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RESEARCH ON URBAN E-WASTE MANAGEMENT IN CHINA BASED ON SMART TECHNOLOGIES

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The improper management of e-waste poses a serious risk to the environment, human health and socio-economic sustainability due to the increasing volume of e-waste globally, its complexity and hazardous components. The management of e-waste is widely recognized as critical around the world, and China has begun to pay attention to e-waste management as well. The development of smart digital technologies provides a new option to realize efficient e-waste management. This study systematically reviews the application of smart digital technologies in e-waste management, which mainly involves the collection and recycling process of e-waste. On the basis, the research topic of advanced digital technologies used in e-waste management literature were unfolded and discussed. To explore the potential application of smart digital technologies in urban e-waste recycling management, this study investigates key digital technologies and equipment for promoting e-waste management in cities, establishing a smart recycling system and an intelligent logistics recycling system for e-waste, using City X in China as an example. In this study, we try to propose an alternative for City X based on intelligent digital technology, which mainly covers the collection process of e-waste, an intelligent logistics recycling system to track and optimize the logistics of e-waste recycling, and an intelligent inventory management that can realize the digital management of e-waste. Our findings could improve the performance of urban e-waste recycling and provide reference for the promotion of smart urban e-waste management system.

Key words: *E-waste, Digital Technologies, E-waste management, Smart system, Circular Economy.*

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Formulation of the problem in general terms. Resource recycling and environmental protection are sustainable lifestyles advocated by countries around the world. However, with the development of science and technology, people's lives are increasingly inseparable from various household appliances and intelligent electric and electronic products, which provide people with smart services and high quality of life. But at the same time, the generation of large amounts of end of life waste electric and electronic equipment (WEEE) is also threatening the human living environment, causing serious environmental pollution, and initiating the hazardous situations for biological life [1]. WEEE, known as urban mine, contains valuable resources in the form of various precious and critical metals that is a misplaced resource with recycling value.

The implementation of e-waste recycling can achieve the secondary recycling of resources, reduce the waste of valuable resources and decrease the negative impact of e-waste on the environment. However, e-waste has a complex composition, containing both valuable components and a large amount of toxic heavy metals and chemical substances, which pose a great threat to the environment and human health if it is simply landfilled or incinerated. But in fact, due to the lack of relevant regulations, a large number of unscru-

pulous traders in China take advantage of the loopholes in the law and the lack of environmental protection awareness of the residents to buy large amounts of WEEE in large cities and transport it to remote places such as Guiyu, where e-waste is recycled with workers' bare hands to recover the metal and other components, without taking into account that, in the process of e-waste disposal, a large amount of toxic substances in e-waste will pollute the local environment and harm the health of workers. Specialized, often «high-tech» methods for handling e-waste are required to maximize resource recovery and minimize potential harm to humans and the environment. However, due to the lack of recycling facilities and recycling awareness, a large amount of e-waste is not recycled through specialized recycling technologies within the formal recycling system. The development of smart technologies and smart recycling management systems for e-waste opens up the possibility of new alternatives.

Analysis of recent research and publications. Intelligent methods were used in waste management in the construction of smart cities. The solid waste management in smart cities is shifting from simplified manual collection and sorting procedures to sustainable systems based on various smart technologies. It has great potential to develop more sustainable business practices to manage waste from a closed-loop lifecycle perspective [2].

The rapid development of digital technologies (DTs) facilitates waste management process towards CE. Smart enabling technologies in the field of CE use electronics, software, sensors, and actuators to exchange and process data for better results [3]. Esmaeilian et al. (2018) [4] identified four types of smart waste management system technology: advancements in sensor-based and data acquisition technologies, communication and data transmission technologies, field experiment technology, and truck route planning and scheduling technologies. Smart technologies such as space technology (GIS, GPS, RS), and data acquisition technology mainly including sensor technology and identification technology (RFID tags, NFC sensors) can be utilized to collect the data on urban waste in real time to facilitate decision-making on waste recycling activities. Recently, several studies related to online e-waste collection systems with mobile applications were conducted to ensure environmental protection and sustainable resource supply in the electronics industry [5–8]. IoT based smart bins can be controlled and monitored by being equipped with sensors to record information about e-waste disposal [9–12]. These devices are wirelessly connected to a central hub to transmit the information, facilitating the tracking of waste collection, optimizing container loads and vehicle routes by a decision-support system. Ramya et al. [13] employed AI algorithm for smart e-waste classification, collecting e-waste images from IoT nodes and storing them in the cloud. These intelligent components use deep learning and machine learning approaches to handle massive volumes of data in order to deliver real-time information and promote efficient decision-making with less human involvement [14; 15]. The blockchain-based IoT-enabled e-waste management system could keep track of all post-production activities, business processes, and operations carried out on electronic devices [16]. This kind of transparent information flow makes consumers more positive to participate in the waste management process.

Formation of the objectives of the article. The sources of e-waste are scattered and widely distributed, so how to achieve efficient collection of all types of waste home appliances is a key step in the large-scale disposal of e-waste. At present, the peddlers and traders can collect a certain number of e-waste, but there are problems such as difficult supervision and low efficiency. Therefore, this research mainly discusses how to build an efficient and intelligent collection system for e-waste, which provides references for the efficient recycling and utilization of e-waste. In order to further explore the application of smart technologies in e-waste management, this study systematically reviews the application of smart digital technology in e-waste management. Then, combined with the actual situation of the e-waste management project in city X in China, a case analysis of e-waste management in this city was conducted, including the collection, logistics and inventory management of e-waste. We propose a recycling system for e-waste based on smart technologies to replace the existing e-waste management system in City X that is mainly recycled by small vendors. Our research results provide city managers and decision makers with an e-waste management solution based on smart technologies, which help to improve the efficiency of e-waste recycling, and also provides a reference for advancing e-waste management in the construction of smart cities.

Methods of research. Municipal e-waste management system is a huge project, and this study chose to build an advanced, efficient and intelligent recycling and management project for waste electronic products in X city for case study, attempt to achieve the enlightenment effect of drawing inferential conclusions in practice. X city is selected as the target city for this study because the economic development level and scale of X city is at the middle level in China, and it is representative to conduct a case study on it. X city is located in the northern part of Henan province, and it is a prefecture-level city, with a total area of 8,249 square kilometers. There are four municipal districts in X city, and the resident population of X city is 6,166,000 at the end of 2022. X city is a national civilized city, national sanitary city, national garden city, national forest city, national intellectual property demonstration city, and national circular economy demonstration city. As of December 2022, X city has 9 counties and districts under its jurisdiction, 1 urban-rural integration demonstration zone, 2 state-level development zones, and 3 county-level cities under its administration. This study was conducted to understand the current status of e-waste management in four municipal districts of X city, and the survey was carried out from May to July 2023.

Results of the study. The intelligent logistics and recycling system for e-waste in City X consists of four parts: coverage of e-waste logistics and recycling network, tracking of e-waste logistics and recycling process, intelligent recommendation of e-waste logistics and recycling routes, and e-waste inventory management. The logistics and recycling

network for e-waste will be combined with intelligent recycling bins of the IoT, and a three-layer logistics and recycling system will be constructed with the core of «points, stations and centers», which will be operated on the basis of the data and information obtained from the urban perception network, and designed in accordance with the principle of «unified planning, fixed-point operation and centralized management». It forms a new intelligent integrated recycling system with reasonable layout and comprehensive coverage by setting up community collection points (collection kiosks or mobile collection vehicles), regional collection stations (collection stores) and regional collection centers (processing and utilization centers).

Community collection points are generally deployed in the form of collection kiosks, which are responsible for the recovery of renewable resources surrendered by the community and its neighboring residential areas and community commercial outlets. In residential communities with limited conditions, mobile recycling vehicles can be set up to provide the community with regular collection services at regular intervals.

The basic principle of setting up community collection points is to build recycling points in accordance with the requirements of convenience for the residents, with one collection point (kiosk) for every 2,000-2,500 residents in urban areas and one collection point (kiosk) for every 3,000-3,500 residents in rural area. Institutions and enterprises are required to designate special persons or points for collection according to the declaration system.

The regional collection station is the key node of the infrastructure [17]. The regional collection station requires a relatively large sorting site and a fixed location for centralized sorting, simple processing and resource distribution of recyclables resources other than hazardous waste. Regional collection stations are required to realize the following functions: (1) Collection. Collecting renewable resources centrally collected from community collection stations and mobile collection vehicles, as well as renewable resources submitted by enterprises, institutions, government agencies and schools. (2) Classification. Based on the principle of maximizing value, formulate classification standards for renewable resources, and carry out sorting and simple processing; (3) Storage. The regional collection stations also have to take on the function of temporary storage of small used home appliances and toxic and hazardous waste. The regional collection stations will sort various types of renewable resources and then distribute them to various specialized collection centers as needed.

The regional collection center is also a renewable resources processing and utilization center, which is the end of the renewable resources recycling and utilization system. Based on the centralized sorting and simple processing of the regional recycling stations, the regional collection center forms an organic whole of the resources recycling chain and combines it with the operation network, which is the greatest point of interest in the development of the recycling industry chain. It integrates resource collection, processing, reuse, information, service and environmental protection, and is characterized by scale, ecology and industrialization.

The tracking of the reverse logistics recycling process of waste home appliances will utilize logistics tracking technology and adopt the fusion of multiple tracking technologies to realize the heterogeneous sharing and the chain query of waste home appliances reverse logistics recycling data. The tracking technologies will integrate the application of barcode identification technology, GPS/GIS technology, Bluetooth technology, RFID and other logistics tracking technology, and further integrate with the ERP system [18], warehousing management system, transportation scheduling system, distribution and picking system and other information management systems. The data of the reverse logistics come from many recycling business links, and the format and content of the data have strong heterogeneity, we will mainly use XML technology (Extensible Markup Language) to achieve the sharing and analysis of different structural data processing. XML technology adopts a standardized data structure standard to convert heterogeneous data into a unified structured data format.

The data traceability of the recycling process of the reverse logistics of used and end-of-life appliances will adopt the cross-platform chain query technology between different systems to track all the links of the reverse logistics in the whole process, and through the multi-database data level connection between the systems, it can realize the chain query of the tracking data, and at the same time, it also facilitates real-time querying on the current links and status of the waste home appliances.

The source of waste household appliances is scattered in all corners of the city, optimize the recycling logistics mode of used and waste household appliances, with the help of GPS/GIS, integrating Bluetooth, barcode, RFID and wireless communication and other advanced technical means, through the construction of cross-platform logistics information platform, the closed recycling logistics information is converted into an open recycling logistics information platform, and recycling logistics information is changed from single-direction and single-channel transmission to multi-direction and multi-channel transmission, so that the recycling logistics information can be further optimized and utilized on the basis of sharing. By building a cross-platform logistics information platform, the closed recycling logistics information will be converted into an open recycling logistics information platform, and the recycling logistics information will be changed from single-direction and single-channel transmission to multi-direction and multi-channel transmission, which will make the recycling logistics information of the waste household appliances further optimized and utilized on the basis of sharing, and the efficiency of the recycling logistics will be greatly improved by the coordinated calculation of the recycling routes and the optimization of recycling routes of the waste household appliances, which will effectively reduce the consumption of the logistics, lower the cost, and achieve the dynamic control of the whole recycling logistics and transportation.

The information on the recycling of waste household appliances mainly comes from the urban waste household appliance perception network established in the early stage; through wireless communication network and technology to obtain comprehensive road traffic information, using GPS/

GIS control center to obtain the road traffic status and logistics vehicle status on the recycling logistics network, the whole process of dynamic tracking of the vehicle, to achieve the comprehensive management and control of the recycling logistics status. Establishment of a visual management platform is to visualize the utilization plan of recycling vehicles, the optimization of transportation schemes and the dynamic control of vehicles and goods within the scope of the platform. We need to establish warehousing management, financial management and customer service supporting systems, the recycling of waste home appliances information to implement the whole supply chain management, combined with the transportation scheduling function, constituting a complete intelligent logistics and transportation system.

Construction of an intelligent service platform for e-waste. Waste home appliances are of various types and huge quantities, and can be categorized into large-sized waste home appliances and small-sized waste home appliances according to the difference in their size or quality. Large-sized used home appliances mainly include CRT televisions, refrigerators, washing machines, air conditioners, etc., which are large in size and heavy in quality, and are not easy for residents to handle and dispose of, but they contain more recyclable resources and have a higher recycling value. Small-sized used home appliances include used cell phones, telephones, plug-in boards, chargers, etc., which are small in size and light in weight, and are easy for residents to handle and dispose of, but due to the large number of wastes and their wide distribution, it is not economically feasible to collect them through door-to-door collection.

Based on the different characteristics of large and small-sized used home appliance products, this study puts forward a targeted approach to build an intelligent recycling system for used home appliances based on IoT technology [3]. On the one hand, for large-sized used household appliances, online methods such as websites, hotlines and mobile apps can be used to make reservations in advance, and door-to-door quotes, settlements and deliveries of large-sized recycled resources can be realized for residents by integrating the traditional recycling system. On the other hand, for small-sized used home appliances, the IoT smart recycling bins set up in communities and major commercial districts are used as recycling carriers, giving full play to the advantages of the smart recycling bins, which integrate the functions of waste delivery and smart and convenient living, and encouraging residents to make real-time deliveries, so that residents can directly realize the quotation, settlement and delivery of small-sized renewable resources through the smart recycling bins. Through the infrared full box alarm system set up in the smart recycling boxes of each recycling outlet, the background data is analyzed in real time to plan the optimized logistics and recycling routes. In addition, after the delivery of large and small used home appliances is completed, the value of the delivered waste will be exchanged through the backstage settlement system in the first time, thus motivating more residents to participate in the delivery of used home appliances for recycling.

The key to building an intelligent recycling system for used home appliances is Internet of Things (IoT) technology [9]. IoT technology is a network that connects objects to the IoT through information sensing devices such as radio frequency identification (RFID), infrared sensors, global positioning systems, laser scanners, etc., in accordance with predetermined protocols, to exchange information and communicate in order to realize intelligent identification, localization, tracking, monitoring, and management of objects.

The related application of IoT technology has become more and more common [16], but the construction of the management platform for the recycling system of end-of-life household appliances is still to be improved [3; 7]. For the construction of IoT management platform for used and waste household appliances, the author analyzes X city as a case study and proposes an intelligent service platform with IoT intelligent bins and waste household appliances recycling information collection, and the platform construction framework is shown in Figure 1. The platform can revolutionize the traditional, low-tech and unordered information collection mode of all kinds of renewable resources industry including used appliances, and initially establish an urban sensing network of used appliances with comprehensive sensing, reliable transmission and intelligent processing. It will change the situation of low level of information collection and excessive labor consumption in the industry, greatly improve the efficiency of information collection on end-of-life household appliances, and provide a reliable and efficient data source for the recycling of used and end-of-life household appliances.

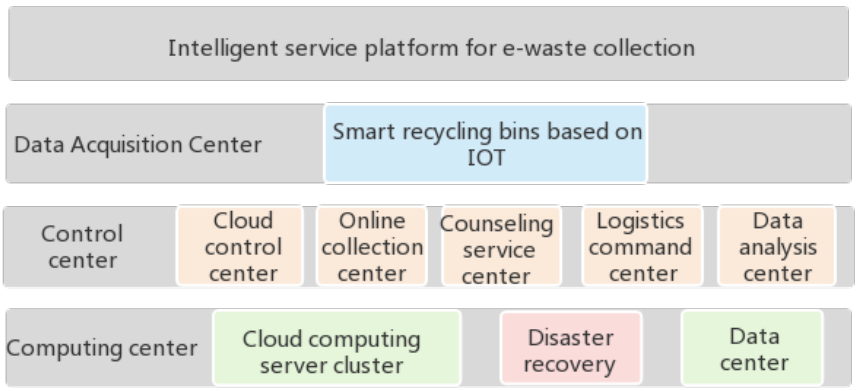

Figure 1 – Framework for building an intelligent e-waste collection service platform

Intelligent service platform for e-waste collection can collect data information and obtain attribute information on end-of-life household appliances distributed in cities anytime and anywhere by means of RFID, QR code, GPS, cameras, sensors, networks and other technical means of sensing, capturing and measuring; and the attribute information on end-of-life household appliances can be accessed to the information network through the convergence of various communication networks and the Internet, and the information can be shared and interacted at anytime and anywhere through the network. Through the integration of various communication networks and the Internet, the attribute information of used and end-of-life appliances is connected to the information network, and the information can be shared and interacted at any time and any place. At the same time, by utilizing information technologies [14], such as cloud computing and intelligent identification, the massive and cross-regional stock and attribute information of end-of-life appliances can be analyzed and processed to enhance the insight into the consumption activities of urban electronic products, the stock of used and end-of-life appliances and the related changes, and to realize the intelligent decision-making and control. The recycling process of IoT based intelligent recycling machine is illustrated in Figure 2.

The current infrastructure of the IoT system includes smart recycling bins, IoT recycling mobile terminals, a Wechat platform, an environmental protection website, a logistics scheduling system, a financial settlement system, a traceability system, a POS management system, a call center, and the infrastructure of each recycling site.

The system is based on the Internet of Things, and the construction of the renewable resources recycling network system strictly follows the principle of «reduce, reuse and recycle» of the circular economy in the process of operation [19], and through the integration of various types of renewable resources chain, it generates economic benefits and becomes a demonstration base for fostering a new type of economic growth point. At the same time, through market-oriented and professional operation, the formation of the circular economy industry chain is driven by the goal of minimizing the pollution emission and maximizing the utilization of resources in the process of recycling and treatment of e-waste renewable resources. Through the IoT technology, the logistics cost of the whole recycling system has been greatly reduced, and the recycling volume has increased.

The IoT Smart Recycling Bin is a customized IoT terminal device that contains two parts: the collection terminal and the cloud control center [13]. The device is oriented to residents, enterprises, and organizations with the service goal of recycling waste home appliances, and is a set of intelligent collection and sensing equipment deployed in buildings, commercial districts, and communities. Its core function is to serve as an information collection terminal for e-waste, providing residents with information and delivery services. Based on this, we have developed other value-added services for it, including open advertising services, ticket distribution services, online redemption services, and social public welfare services, taking into account the needs of the community and the commercial district.

Reverse logistics inventory management. The waste appliance logistics inventory management is built on the basis of logistics and recycling information data management, providing daily management and decision-making support for used and end-of-life appliance inventory. The completed logistics inventory management system can effectively reduce the fragmentation of data and information and the resulting loss of data in substance [20], establish appropriate decision-making models through the mining and utilization of logistics data, apply the theory of decision-making knowledge, and form solutions to help managers make correct decisions on the problems exposed in recycling logistics.

Among them, to effectively control and manage the inventory of waste electronic products means to do a good job in the daily management of the warehouse inventory, in accordance with the standard requirements and procedures of the work of the warehouse, the collection of all the data in

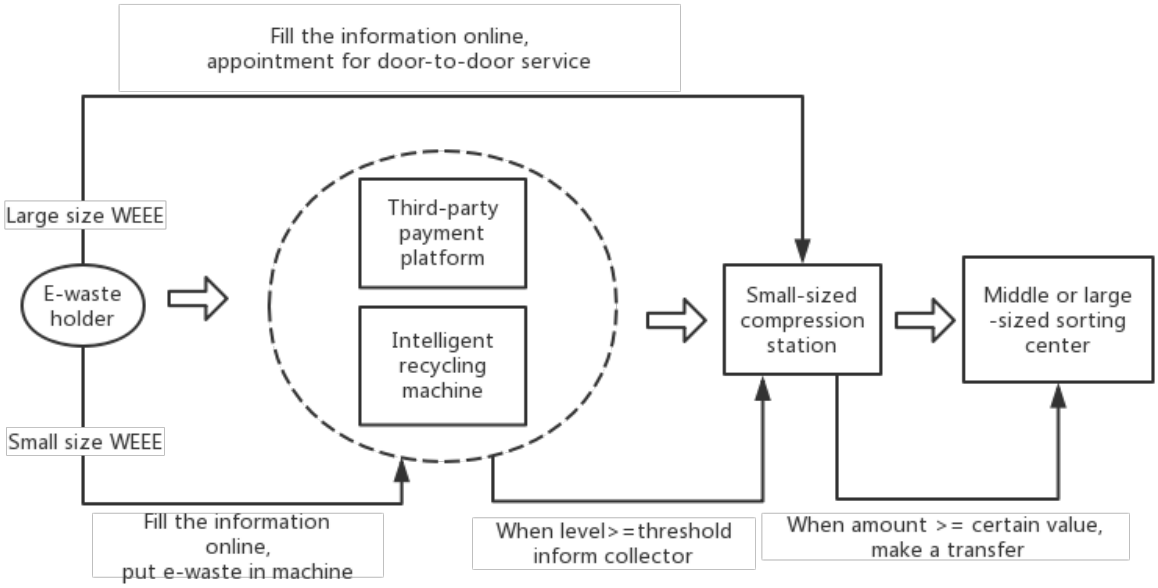

Figure 2 – The e-waste collection process based on IoT platform

the inventory processing work, such as records of entry and exit of the warehouse, bills, bills and so on, and to realize the all-around management of the waste electronic products into the warehouse, out of the warehouse, and the inventory. Inventory decision support mainly realizes decision support for the formulation of inventory management programs. (1) The system collects information on inventory, raw materials and prices, makes forecasts on the price trend and market trend of inventory items, and puts forward decision-making plans on the recycling and sales strategies of waste electronic products as well as the optimization of inventory. (2) Management of basic database, decision-making model library and knowledge database. The basic database system is responsible for adding, modifying, deleting, storing and querying various basic data, forecasting data and decision-making data. The decision model library system is responsible for generating various models and methods for prediction and decision-making, and finding the optimal solution through the continuous combination of decision models. The knowledge database is responsible for storing all kinds of knowledge rules, knowledge reasoning and all kinds of decision-making models, and can use knowledge rules to carry out knowledge reasoning, providing theoretical basis and practical basis for decision-making.

Effectiveness of the implementation of smart e-waste recycling system. So far, the city of X is in the process of building an Internet and IoT based e-waste recycling system, and volunteers are often recruited and organized to carry out a series of environmental protection publicity activities, such as «going into institutions, enterprises, schools and communities». Through the implementation of a variety of ways to standardize the recycling of waste home appliances, the residents' environmental protection concepts have been cultivated, and the recycling rate of used home appliances has been improved by the residents' correct delivery. Taking going into the community as an example, through the deployment of points in the community, the establishment of publicity strongholds and recycling logistics points, the formation of effective publicity channels to enhance the enthusiasm of the residents to participate, and at the same time to strengthen the linkage between the community to form the active participation of the residents of various regions. Several community-specific waste separation and recycling activities were carried out, and established a trusting and interactive relationship between the model system and consumers through this regular community activity. Waste home appliance recycling bins are placed at each site, and regular maintenance of recycling bins and collection and transportation of waste home appliances is carried out. The original scattered and disorderly recycling system [21] has gradually moved towards standardization and rationalization, greatly improving the quality of recycling services and gradually replacing illegal peddler traders.

Conclusion. Achieving efficient recycling of e-waste can maximize the use of recyclable resources and minimize the harmful impact of e-waste on human health and the environment. With the development of smart digital technologies, governments, academia and related enterprises are increasingly considering how to utilize smart technologies to assist in the e-waste collection and disposal. This study systematically reviews the relevant literature on e-waste management based on smart technologies. In order to explore the application of smart technologies in urban e-waste management, this study takes X City as a case study and investigates the key technologies to promote e-waste management in the city, and establish a smart e-waste management system. The smart e-waste recycling system and the smart logistics recycling system will replace the traditional e-waste recycling management system that mainly focuses on informal recycling. The intelligent recycling system for e-waste proposed in this study mainly covers the collection process of e-waste, intelligent logistics of recycling that tracks and optimizes the logistics of e-waste recycling, and intelligent inventory management that can realize digital management of e-waste.

Based on the results of the study, we argue that the application of smart digital technologies to e-waste recycling management in City is of practical significance for improving e-waste recycling performance. However, the wide promotion of this intelligent system in cities requires subsequent technological research and development of smart terminals based on this framework. In addition, the economic benefits of e-waste recycling based on smart technologies are still worth expecting and verifying, despite the significant positive externalities and public welfare characteristics of e-waste recycling.

References:

1. Gupta P.K., Shree V., Hiremath L., Rajendran S. (2019) The use of modern technology in smart waste management and recycling: artificial intelligence and machine learning. Recent advances in computational intelligence, pp. 173–188.
2. Alcayaga A., Wiener M., Hansen E.G. (2019) Towards a framework of smart-circular systems: An integrative literature review. *Journal of Cleaner Production*, vol. 221, pp. 622–634.
3. Anagnostopoulos T., Zaslavsky A., Kolomvatsos K., Medvedev A., Amirian P., Morley J., Hadjieftymiades S. (2017) Challenges and opportunities of waste management in IoT-enabled smart cities: a survey. *IEEE Transactions on Sustainable Computing*, vol. 2, no. 3, pp. 275–289.
4. Esmaeilian B., Wang B., Lewis K., Duarte F., Ratti C., Behdad S. (2018) The future of waste management in smart and sustainable cities: A review and concept paper. *Waste Management*, vol. 81, pp. 177–195.
5. Gao S., Shi J., Guo H., Kuang J., Xu Y. (2015) An empirical study on the adoption of online household e-waste collection services in China. Paper presented at the Open and Big Data Management and Innovation: 14th IFIP WG 6.11 Conference on e-Business, e-Services, and e-Society, I3E 2015, Delft, The Netherlands, October 13-15, 2015, Proceedings 14.
6. Gu F., Zhang W., Guo J., Hall P. (2019) Exploring "Internet+ Recycling": Mass balance and life cycle assessment of a waste management system associated with a mobile application. *Science of the Total Environment*, vol. 649, pp. 172–185.
7. Wang W., Qu Y., Liu Y., Zhang Y. (2020) Understanding the barriers for Internet-based e-waste collection system in China. *Journal of Environmental Planning and Management*, vol. 63, no. 4, pp. 629–650.

8. Wang H., Han H., Liu T., Tian X., Xu M., Wu Y., Gu Y., Liu Y., Zuo T. (2018) “Internet+” recyclable resources: a new recycling mode in China. *Resources, Conservation and Recycling*, vol. 134, pp. 44–47.
9. Kang K.D., Kang H., Ilankoon I., Chong C.Y. (2020) Electronic waste collection systems using Internet of Things (IoT): Household electronic waste management in Malaysia. *Journal of Cleaner Production*, vol. 252, pp. 119801.
10. Ali T., Irfan M., Alwadie A.S., Glowacz A. (2020) IoT-based smart waste bin monitoring and municipal solid waste management system for smart cities. *Arabian Journal for Science and Engineering*, vol. 45, pp. 10185–10198.
11. Harith M.Z., Hossain M.A., Ahmedy I., Idris M.Y.I., Soon T.K. Noor R.M. (2020) Prototype development of IoT based smart waste management system for smart city. Paper presented at the IOP Conference Series: Materials Science and Engineering.
12. Shyam G.K., Manvi S.S., Bharti P. (2017) Smart waste management using Internet-of-Things (IoT). Paper presented at the 2017 2nd international conference on computing and communications technologies (ICCCT).
13. Ramya P., Ramya V. (2023) E-waste management using hybrid optimization-enabled deep learning in IoT-cloud platform. *Advances in Engineering Software*, vol. 176, pp. 103353.
14. Ihsanullah I., Alam G., Jamal A., Shaik F. (2022) Recent advances in applications of artificial intelligence in solid waste management: A review. Chemosphere, pp. 136631.
15. Gupta P.K., Shree V., Hiremath L., Rajendran S. (2019) The use of modern technology in smart waste management and recycling: artificial intelligence and machine learning Recent advances in computational intelligence (pp. 173–188): Springer.
16. Khan A.U.R., Ahmad R.W. (2022) A blockchain-based IoT-enabled E-Waste tracking and tracing system for smart cities. *IEEE Access*, vol. 10, pp. 86256–86269.
17. Orlins S., Guan D. (2016) China’s toxic informal e-waste recycling: local approaches to a global environmental problem. *Journal of Cleaner Production*, vol. 114, pp. 71–80.
18. Schnoor J.L. (2012) Extended producer responsibility for e-waste. *Environ Sci Technol*, vol. 46, pp. 7927–7927.
19. Geng Y., Zhu Q., Doberstein B., Fujita T. (2009) Implementing China’s circular economy concept at the regional level: A review of progress in Dalian, China. *Waste Management*, vol. 29, no. 2, pp. 996–1002.
20. Tanskanen P. (2013) Management and recycling of electronic waste. *Acta Materialia*, vol. 61, no. 3, pp. 1001–1011.
21. Zhang A., Venkatesh V.G., Liu Y., Wan M., Qu T., Huisingh D. (2019) Barriers to smart waste management for a circular economy in China. *Journal of Cleaner Production*, vol. 240, pp. 118198.

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ДОСЛІДЖЕННЯ ПОВОДЖЕННЯ З МІСЬКИМИ ЕЛЕКТРОННИМИ ВІДХОДАМИ В КИТАЇ НА ОСНОВІ СМАРТ-ТЕХНОЛОГІЙ

Неналежне поводження з електронними відходами створює серйозний ризик для навколишнього середовища, здоров’я людини та соціально-економічної стабільності через збільшення обсягу електронних відходів у всьому світі, їх складності та небезпечних компонентів. Управління електронними відходами широко визнано критично важливим у всьому світі, і Китай також почав звертати увагу на управління електронними відходами. Розвиток інтелектуальних цифрових технологій надає нові можливості для реалізації ефективного управління електронними відходами. У цьому дослідженні систематично розглядається застосування інтелектуальних цифрових технологій в управлінні електронними відходами, які в основному включають процес збору та переробки електронних відходів. На цій основі були розгорнуті та обговорені теми дослідження передових цифрових технологій, які використовуються в літературі з управління електронними відходами. Потім були представлені найновіші розробки інтелектуального збору електронних відходів і ініціатив у Китаї, які були впроваджені та розширені через місцеве місто та громаду як альтернативу неформальним підходам. Щоб вивчити потенційне застосування інтелектуальних цифрових технологій в управлінні переробкою електронних відходів у містах, у цьому дослідженні досліджуються ключові цифрові технології та обладнання для сприяння управлінню електронними відходами в містах, створення розумної системи переробки та інтелектуальної логістичної системи переробки для е-відходів, на прикладі міста X у Китаї. У цьому дослідженні ми намагаємося запропонувати альтернативу для City X на основі інтелектуальних цифрових технологій, які в основному охоплюють процес збору електронних відходів, інтелектуальну систему логістичної переробки для відстеження та оптимізації логістики переробки електронних відходів, а також інтелектуальну систему переробки електронних відходів. управління запасами, яке може реалізувати цифрове управління електронними відходами. Наші висновки можуть підвищити ефективність переробки міських електронних відходів і стати джерелом для просування розумної міської системи управління електронними відходами.

Ключові слова: *електронні відходи, цифрові технології, управління електронними відходами, розумна система, циркулярна економіка.*

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