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ANALYZING THE QUALITY ASPECTS OF THE EEW MANAGEMENT IMPROVEMENT PROCESS

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Abstract: The problem of electrical and electronic waste (EEW) management is present in developing countries as well as in developed countries. Inadequate EEW management leads to exposure of hazardous materials into the environment. In this paper a theoretical EEW management model is developed. Additionally, the use of quality practices and quality management systems for EEW management improvement is addressed. For every element of the developed model, an appropriate quality practice is suggested. The proposed quality practices are generic in nature in order to provide a broad framework for future research on specific EEW management system segments. In sum, the paper provides a solid basis for future research in the domain of quality practices and EEW management.
Keywords: EEW, quality practices, improvement, EEW management model

1. INTRODUCTION

The problem of electrical and electronic waste (further referred to as EEW in the article) is a growing problem in developed countries, and in developing countries as well (Atasu, & Van Wassenhove, 2012). The management of EEW and the recycling process of EEW is complex. It includes various processing steps such as shape separation, magnetic separation, electrostatic separation and others (Cui, & Forssberg, 2003). EEW often contains hazardous materials, thus their management often faces several challenges. These may include issues in the separation process, sorting process and classification process. Therefore, recycling, as the main part of EEW management, has to be conducted in accordance with defined legislations. It was noted that EEW recycling includes three major steps. These are disassembly, upgrading and refining (Cui, & Forssberg, 2003).

A large set of legislations provide guidelines for a safe handling of EEW. However, the EEW management processes can and should be improved. This is conducted through various registered companies (manufacturers, recycling facilities, transportation, and storage facilities) and an important factor for improvement is quality. The consistency of quality as an output is a crucial part of successfully managed processes (Masood, Davis, & Davis, 1995). Some of the factors of quality management are customer approach, management commitment, leadership, continuous improvement, involvement of employees, and process management (Claver, Tari, & Molina, 2003). Now, total quality management (TQM) brings a new paradigm on how quality is managed. There is a large body of literature that addresses the positive impact of TQM on overall performance in organizations (Kaynak, 2003). In the same article it can be seen that TQM practices are similar to quality management factors such as management leadership, employee relations, and process management (Kaynak, 2003). Nevertheless, how can quality factors and/or practices affect the improvement of EEW management? It is assumed that if driven by quality, EEW management could face drastic improvement in several sections of the recycling and reusing procedures. Quality can be viewed as a degree in which pre-defined requirements of product and service characteristics are met (Popović, & Miletić, 2016). If quality of the obtained recycled raw material or secondary parts is put forward as a goal, then there is a higher chance that the overall EEW management process will be improved in order to meet the quality requirements.

In this paper the important quality factors of EEW management improvement are analyzed. This includes a thorough analysis of empirical and theoretical research in the domain of EEW management and quality management principles. Furthermore, a theoretical model for EEW management improvement through quality practices is proposed. The whole paper consists of three main sections. The first section analyses the quality factors that may contribute to the improvement of EEW management systems. The second section is the review of EEW management and the future potential of EEW management. The third section proposes a theoretical model which is based on the previously conducted analyses. Finally, conclusions are drawn and future research is recommended.

2. QUALITY MANAGEMENT PRACTICES

Quality management is an imperative for developing competitive positions on the market. This includes several procedures and defined plans that positively affect the quality aspects of products and services. One step further is TQM, where the focus on quality becomes part of the organizational culture, and its goal is to satisfy customers (Gunasekaran, 1999). However, in this paper the quality management is not focused on customers per se, but on the improvement of EEW management. Before, this issue is thoroughly addressed, quality management needs to be analyzed. According to the ISO 9001:2015, there are eight quality management principles. These are leadership, process approach, customer

focus, leadership, involvement of people, factual approach to decision making, system approach to management, and mutually beneficial supplier relationships (Anttila, & Jussila, 2017).

TQM is known for its long-term approach to business excellence through continuously satisfying the customers' needs (Yusof, & Aspinwall, 1999). However, when it comes to EEW management, the customer satisfaction aspect of quality is not crucial. In fact, customers are mainly in the form of wholesale buyers of raw, unprocessed EEW, and wholesale buyers of various categories of recycled EEW. However, some of the principles of quality management are indeed important for overall improvement of EEW. The whole improvement process should include quality as this factor further positively affects other aspects of EEW management. If quality is in the focus of improvement, then sloppy management techniques will be consequentially eliminated as they can't fulfill quality requirements. After all, quality management can be viewed as an integrated whole made up from sets of principles, techniques and practices (Sousa, & Voss, 2002).

There are ten generic quality management practices. These are top management commitment and support; employee training; continuous support; employee participation; quality system improvement; organization for quality; information and analysis; statistical techniques for achieving quality; customer focus; and supplier quality management (Lakhal, Pasin, & Limam, 2006).

In order to correctly implement some of these practices into the EEW management improvement process, it is necessary to broaden the meaning and scopes of these practices.

Top management commitment and their support is an imperative for adequate workflow and efficiency. This practice may include reporting, and communicating important data to employees. This data may provide support and it can reduce bottlenecks on the workplace. Other actions of top management include effectively analyzing external and internal factors and participants who are relevant to the company, collect and process quality related data and information, and ensure proper communication of this relevant data to employees (Ahire, & O'shaughnessy, 1998). Next, employee training and employee commitment are two important quality practices that includes the development of new skills, motivation, and professional development opportunities (Elnaga, & Imran, 2013). Information analysis or quality information systems refer to distribution of crucial information that contributes to achieving the desired level of quality for products and services (Sadeh, Arumugam, & Malarvizhi, 2013). Continuous support is among managers and employees is necessary in order to control and maintain a stable level of desired quality. This includes periodic evaluation, control, and reporting critical data (Lakhal, Pasin, & Limam, 2006). Furthermore, quality system improvement and organization for quality are key factors for creating a productive and efficient environment where quality results can be obtained through input-output processes (Lindsay, & William, 2010). The inputs may include various financial resources, materials, knowledge, employees, and data information while outputs may be products or services and other elements that may be wanted (secondary raw material) and unwanted (waste, hazardous materials). Next, statistical techniques and methods are used to analyze and process various data that is collected from the internal and external environment of the organization. Some of the main statistical control techniques are control charts, design of experiments, loss function, and robust design (Montgomery, 2009).

Furthermore, customer focus drives the company forward. This process has an internal and external part. The internal part addresses the quality of products and services, while the external part includes quality from the aspect of people and the environment (Goetsch, & Stanley, 2014). Finally, supplier quality management addresses the quality of materials and other resources from suppliers, as well as the procedures done by the suppliers that ensure stable quality products (Lakhal, Pasin, & Limam, 2006).

Based on the analyzed literature, it is evident that quality management enhances the processes that occur in the organization. In this paper these quality aspects are analyzed for the improvement process of EEW management. In the next section, EEW management is addressed.

3. EEW MANAGEMENT

As the quantity of EEW rises, there is an urgent need to develop sustainable solutions for an effective and efficient EEW management system (Achillas, Vlachokostas, Moussiopoulos, & Banias, 2010). Certainly, EEW requires special handling and management as it may contain hazardous materials. The situation on a global scale is getting worse by each year as the agreements, procedures, protocols, and overall recycling intensity are not enough to handle the increase in EEW (Kollikkathara, Feng, & Stern, 2009). EEW is often extremely heterogeneous. Besides plastics, it may contain aluminum, copper, and gold. However, the percentage of precious metals in EEW is decreasing every year. This puts big stress on recycling plants as their economic growth and stability depends on the extracted precious metals from EEW (Cui, & Forssberg, 2003). Some of the main issues of EEW management include insufficiency of material reuse, as a large amount of precious metals such as gold, platinum, aluminum, silver, and palladium are incinerated or buried in a landfill (Elia, & Gnoni, 2015). In the same study a multi-level taxonomy is proposed. Here, the first level includes categories such as strategic system planning, system design, and system management. Further, the second level includes sub-categories that are part of the first-level categories. Thus, under strategic system planning there are social liability assessments, organizational systems, and waste prevention. System design includes recovery process design and secondary market development. Finally, the system management includes waste generation, end-of-life scenario and network configuration.

The third level includes ten tools/techniques/models. These are survey analysis, review analysis, policy assessment, field study, experimental study, multi-criteria decision making, simulations, mathematical programming, life cycle analysis, and material flow analysis (Elia, & Gnoni, 2015). Other studies proposed closed-loop supply chains (CLSC) that reduce the environmental impact of supply chains. EEW supply chains are prone to releasing hazardous materials into the environment. Through closed-loop supply chains, EEW management is improved and raw materials are used more efficiently thus reducing its environmental impact (Quariguasi, 2010). Through the Waste of Electrical and Electronic Equipment (WEEE) directive, Denmark implemented various models for an efficient EEW management system. This model included collective schemes where consumers deliver waste to the collection points. This way municipalities have significantly lower administrative burden and lowering cost in the long-term (Gamberini, 2008).

For comparison, in Switzerland EEW is managed through the Ordinance on the Return, Taking back and Disposal of Electrical and Electronic Equipment (ORDEE) form. This includes product take back programs, regulatory approaches, voluntary industry practices, and economic instruments (Khetriwal, Kraeuchi, & Widmer, 2009). There are many more studies that propose extended producer responsibility (Herat, 2007); reverse logistics which incorporate design of logistics network, planning the disassembly processes, and organizing the reverse supply chain (Melacini, Salgaro, & Brognoli, 2010); effective system of monitoring the shipment and transportation of EEW (Nnorom, & Osibanjo, 2008). It is evident that EEW management can incorporate various models, and various levels of regulation. For example, in Europe the main emphasis for EEW management is on non-state/non-government actors, while in China EEW is managed by traditional approaches by the government [27]. Surely, EEW is a big concern to the vast majority of developing and developed countries. As mentioned above, there are many models that address this issue.

Now, in this paper a model for EEW management improvement is suggested through the aspects of quality management. The main idea is that if quality is the priority, then results will follow. This may lead to increased extraction rates of precious metals, and lower recycling costs. The proposed theoretical model is presented in the next section.

4. A MODEL FOR EEW MANAGEMENT IMPROVEMENT

The EEW management improvement process is presented in the form of a developed EEW management model where every element of the model is labeled with numbers and a capitalized "Q" letter (ex. 1Q, 2Q, 3Q...). This type of labeling is used to explain in detail the possible application and procedure of various aspects of quality with the goal to improve the whole EEW management model/system. On Figure 1, the EEW management model is depicted. This model is based on other models presented and suggested in similar studies (Gaidajis, Angelakoglou, & Aktsoglou, 2010; Gamberini, 2008; Kiddee, Naidu, Wong, 2013; Quariguasi, 2010; Salhofer, Steuer, Ramusch, & Beigl, 2016; Wath, Dutt, & Chakrabarti, 2011).

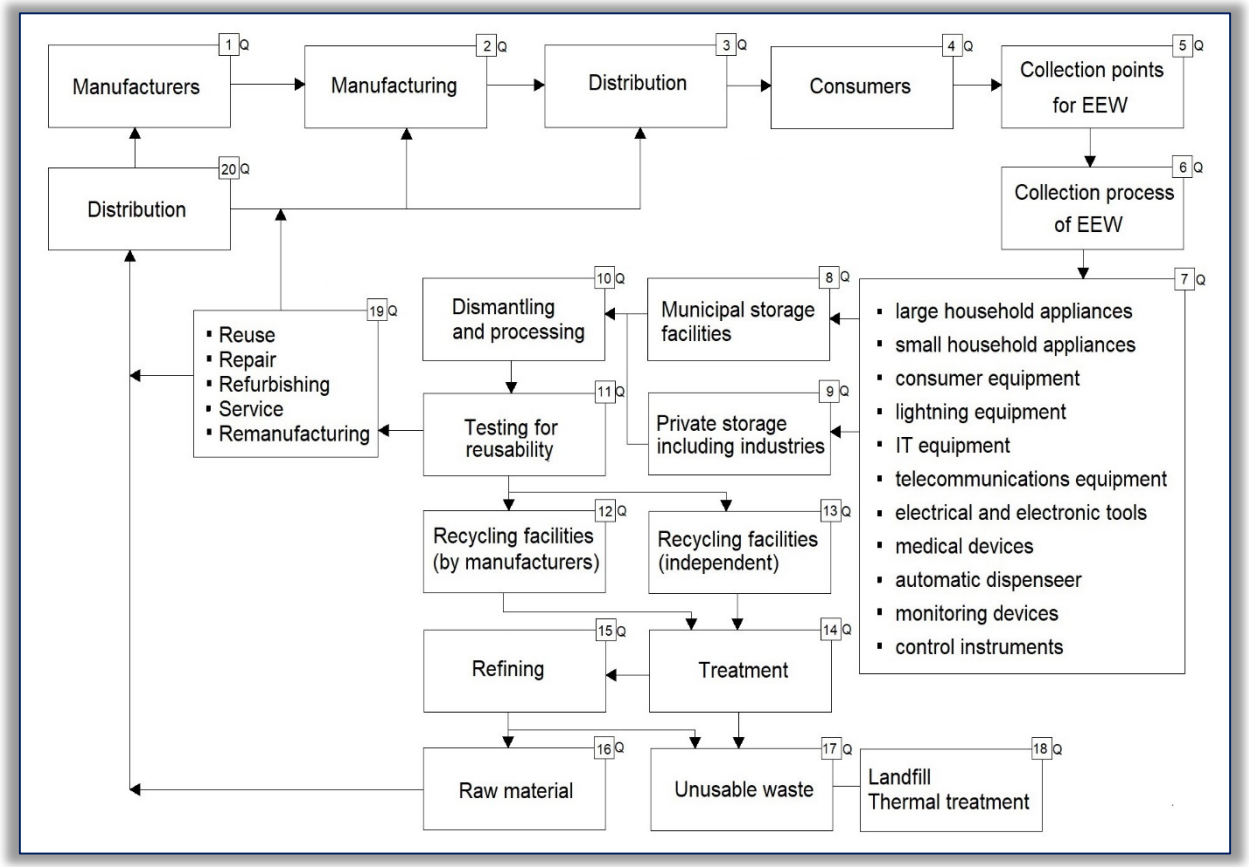

Figure 1. EEW management model

As mentioned before the labels (1Q, 2Q... etc.) for each element of the model are used to give detail on the improvement of the EEW management process through the various aspects of quality. The meanings behind the labels are presented in Table 1.

Table 1. Label description

Label	Meaning/process/procedure	Label	Meaning/process/procedure
1Q	Manufacturers are encouraged to implement various quality management standards (in accordance with the industry, products and services). Some of the quality practices that should be implemented are supplier quality management and organization for quality. This can improve the overall quality of products and reduce waste and production costs.	11Q	As mentioned in the previous section, employee training is also necessary to create a quality driven atmosphere where strict procedures are implemented to ensure that reliable parts are selected for repair, reuse, service, refurbishment, or remanufacturing.
2Q	In the manufacturing process, employee training, management commitment and support are crucial for achieving high standards of quality thus increasing the exploitation period of products (in this case electrical and electronic devices).	12Q	Recycling facilities owned and managed by product manufacturers should consider quality management system standards such as ISO 9001 and ISO 14001. This would lower costs and increase productivity.
3Q	Here, quality can be involved through information and analysis of orders, and achieving a high level of consistency of delivery times and sticking to predefined schedules.	13Q	Similarly to the recycling facilities owned by manufacturers, independent recycling plants should also consider implementing some of the mentioned ISO standards and to focus on quality system improvement.
4Q	Consumers should be informed about the importance of proper EEW disposal. Here, customer focus has to be involved in order to make the customer feel respected rather than instructed.	14Q	The treatment process can include the focus on customers (in this case customers are manufacturers that buy raw material from the processed EEW). In addition employee training can increase the quality and extraction rates of raw materials (precious metals, plastics, glass etc.)
5Q	Collection points have to "enjoy" continuous support from manufacturers and the government. This would increase the volume of collected EEW.	15Q	The refining process should integrate statistical techniques that will help increase the "pureness" of certain raw materials (especially precious metals).
6Q	The collection process has to integrate statistical techniques through which significant data can be obtained and used for future optimization of the EEW management process.	16Q	The extracted raw material should be thoroughly inspected for quality, homogeneity and consistency of quality between batches.
7Q	For effective collection of EEW, it has to be categorized and clearly defined in order to increase the efficiency of the whole process.	17Q	Unusable waste has to be handled carefully, and the ISO 14001 standard is a necessity at this point.
8Q	These storage facilities have to develop information analysis techniques and to implement an effective distribution system.	18Q	Landfills and thermal treatment can be extremely hazardous for the environment, thus ISO 14001 is highly recommended. This way the negative impact of these hazardous materials can be kept at a minimum.
9Q	Similarly to municipal storage facilities, private storage facilities are also encouraged to implement quality systems that will ensure an efficient flow of EEW.	19Q	In the repair, reuse, service and refurbishment processes ensuring high quality end-products is important for future reduction of EEW.
10Q	At this stage EEW is dismantled and processed. Here, employee training can significantly improve the productivity of dismantling and preparing it for testing.	20Q	Finally, closing the loop-based model of EEW management, distribution of raw material to the manufacturers, and refurbished/repaired/serviced products to consumers is addressed. Here, continuous support, information analysis and supplier quality management should be used to ensure reduced EEW waste in the future.

Through these quality-based improvements, the goal is to reduce the amount of EEW that is treated as unusable waste, and to increase the volume of EEW that goes through the collection points. This can lead to reduced EEW that end up along the roads, and among organic waste. This could further reduce recycling costs and distribution costs, and increase the amount of precious metals that are extracted. The depiction of this model has its limitations. Certainly, this is just a theoretical model and the quality aspects of improvement could be presented in more detail. However, the paper doesn't focus on particular manufacturers, or markets, but rater EEW management as a whole. This way a more generic approach

was seemed fit for this paper. The model takes into consideration the before mentioned findings in the domain of EEW management and quality management. It is suggested that this approach can increase productivity of every participant in the EEW management cycle. This includes manufacturers, recycling plants, storage facilities, and distribution channels. Certainly, implementing quality manage systems is an imperative for a modern EEW management system.

5. CONCLUSIONS

In this paper the improvement of EEW management through quality practices was addressed. After thorough analysis of relevant literature in the domain of quality management systems and EEW management systems, it can be concluded that certain aspects of quality practices can contribute to the effectiveness and efficiency of EEW management systems. An EEW management system model was developed in order to present where quality practices could be implemented and used to reduce costs, to increase productivity, and most importantly to increase the percentage of extracted precious metals. As mentioned before in this paper, numerous recycling facilities have economic stagnation or hardship due to inadequate precious metal extraction. If process quality and overall organization quality would be priority, there is a good chance that the extraction and refinement processes of EEW would result in a higher percentage of extracted precious metals.

Now, in this paper the EEW management model presented twenty (20) elements. Every element was labeled (1Q, 2Q, 3Q...20Q). Furthermore, these labels were described as quality practices/aspects through which the EEW management process could be improved. The theoretical model, and theoretical improvements through quality practices are based on credible research in this domain. It can be concluded that this type of approach can indeed improve the overall EEW management system, as the goal of high quality products/service/processes may result in lower costs, higher productivity, and less waste.

The contribution of this paper to the existing body of literature is moderate. It depicts a model that is based on other EEW management models. The quality practices proposed are generic, and moderately defined. This is a major limitation. However, given the nature of this paper, this limitation is not severe. The goal was to present the possibility and framework of EEW management improvement through quality practices. For future research it is recommended to address specific quality techniques for specific segment of the EEW management system. If possible, several studies are necessary to address and research the proposed theoretical model and the possibility of quality practices use for EEW management improvement.

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