned to the codes (Name). In the ID column, the ID was displayed as "Document number: Quote order". The ID is used as reference to the quotations being cited in the following chapter as "[Document number: Quote order]".

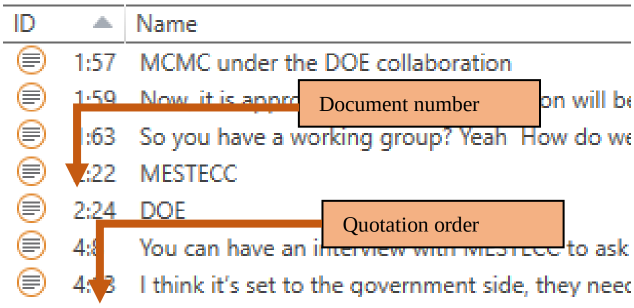

Fig. 4. Displaying code ID

Codes are then being categorized into elements taken from the model. Figure 5 shows the categorization of codes in the code group's panel. The example shows the codes being categorized under the dimension "Stakeholders".

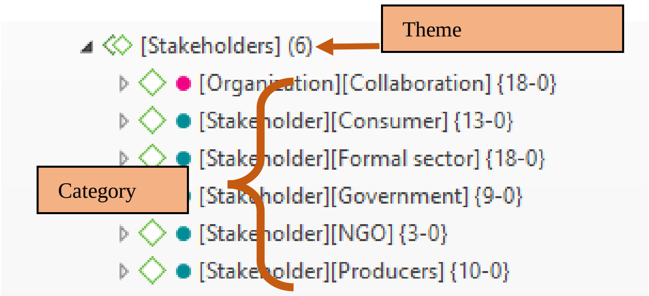

Fig. 5. Code category of "Stakeholders" element.

IV. RESULTS AND DISCUSSION

Upon completing the analysis from three cases of participants, numbers of stakeholders were identified as important in developing a Sustainable Household IoT E-waste Management Guideline. On top of that, all elements included in the "Waste System Elements" dimension of ISWM was also mentioned by the participants.

A. "Stakeholders" Involved in Developing a Sustainable Household IoT E-waste Management Guideline

The interviews conducted with each of the three-case study of IoT consumers mentioned the names of stakeholders involved in the process of E-waste management at household level. These findings were extracted using codes specifically relating to the groups of people and organization involved in the process which later categorized under the theme of "Stakeholders" as per summarized in Table I. Responses about stakeholders, either by specifically mentioning the names of parties, generally describing the characteristics of the ones responsible for the action, or any collaboration related to e-waste management were all coded and used as data for examining this specific theme.

Table I: Stakeholders code category

Open Code	Category	Theme
[Stakeholder][Government] [Organization][Collaboration]	Government	Stakeholders
[Stakeholder][Consumer] [Organization][Collaboration]	Consumers	
[Stakeholder][Formal sector] [Organization][Collaboration]	Formal Sectors	
[Stakeholder][NGO] [Organization][Collaboration]	NGO	
[Stakeholder][Producers]	Producers	

Government, Consumers, Formal Sectors, NGO, and Producers are the most mentioned by the participants in regard to managing a sustainable household E-waste. Thus, these selected parties carry the responsibility of creating a better E-waste management especially in facing the future of technological development impacts towards the E-waste generation which could lead towards the existence of IoT E-waste as well. Hence, the identified stakeholders are the contributors towards the "institutional" and "socio-cultural" elements in the "ASPECTS" dimension for the development of the Sustainable Household IoT Management Guideline.

B. "Waste System Elements" in Developing a Sustainable Household IoT E-waste Management Guideline

The elements in this dimension represent the technical constituents and measures of the waste management system. They show how e-wastes are being handled and where it remains at the end of the process. Several categorization and prioritization have been developed in the form of waste management hierarchy where it aims at reversing the traditional approach of waste disposal. This is done by strategically putting prevention, minimization, recycling, and recovery before even approaching the disposal phase.

In this research, participants were asked on their knowledge and opinion towards E-waste management either in their homes or Malaysia households as a general. The purpose of this section of interview is to collect any possible waste system elements exist from the perspective of the participants or the user of IoT themselves. Although at the time being, the answers are towards their own management on E-waste, the findings can be used to contribute towards the development of IoT E-waste management guideline because the participants were also asked on their opinion to relate the impact of IoT usage in their households. The targeted waste system elements include seven components: generation and separation, collection and transport, treatment and disposal, reduction, reuse, recycling, and recovery. Categorization of codes on waste system elements are presented in Table II.

Table II: Waste System Elements code category

Open Code	Category	Theme
[Mgmt][E-waste][Household][Generation &Separation] [Management][EE][E-waste][Household]	Generation & Separation	Waste System Elements
[Mgmt][E-waste][Household][Collection& Transport] [Management][EE][E-waste][Household] [Organization][Operation] [Organization][Collaboration]	Collection & Transport	
[Mgmt][E-waste][Household][Treatment& Disposal] [Management][EE][E-waste][Household] [Organization][Operation]	Treatment & Disposal	
[Mgmt][E-waste][Household][Reduction][Monitoring][IoT]	Reduction	
[Mgmt][E-waste][Household][Reuse] [Management][EE][E-waste][Household]	Reuse	
[Mgmt][E-waste][Household][Recycling]	Recycling	
[Mgmt][E-waste][Household][Recovery] [Organization][Operation] [Organization][Collaboration]	Recovery	

Thus, a model was developed as a contribution from the data collected and the modification of ISWM model. The developed model is illustrated in Figure 6. The "Aspects" dimension is set as reference for the guideline development in the future work of this research.

Since every dimension is interrelated, findings from "Stakeholders" and "Waste System Elements" are important to the "Aspects" as they contribute in the Sustainable Household IoT E-waste Management Guideline creation.

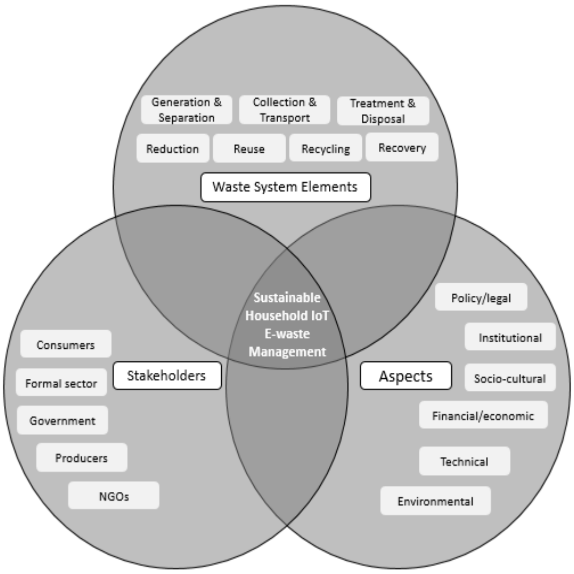

Fig. 6. Sustainable Household IoT E-waste Management.

V. CONCLUSION AND FUTURE SCOPE

In a nutshell, this study does not negate the potential benefits IoT has in revolutionizing the way society communicate and interact that will increase the standard of living towards knowledge-based society with more accessible, affordable and analytical utilization of resources. However, this paper delivers one of the solutions to improve the future of IoT, following the E-waste problem that keeps on increasing by days which with IoT in sight, "IoT E-waste" could be the next waste issue to be concerned about. Although report on household E-waste has been produced by the Department of Environment (DOE) in Malaysia, it is a fact that most E-waste goes to landfills and incinerators which will end up contributing harm to the land and environment. This indirectly shows that a proper and improved guideline is needed by the policymakers and thus, improvements on the regulations shall be stated as necessary.

Stakeholders and the Waste System Elements that are crucial for regulating a sustainable waste system are identified in this paper, thus, the following step is the creation of guideline from the "Aspects" dimension in the Sustainable Household IoT E-waste Management model developed. On top of that, in the following study, this research is expected to come out with a full guideline on the Sustainable Household IoT E-waste Management and validation from the experts.

Apart from that, the guideline developed from this research will assist the policymakers in guiding the stakeholders involved to meet the long-term environment protection and ecological stability through an efficient way of managing E-waste from IoT embedded products. Not only that, the regulatory bodies can introduce and implement new policies or regulations on IoT usage in Malaysian households.

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