Evaluation of electrical and electronic waste potential within the framework of sustainable development (Bitlis province example)

Muhammed Ömer Yaman[1], Sevgi Akkoy[2] & Edip Avşar[3]

[1] Environmental Engineering, Bitlis Eren University, Bitlis, Turkey

[2] Industrial Sustainability Master's Student with Thesis, Bilecik Şeyh Edebali University, Bilecik, Turkey

[3] Environmental Protection and Control Department, Bilecik Şeyh Edebali University, Bilecik, Turkey

Correspondence: Industrial Sustainability Master's Student with Thesis, Bilecik Şeyh Edebali University, Bilecik, Turkey. E-mail: akkoysevgi@gmail.com

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Abstract

Rapid developments in technology and increasing consumer demand in the last century have revealed the problem of electrical and electronic waste (e-waste). Today; with rapid industrialization, urbanization, population growth, and economic developments, this problem has grown even more and become a global environmental problem. The amount of e-waste per person in Türkiye is around 7-8 kg. It is thought that e-waste, which is tried to be destroyed by incineration due to its heavy metal content, will reach 640 thousand tons in 2024. In this case, it causes serious negative effects on human and environmental health in the world and Turkey. At this point, decision-making mechanisms need to ensure e-waste management in a way that causes the least harm to the environment by creating effective waste management strategies for the recovery of e-waste. In this context, the study aims to examine the electrical and electronic waste potential in Bitlis, which was selected as a pilot province within the framework of sustainable development, and to present suggestions for the environmental and economic evaluation of these wastes. In addition, the study tried to reveal the benefits to be provided by electrical and electronic recycling in the context of the economic and environmental effects of sustainable development.

Keywords: Sustainable Development, electrical and electronic waste, e-waste, Bitlis

Avaliação do potencial de resíduos elétricos e eletrônicos no âmbito do desenvolvimento sustentável (exemplo da província de Bitlis)

Resumo

Os rápidos desenvolvimentos tecnológicos e a crescente procura dos consumidores no último século revelaram o problema dos resíduos elétricos e eletrônicos (lixo eletrônico). Hoje, com a rápida industrialização, urbanização, crescimento populacional e desenvolvimento económico, este problema cresceu ainda mais e tornou-se um problema ambiental global. A quantidade de lixo eletrônico por pessoa na Turquia é de cerca de 7 a 8 kg. Pensa-se que o lixo eletrônico, que se tenta destruir por incineração devido ao seu teor de metais pesados, atingirá 640 mil toneladas em 2024. Neste caso, causa graves efeitos negativos na saúde humana e ambiental no mundo e na Turquia . Neste ponto, os mecanismos de tomada de decisão precisam de garantir a gestão do lixo eletrónico de uma forma que cause o menor dano ao ambiente, criando estratégias eficazes de gestão de resíduos para a recuperação do lixo eletrónico. Neste contexto, o estudo visa examinar o potencial dos resíduos eléctricos e electrónicos em Bitlis, que foi seleccionada como província piloto no âmbito do desenvolvimento sustentável, e apresentar sugestões para a avaliação ambiental e económica destes resíduos. Além disso, o estudo procurou revelar os benefícios proporcionados pela reciclagem eléctrica e electrónica no contexto dos efeitos económicos e ambientais do desenvolvimento sustentável.

Palavras-chave: desenvolvimento sustentável, resíduos elétricos e eletrônicos, lixo eletrônico, Bitlis

1. Introduction

From past to present, the production resulting from human activities and the resources consumed as a result of these productions have caused environmental problems. Increasing production and consumption after the Industrial Revolution and the wastes generated afterward have led to the emergence of environmental problems and the world has faced unsustainable realities. The concept of sustainability, which started to be pronounced as a result of the environmental movements initiated in 1960 and later, is examined in three different dimensions: economic, social, and environmental (Environment Foundation of Turkey, 2023). Sustainability consists of three dimensions that can be defined as economic, social, and environmental sustainability.

The first of these dimensions refers to fair sharing, the second refers to participation, and the third refers to the protection of natural resources. Sustainability can only be achieved by realizing these three dimensions, economic, social, and environmental, in parallel and at the same time (Haştemoğlu, 2006). The concept of sustainability is defined as "meeting today's needs without compromising the ability of future generations to meet their own needs" in the document "Our Common Future" of the World Commission on Environment and Development, known as the Bruntland Report (UN, 1987) (T.R. Ministry of Development, 2012). In other words, sustainability is “a common principle for all systems and a framework that can be applied in every context and situation and shows the dimensions of continuity” (Manderson, 2006; Yorgancı, 2011).

Today, problems such as inefficient use of resources, waste, climate problems, natural disasters, epidemics, and unnecessary consumption behaviors make it difficult for the environment, natural life, and above all, humanity to live a sustainable and comfortable life. In this respect, experts and academics from many different disciplines are developing solutions for this situation. One of the sectors where unconscious consumption is experienced is the electrical and electronics sectors. The product diversity, production quantities, and usage areas of the electrical and electronics sector, which form the backbone of our daily lives, should also be addressed with its environmental dimensions (Mateo Pla et al., 2021). The use of electrical and electronic devices has become indispensable to improve and maintain the standard of living in modern societies. In this case, it has led to an increase in e-waste consumption (Forti et al., 2020). With the digital revolution that started in the 1970s, the qualities and capabilities of e-products have increased, their prices have decreased, and their lifespans have shortened due to the increase in internet usage, thus a new type of waste has recently become a significant threat to the environment and health (Yılmaz, 2009).

While e-waste is a potential threat to natural resources and the environment; It is suitable for creating a new market with its economic values. Considering the economic value and environmental damage of the materials contained in e-waste, it becomes important to effectively manage e-waste, ensure its reuse, collect it from customers, recover it, and dispose of it at low costs. In this context, many legal regulations on the subject are being created and implemented, especially in developed countries (Wang et al., 2017).

In developing countries, the issue of e-waste has attracted attention in recent years. However, differences and problems arise in terms of both legislation and implementation. Among these countries, many countries are experiencing difficulties both because they are the countries where the most e-waste is produced in the world and because of the problems in the disposal, recycling, and management of this e-waste (Zenga et al., 2017).

The rapidly developing technology in recent years has increased the consumption of electrical and electronic products and brought along the problem of electrical and electronic waste (e-waste). Waste Electrical and Electronic Equipment (e-waste) are expired materials containing one or more electrical transmission elements. If these waste materials are not evaluated according to their qualities, they pose a problem for the environment, human health, and the national economy. The recovery of valuable products from electronic wastes has been developed with a simple and economical ore dressing process, taking into account the recycling methods used today (Koshta et al., 2021).

Computers, monitors, televisions, refrigerators, washing machines, washing machines, cell phones, and similar devices that are used in the home, office, and industry, have completed their useful life or are no longer used due to malfunction and cannot be repaired are all collected under the category of electronic waste. These devices consist of a wide variety of components, mainly metal and plastic (Çiftlik et al., 2009). Electrical and electronic waste has become a rapidly growing problem in modern society. Technological developments and changes in consumption habits cause electronic devices to rapidly become obsolete and discarded. With the rapid development of technology, many studies have been conducted nationally and internationally on the proper management of electronic waste.

Our research consists of two parts. In the first part of the study, studies on electrical and electronic waste management, its importance, sustainable e-waste management, and the latest situation in Turkey are mentioned

to provide a basis for the empirical study in the second part. In the second part, the potential of electrical and electronic waste in Bitlis province, which was selected as a pilot province, and the environmental and economic impacts of these wastes were analyzed.

2. E-waste management within the framework of sustainable development

2.1 Development, formation process, and importance of e-waste management

With the increasing effects of global warming, the gradual increase in carbon dioxide emissions and the decrease in natural resources have led to an increase in environmental problems in the world. The unlimited consumption of natural resources and the fact that natural resources are not sustainable has led to an increase in the studies conducted in this field day by day (Örten, 2009). In the 1970s, people only tried to determine what the problems in the environment were. They realized that the environment is an issue that not only institutions but also every human being should care and protect (Fraj; Martinez, 2007). In 1987, the World Commission on Environment and Development (WCED) in its report "Our Common Future" explained sustainability as "meeting the needs of future generations with the needs of today" (Aksu, 2011).

Launched in 1992, the Rio Earth Summit led to the Framework Convention on Climate Change, which recognizes our shared responsibilities and the social and economic conditions for stabilizing greenhouse gases in the atmosphere. The Convention entered into force in 1994. In 1997, country states convened for the Kyoto Protocol. The Protocol contains guidelines and rules on the extent to which participating industrialized countries should reduce emissions of six greenhouse gases: carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, hydrofluorocarbons, and perfluorocarbons. The decisions taken in the Protocol entered into force in 2005. In addition, one of the decisions taken in the protocol calls for a 5.2% reduction in greenhouse gas emissions between 2008 and 2012 compared to 1990 levels. This figure is insufficient to achieve climate change by 2100 (Gundimeda, 2004; Sathaye et al., 2006).

Electrical and electronic waste is material in which electrical or electronic devices have become unusable or have been discarded (Aurubis, 2024). This waste usually includes electronic items such as household appliances, computers, televisions, cell phones, batteries, and lamps (İkhlayel, 2018). Electrical and electronic waste is divided into different categories according to their characteristics. These can be classified as large household appliances, small household appliances, IT and telecommunication equipment, consumer equipment, lighting equipment, and electrical and electronic toys (Aksoy, 2014). The importance of e-waste should be evaluated in terms of its environmental impacts and resource management.

The generation of e-waste is influenced by factors such as consumer demand, production process, lifecycle, and waste management. Proper management of e-waste helps to reduce environmental impacts, conserve resources and protect human health. Therefore, an effective e-waste management system is crucial for reducing waste generation and ensuring a sustainable future.

Table 1. Environmental impacts and importance of E-waste.

	E importance of waste
Environmental Impacts	Electrical and electronic waste can cause significant damage to the environment as a result of the toxic substances they contain and improper waste management. Irregular disposal or improper segregation of waste can lead to soil, water, and air pollution. This in turn damages natural ecosystems, vegetation, water resources, and biodiversity.
Resource Management	Electrical and electronic waste has significant resource potential in terms of the precious metals and other materials they contain. The management of this waste through recycling contributes to conserving natural resources and reducing the need to extract new raw materials.
Human Health	Electrical and electronic waste can pose a significant threat to human health due to the toxic substances they contain. Environmental pollution resulting from improper waste management or irregular disposal can harm people through inhalation or water sources.

Source: Authors, 2024.

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2.2. Current status of E-waste management system in Turkey

With the developing technology, the amount of electrical and electronic waste is increasing rapidly, and developments are being made in properly managing these wastes. The amount of e-waste and electrical and electronic waste in Turkey is growing every year. Recycling infrastructure in Turkey is still under development. According to research, the number and capacity of recycling facilities in Turkey are insufficient.

Furthermore, the efficiency and coverage of waste collection and sorting systems should be improved. Turkey has made legal arrangements for the management of electrical and electronic waste. Regulations such as the Regulation on Control of Electrical and Electronic Waste and Regulation on Control of Packaging Waste have introduced some requirements for waste management and recycling. However, there are some difficulties in the implementation and supervision of the regulations (Li et al., 2014).

While Turkey is trying to solve its e-waste problems, the most rational way to succeed is to establish a reliable and feasible process method. Knowing the quantities of e-waste generated/to be generated and their characteristics is very important for concluding. In general, there are various approaches to calculating e-waste quantities in studies. The most common of these approaches is to know the number of devices in use. The accuracy of estimates of e-waste quantities largely depends on the average lifespan of these devices and their representativeness on the consumer trend in a country (Yıldırım, 2023).

In Turkey, the collection, transportation, sorting and recovery of e-waste is carried out by companies approved by the Ministry of Environment and Urbanization. Companies are issued certificates of conformity for the collection, sorting and reuse processes they will apply to waste and compounds in the e-device category. These certificates aim to record, control and supervise these activities (Ministry of Environment, Urbanization and Climate Change, 2022).

2.3 E-waste recovery cycle

Electrical and electronic waste (EEEs) is a rapidly growing waste stream and can cause environmental and health risks worldwide. This waste includes end-of-life or faulty electrical and electronic equipment. They cover a variety of products such as computers, televisions, cell phones, household appliances, medical devices, and other electronic equipment. Effective management of these wastes is important in terms of protecting natural resources, reducing environmental pollution, and utilizing the recycling potential (Salihoğlu; Kahraman, 2016).

The first step in the recovery of electrical and electronic waste is the role of accumulation systems. Accumulation is the process of collecting waste electrical and electronic equipment in a regular and organized manner and transporting it to temporary storage areas. These systems ensure the effective recovery and utilization of waste in waste management (Erbay, 2009).

In the second step, the role of transportation in recovery is critical. The transportation process covers the journey of waste equipment from collection points, and accumulation areas and then to recycling or disposal facilities. The transportation process in the recovery of electrical and electronic waste plays one of the most effective roles in the effective and efficient use of waste management by ensuring the transportation of waste equipment from collection points to accumulation areas, from temporary storage areas to recycling or disposal facilities (Resmi Gazete, 2021).

In the third step, the Waste Electrical and Electronic Equipment (WEEE) landfill plays an important role in the waste management process. WEEE storage is a process where used, faulty, or inert electrical and electronic equipment is temporarily stored. This storage phase is a temporary stage where waste equipment is stored for a certain period before being diverted to recycling or disposal processes (Ernst et al., 2000).

In the fourth step, the recycling process of electrical and electronic waste begins. This process provides many waste management benefits and is an essential component for sustainable waste management Recycling is a fundamental step in the recovery of electrical and electronic waste. This process provides many benefits such as conservation of natural resources, reduction of waste volume, energy savings, economic benefits, controlled disposal of hazardous substances, and transition to a circular economy. Recycling of electrical and electronic

waste makes significant contributions to sustainable waste management and environmental protection efforts (Kang and Schoenung, 2005).

The fifth step is the disposal of hazardous waste. Electrical and electronic waste may contain some hazardous substances. These substances can harm the environment and human health. In the recovery process of electronic waste, hazardous substances must be disposed of safely. Hazardous substances are separated by specialized processes and disposed of effectively without harming the environment or human health. Proper management of hazardous materials ensures that the recovery process is environmentally friendly and sustainable (Karaman, 2023).

The sixth step is the final stage, sorting, where collected electrical and electronic waste is separated before entering the recycling process. The sorting process can be carried out manually or automatically. The waste is sorted into different groups such as plastics, metals, glass, circuit boards, and other materials. Sorting is important to increase the efficiency of the recycling process and to ensure more effective utilization of materials (Çayırlı; Toraman, 2018).

3. Findings

3.1. Electric and electronic waste potential in Bitlis province

The potential for electrical and electronic waste is related to population, economic activity, consumption habits, technology use, and other factors in a region. Bitlis province is located in the Eastern Anatolia Region of Turkey. Its population, economic structure, technology use, and consumption habits are among the factors affecting the potential for electrical and electronic waste (Daka, 2013). There are various application areas for electrical and electronic waste management in the city. These areas contribute to e-waste management through various measures such as waste collection, recycling, awareness raising, and social responsibility projects. In this way, important steps are taken for a sustainable future by protecting the environment and human health.

The e-waste management and recycling infrastructure in Bitlis province is directly related to the waste potential. Table 2 shows the electrical and electronic product information of Bitlis province for the years 2017-2022.

Table 2. 2017 - 2022 Electrical and electronic product list for Bitlis province.

Types of electronic materials	2017	2018	2019	2020	2021	2022
3D Prınter	0	0	1	0	0	3
Aspirator	533	498	451	508	484	552
Dishwasher	1.142	1.071	848	1.032	987	896
Refrigerator	2.218	1.957	2.031	1.442	393	442
Washing Machine	1.867	1.763	1.575	1.588	1.510	1.430
Interactive Board	0	0	0	389	196	187
Oven	1.266	1.106	874	932	881	873
Kettle	480	333	213	167	105	189
Klima	34	28	38	19	30	21
Drying Machine	17	18	9	20	43	65
Small home appliances	7	4	1	0	1	6
NON-TV	0	0	0	0	0	0
Cooker	569	589	568	583	641	692
Field Test Product	0	0	0	0	0	0
System Air Conditioners	14	0	0	0	0	0
Water Purifier	0	0	2	1	0	2
Water Dispensers	21	16	7	5	4	5
TV	1.304	1.269	1.092	1.221	867	912

Commercial Heating Systems	0	1	0	0	0	0
Commercial Air Conditioner	24	10	0	0	7	0
Total	9.496	8.663	7.710	7.907	6.149	6.275

Source: Authors, 2024.

The end of the life of electronic materials and the fact that they become user-generated waste depends on the ability to obtain the product through the recycling process. The end-of-life of electronic materials is more sensitive than other materials. The fact that electronic materials are not immediately seen as waste, of course, expands the level of impact on products. This is seen as an important factor in the economic development of users. Figure 1 shows the graph of electrical and electronic waste in 2017. Figure 1 shows the lower limit and upper limit data. In 2017, it was observed that the refrigerator exceeded the upper limit.

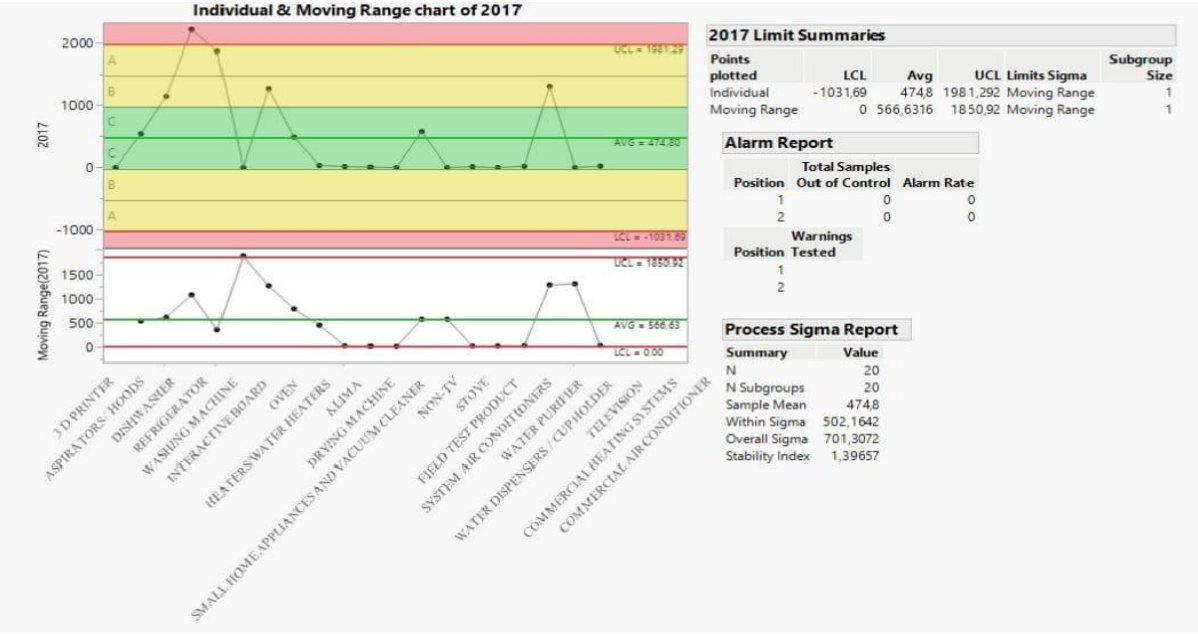

Figure 1. Electrical and electronic waste statistics for 2017. Source: Authors, 2024.

Figure 2 shows the graph of electrical and electronic waste in 2018. Figure 3 shows the lower limit and upper limit data. In 2018, it was observed that refrigerators and washing machines exceeded the upper limit.

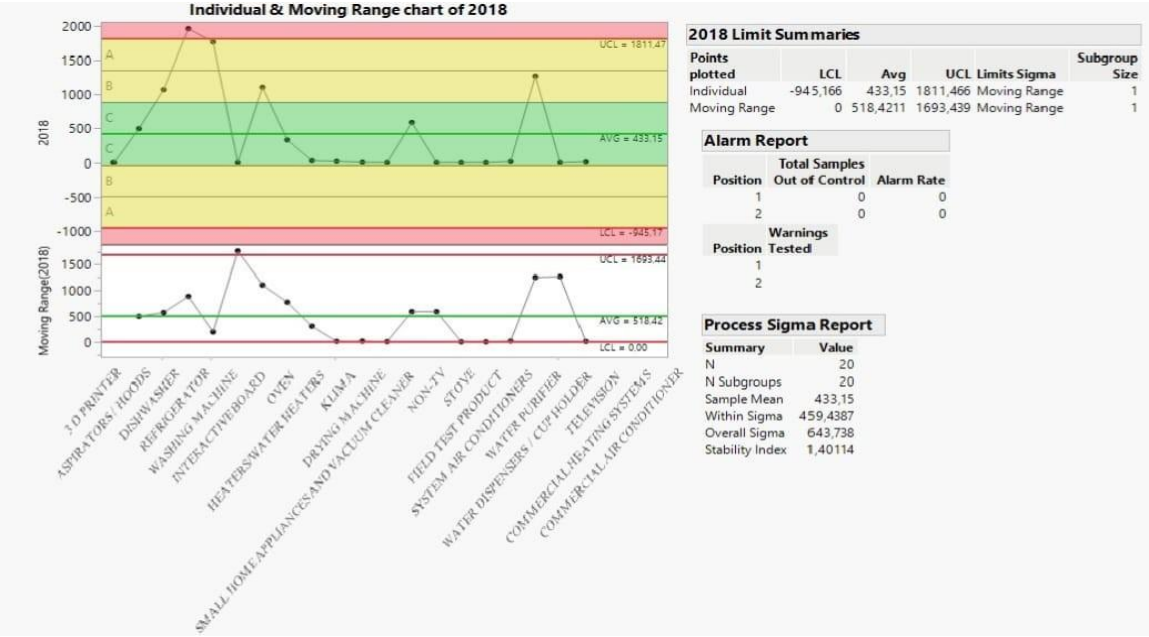

Figure 2. Electrical and electronic waste statistics graph for 2018. Source: Authors, 2024.

Figure 3 shows the electricity and electronic waste graph for 2019. The graph shows the lower limit and upper limit data. In 2019, it was observed that the refrigerator exceeded the upper limit, and the washing machine approached the upper limit.

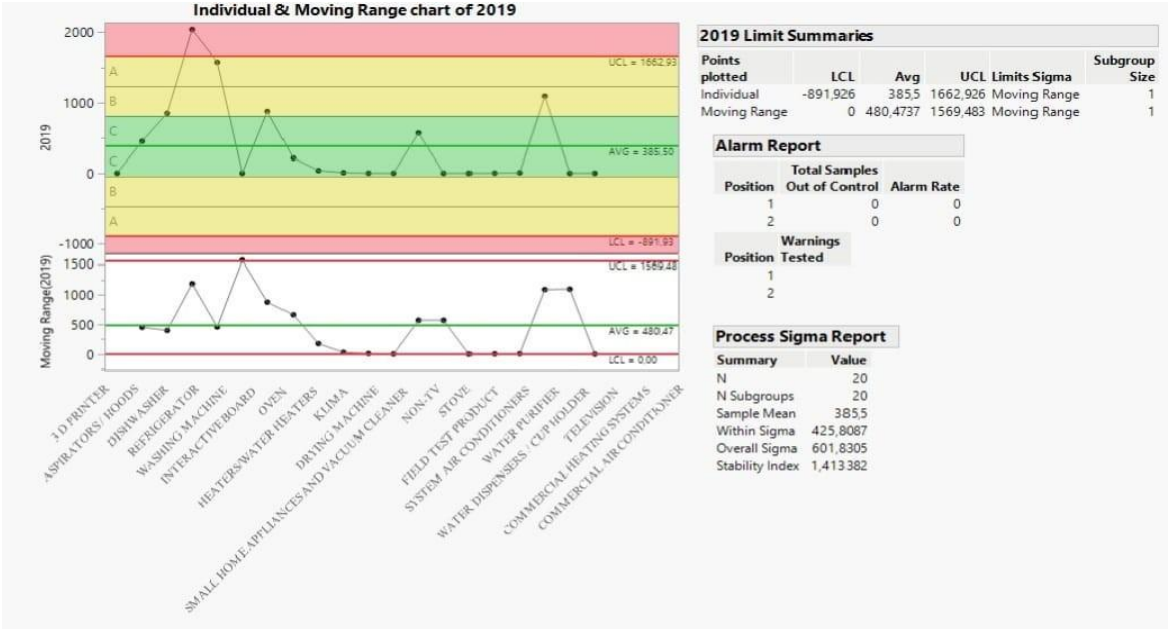

Figure 3. Electrical and electronic waste statistics graph for 2019. Source: Authors, 2024.

Figure 4 shows the electricity and electronic waste graph for 2020. The graph shows the lower limit and upper

limit data. In 2020, it was observed that the washing machine exceeded the upper limit, and the refrigerator approached the upper limit.

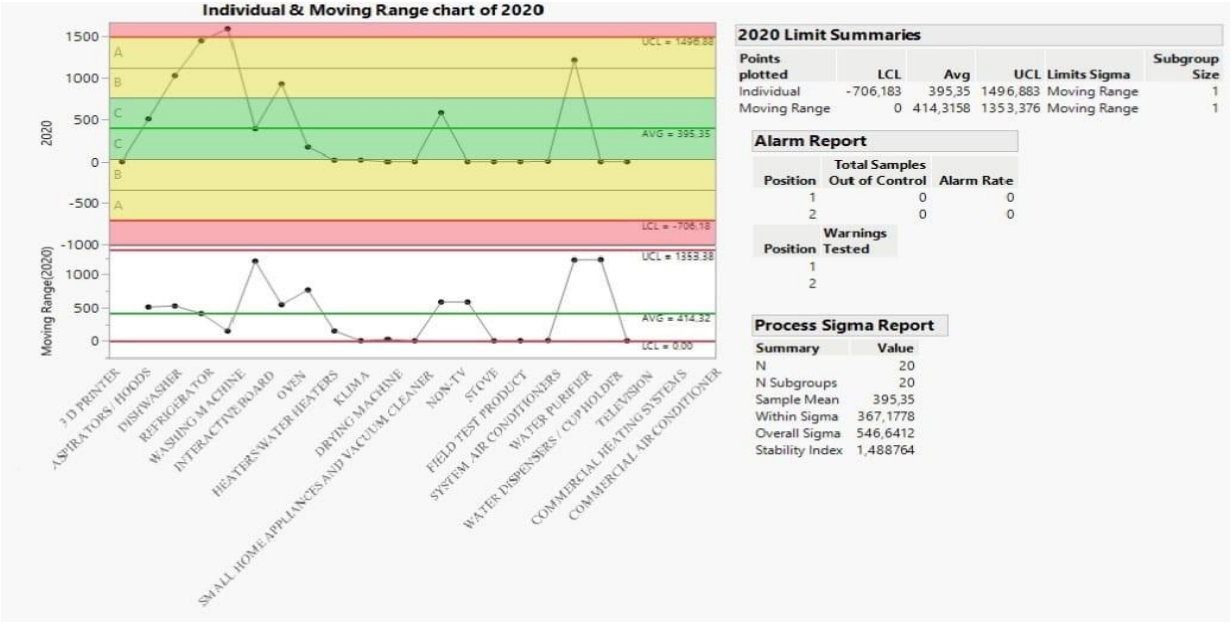

Figure 4. Electrical and Electronic Waste Statistics Graph for 2020. Source: Authors, 2024.

Figure 5 shows the electricity and electronic waste graph for 2021. The graph shows the lower limit and upper limit data. In 2021, it was observed that the washing machine exceeded the upper limit.

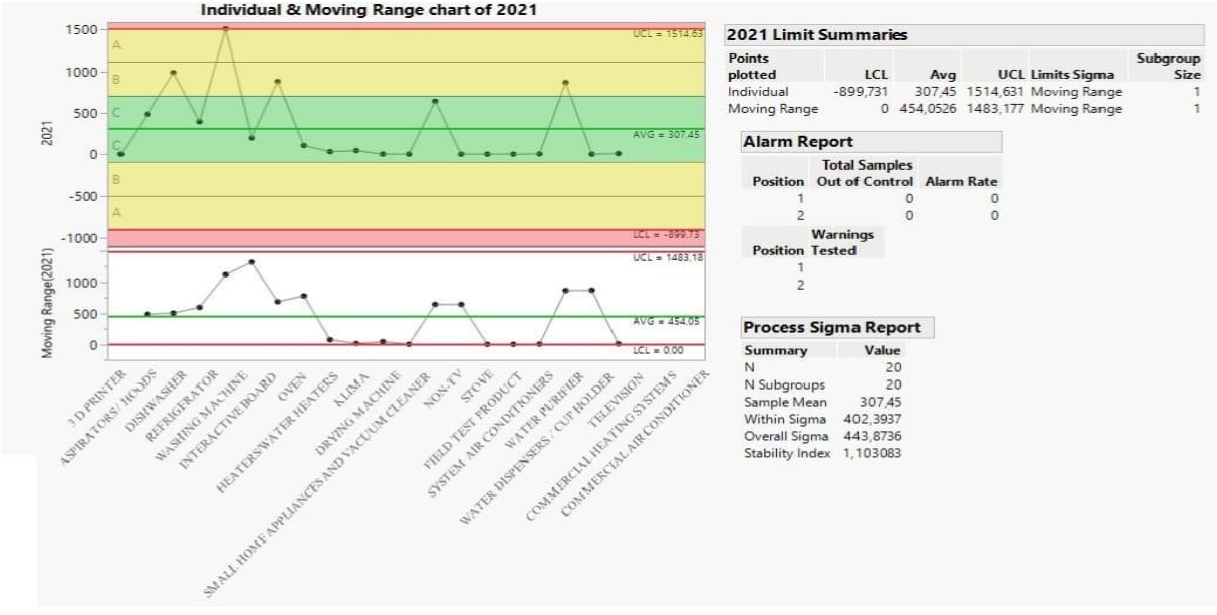

Figure 5. Electrical and electronic waste statistics graph for 2021. Source: Authors, 2024.

Figure 6 shows the graph of electricity and electronic waste for 2022. The graph shows the lower limit and upper limit data. In 2022, it was observed that there were no products exceeding the upper limit and the washing machine approached the upper limit.

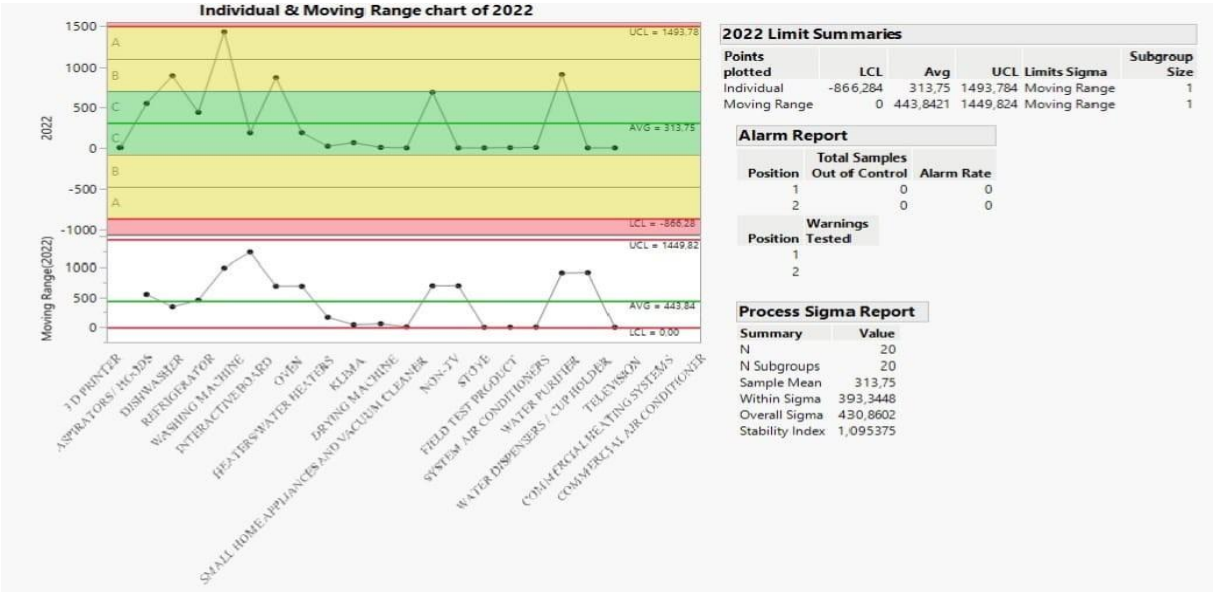

Figure 6. Electrical and electronic waste statistics graph for 2022. Source: Authors, 2024.

4. Discussion

In the study, firstly, the relationship between sustainability, development, and e-waste is examined and then the current situation in Turkey is analyzed. Then, the potential of electrical and electronic waste in Bitlis, which was selected as a pilot province, between 2017-2022 was determined and various policy recommendations were presented with the help of national and international literature.

The environmental problems that emerged as a result of the technology that developed with the Industrial Revolution led to major environmental problems as well as the economic growth of countries. In these problems, the concepts of sustainable development have been put forward by establishing a balance between economic growth and environmental problems and considering the rights of future generations. One of the main environmental problems is electrical and electronic waste.

With the developing technology, e-waste has rapidly become a threat to the world. The key to success in terms of e-waste management is the development of eco-designed devices, proper collection of e-waste, safe recovery and recycling of material, proper disposal of e-waste, banning the transfer of used electronic devices to developing countries, and raising awareness of the impacts of e-waste pollution among both users and producers. This approach is now routinely used in most developed countries but developing countries and countries in transition have yet to convince local communities to adopt such management strategies. In these countries, education of the younger generation can be a way forward in e-waste management.

In addition, recycling e-waste through appropriate methods can help the environment and create jobs. With the recovery of e-waste, precious metals will be recovered for Turkey and our need to purchase precious metals from foreign markets will decrease. The recovery of e-waste with appropriate methods can be both environmentally friendly (reducing environmental damage) and an important market that can create significant jobs. The advantages of recycling are not limited to these. The higher the raw material prices in the world, the more valuable the recycled material is.

In Bitlis province, studies and measures taken on e-waste management are important for the protection of the environment and human health. Proper waste management and recycling processes are critical for Bitlis to contribute to a sustainable future and minimize environmental impacts. Raising public awareness and investing in e-waste management will enable Bitlis to move forward in e-waste management.

The assessment process involves local authorities, environmental organizations, and other interested parties coming together to assess the state of e-waste management in Bitlis province and develop solutions. In this way,

the electrical and electronic product framework can be managed in a more sustainable and environmentally friendly way.

5. Conclusion

In general terms, frequent changes in technology, electronic shortened lifespan of devices, lack of recycling and disposal facilities, import of food waste in the form of second-hand goods, and recycling and reuse are more common. The amount of e-waste is increasing rapidly due to a lack of focus on e-waste. This ever-increasing amount of e-waste is not only harmful to the environment but also to human health.

Therefore, it must be effectively needs to be managed. As a result, the recycling of electrical and electronic waste and a proper managing the environment, reducing environmental impacts and recovering valuable resources is important. However, the increase in the amount of waste, the inclusion of hazardous substances, and the disadvantages such as conversion difficulties must also be taken into account. Therefore, electricity-appropriate infrastructure, regulations, and procedures for the effective management of electronic waste awareness measures are necessary.

6. Recommendations

E-waste is a serious problem both locally and globally. Problems with e-waste initially emerged in developed countries. Nowadays, it is spreading rapidly in other countries of the world. To prevent this problem, first of all, the safe and secure collection, disposal, and recycling of e-waste, which is growing like an avalanche in Turkey and our country, should be turned into an industry. It is seen that legal sanctions regarding e-waste in the world include taking back the product of the producer, charging a prepaid recycling fee, and imposing tax credits. Therefore, various studies should be carried out to ensure that the electrical and electronic materials produced in Turkey do not contain hazardous waste and are environmentally friendly. In this context, manufacturers should be forced to produce clean/environmentally friendly products, and if this is not possible, recycling should be encouraged.

Recycling e-waste with appropriate methods can be a significant business area in terms of sustainable development and ensuring proper environmental management. Additionally, our recommendations for the management of e-waste in Turkey are as follows; It is very important to raise public awareness about the harms of e-waste and to educate them about the importance of recycling. Therefore, awareness and education campaigns can be carried out. More recycling centers need to be established throughout Turkey and these centers need to specialize in collecting, separating, and recycling e-waste.

These centers should have the necessary technology and equipment to recycle the components of electronic devices. Therefore, recycling centers can be established in every city. Finally, stricter legal regulations should be introduced on the management of e-waste and inspections should be increased to ensure compliance with these regulations. Additionally, tax breaks or other economic incentives may be provided to encourage recycling. The evaluation process involves local governments, environmental organizations, and other relevant parties coming together to evaluate the situation of e-waste management in Bitlis province and develop solutions. In this way, the electrical and electronic product framework can be managed in a more sustainable and environmentally friendly way.

7. Availability of data and materials

The data supporting the findings of this study were calculated from the site called the individual moving range chart. https://sixsigmastudyguide.com/i-mr-chart/

8. Authors' Contributions

Muhammed Ömer Yaman: conceptualization, methodology, and investigation. *Sevgi Akkoy*: validation, writing, methodology, investigation, and writing. *Edip Avşar*: coordination of the article, methodology, and data collection.

9. Conflict of interest

The authors declare no conflict of interest.

10. Ethics Approval

Not applicable.

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