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Electronic Waste Collection Incentivization Scheme Based on the Blockchain

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Abstract: The approaches of motivating people for the collection of electronic waste (e-waste) are often insufficient due to inadequate methods of given incentives. Prior research studies have been carried out to tackle the issue of e-waste management in a broad sense. The findings of those studies indicated diverse strategies, each of which is relevant solely to a restricted range of electronic e-waste reprocessing circumstances. The current study has presented a proposed technique for incentivizing tasks and activities associated with the collection of e-waste through the adoption of the vector space technique. The method this research undertakes lies with utilizing blockchain smart contract technology. The reason for selecting this approach lies with the mapping of tasks, the nature of activities, and their magnitude, in order to derived an incentive. While the vector space model defines the set of tasks with their corresponding incentives, blockchain smart contract maps them together and establishes them in a record. Experimental scenarios for the calculation of incentives are presented; the findings reveal that among many scenarios of allocating incentives for e-waste collection, the best case is by utilizing a weighting scale scheme where each task and activity is mapped to its associated incentive rather than providing fixed incentive values. Ethereum was used as a digital token for each unit of incentive. This concept has contributed in encouraging personal accountability in the management of e-waste collection in order to cultivate sustainable behaviors for a long-term solution.

Keywords: incentivization; e-waste; vector space; smart contract

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1. Introduction

The escalating quantity of e-waste and its detrimental effects on both the environment and human health have rendered it a significant worldwide ecological issue. The potential exists for a novel approach to waste management that makes use of an enabling technology such as the blockchain. This might serve as a blueprint for incorporating blockchain technology into an environmentally friendly waste management system, which would help bring about a circular economy [1]. The system might potentially be used as a learning tool with information about e-waste, and to locate the nearest collection point [2]. The implementation of recycling and appropriate disposal methods for e-waste is imperative in promoting sustainable development [3]. To address e-waste, several governments have passed laws requiring the recycling of electronic equipment and promoting environmentally responsible disposal [4]. This includes encouraging electronic device reuse and recycling, requiring producers to properly dispose of their products, and motivating customers to responsibly dispose of their electronic trash. This also includes holding manufacturers accountable for product disposal. Repairing and upgrading gadgets, donating or selling them, and recycling them at licensed facilities can reduce e-waste [5]. Improperly handled and disposed of e-waste may expose the environment to toxic substances.

Conventional methods of incentivizing e-waste collection are frequently inadequate, owing to insufficient incentive calculation techniques and a lack of transparency [6]. The advent of blockchain technology has presented novel opportunities for the implementation of incentivization mechanisms for the purpose of e-waste collection [7]. That is why this paper proposed and evaluated various incentivization schemes that utilize blockchain technology in the context of e-waste collection and assessed their effectiveness. The utilization of blockchain-based incentivization schemes for the collection of e-waste involves the application of blockchain technology, particularly smart contracts, to offer a decentralized and transparent approach to motivating individuals or organizations to gather their e-waste. Numerous research studies have put forth incentivization plans based on blockchain technology for the purpose of e-waste collection [7].

In comparison to conventional incentivization schemes, incentivization schemes based on blockchain technology present a number of benefits. To begin with, the utilization of blockchain technology offers transparency and security, thereby rendering fraudulent activities arduous to perpetrate [8]. Furthermore, the decentralized characteristic of blockchain technology obviates the necessity for central governing bodies, thereby mitigating the potential for malfeasance and deceit [9]. In addition, blockchain-based methodologies offer contemporaneous monitoring of e-waste retrieval and reprocessing, allowing governing bodies to evaluate the efficiency of the initiative and implement requisite modifications [10]. The utilization of blockchain technology in incentivizing e-waste collection has demonstrated encouraging outcomes in enhancing e-waste recycling rates and mitigating the quantity of e-waste that is deposited in landfills [11]. Blockchain technology's transparency and security render it a suitable option for incentivization schemes, while its ability to track in real-time allows authorities to assess the program's efficacy. Subsequent research work should prioritize the assessment of the enduring effects of blockchain-driven incentivization systems for e-waste retrieval, as well as the identification of plausible hindrances to their adoption [7].

One of the feasible attempts for collection of e-waste lies with the principle of extended producer responsibility (EPR). This is a policy approach that holds manufacturers responsible for the safe and legal disposal of their products once they have reached the end of their useful lives [12]. The objective of EPR is to incentivize enterprises to manufacture environmentally sustainable, long-lasting, and reusable goods [13]. An additional objective of EPR is to transfer the economic responsibility of managing waste from the government's budget to other entities [14]. In compliance with the regulations of an EPR program, manufacturers are obligated to collect and appropriately dispose of products that have reached the end of their useful life. The item has the potential to undergo recycling, reutilization, or environmentally sound disposal [15]. Under this plan, manufacturers will receive financial incentives to produce goods that have high rates of recyclability and reusability, and to integrate recycled materials into their products whenever feasible [16]. EPR initiatives can be implemented across various tiers of governance, ranging from the national to the regional and local levels [17]. This initiative represents an important effort aimed at establishing a systematic and clearly defined methodology for the gathering of e-waste. Although an incentive package has been disclosed for the collection of e-waste, regrettably, there is a lack of established techniques to determine the associated incentive for e-waste collection. Hence, the present study deems it imperative to establish a suitable methodology for generating incentives.

Considering this approach, the current research will be contributing in so many ways, but the most crucial contributions will be the following:

- The current research makes a contribution towards the creation of a weighted scoring model that makes use of a vector space method. To be more specific, the representation of an incentive itself is a vector in an n-dimensional space, whereas the representation of each individual task that is connected with an incentive is a wide space within a

vector space. In this case, the number of tasks or components is given by the letter n, and the set of tasks is indicated by the letters A, B, C, D, and E. The importance of the related variable in the task at hand is indicated by the magnitude of each component of the vector.
- During the process of mapping, this research presents a method that proposes assigning obtained values to the various factors that have an effect on the collection of e-waste. Utilizing a numeric scale that is controlled by the central command and control facility for e-waste smart contracts is one way to accomplish the allocation.
- In the course of the research, we developed and put into practice a smart contract for the handling of e-waste, making use of a proposed incentive structure. The system has been successfully deployed, and all of its components are fully functioning; it is now ready to begin operations in real-world environments.

Apart from this section, which expresses the background of the study, Section 2 presents the research-related work. Section 3 discusses the research methodology, as well as the evaluation of the smart contract implementation. Section 4 presents the principal findings and interpretation, and Section 5 present the future research directions and limitations. Section 6 presents the conclusion of the paper.

2. Related Work

The escalating volume of e-waste and its detrimental effects on human health and the environment have rendered it a significant ecological concern. Consequently, research in this domain has gained substantial significance within the research community. In the realm of e-waste management, it is imperative to establish sustainable research solutions for the purpose of managing e-waste. The present paper provides a comprehensive review of the current literature on the management of e-waste through the utilization of blockchain technology. Some of the crucial research in the area has been presented below.

McGrenary [18] proposed a blockchain-based solution for e-waste in the form of satellite recycling consoles placed in public spaces, at which users could trade in obsolete electronics for cryptocurrency. Information entered into the consoles about individual products is recorded in the blockchain ledger, and the digital token's worth is pegged to the expected price of fixing or refurbishing those products. There is less need for recourse to legal mechanisms for dispute resolution because all parties, including the original manufacturer, have visibility into the products' financial and physical outcomes, and the immutability of the record ensures honest transactions in profit sharing. Although McGrenary's [18] study revealed that when their proposed blockchain-based solution for e-waste is utilized, users could trade in e-waste for digital tokens. The study falls short of explaining the specifics of incentives per e-waste trading, such as where and how it occurs. The study does not reveal how the payment would be made, despite the fact that it was successful in having product details recorded in the blockchain ledger, and that the value of the digital token is tied to those products.

In a similar approach, Dua et al. [7] proposed a viable strategy for managing e-waste through the utilization of blockchain technology within the framework of the fifth generation (5G) landscape. The study emphasized the importance of a fundamental concept in the creation of intelligent agreements that are linked to multiple stakeholders participating in the procedure. Therefore, the study recognizes that the integration of all the necessary activities within the smart contract is essential. While the study's findings do emphasize the importance of incentives for e-waste collection, they fall short of describing how those incentives might be distributed. Despite establishing that all e-waste lifecycle details should be recorded in the blockchain ledger, and that the value of the digital token should be tied to the collection of the e-waste, the study does not reveal a mechanism by which the incentive would be allocated.

Chaudhary et al. [19] proposed a range of blockchain-based applications that can be utilized in the waste management industry. These applications enable stakeholders involved in the e-waste chain to monitor and track the movement of e-waste in real-time, thereby highlighting instances of noncompliance with the established regulations for efficient e-waste treatment. Chaudhary et al. [19] neglect to consider the significance of providing incentives for the collection of e-waste. Rather, the focus of the research centers on emphasizing cases of nonadherence to established regulations for effective management of electronic waste.

The research by Sambare et al. [20] demonstrates that dynamic blockchain technology, such as Ethereum, possesses extensive applications across multiple sectors. However, its potential in waste management remains relatively unexplored. Therefore, the study highlights the various opportunities presented by blockchain technology in the effective management of diverse waste categories, including solid waste, e-waste, medical waste, and industrial waste. The work of Sambare et al. [20] underscores the necessity of employing digital tokens in the realm of waste management at large, and that this area of inquiry has yet to be extensively investigated. This study has identified the potential of digital tokens as a means to facilitate the efficient management of various waste categories, including e-waste.

As more and more research is developed concerning the use of blockchain in e-waste management, a blockchain-based smart contract-based approach for e-waste management was proposed by Gupta and Bedi [21]. It is believed that the implementation of smart contracts for e-waste management will enhance coordination among multiple stakeholders in the supply chain. The implementation of this measure would empower the governing body to oversee the management of e-waste, including its collection and recycling. The work of Gupta and Bedi [21] emphasizes the necessity of utilizing blockchain technology, both in a general sense and specifically in the management of the entire collection and recycling process as a unified system. Regrettably, the research seems to be deficient in terms of adequate comprehensiveness. The paper lacks clarity regarding the implementation of the collection and recycling process, and does not address the role of individual efforts in the collection process.

Previous research has brought to light one more justification in favor of utilizing blockchain technology for the management of e-waste. This particular argument, which approaches the topic from a slightly different direction, focuses on the benefits it provides to supply chains and logistics. The utilization of blockchain technology in logistics and supply networks was introduced by Pedrosa and Pau [22]. The paper posited that blockchain technology could potentially address various challenges in supply chain management, including the establishment of a secure and authenticated logistics system, the management of trust issues, and the facilitation of information exchange within supply networks.

As a result of performing this literature analysis, it has become clear that the recent development of blockchain technology has shown promise as a potential long-term solution to the challenge of managing e-waste. Therefore, the implementation of incentivization schemes for e-waste collection is crucial to circumvent traditional incentivization schemes that rely solely on central authorities to administer rewards. In support of this, Sahoo and Halder [23] conducted a study proposing an e-waste management system that utilizes smart contract and blockchain technology. The system is designed to encompass both forward and reverse supply chains. The proposed solution facilitates the comprehensive tracking of the complete life cycles of electronic products, starting from their production phase through their disposal at e-waste centers, and culminating in their reprocessing into raw materials. The authors of the study have identified various challenges and limitations that are currently being encountered by blockchain-based proposals. These include inadequate coverage of the entire life cycle of e-waste, scalability issues, and incentivization concerns.

It is noteworthy to mention that the aforementioned literature [13–23] primarily centers on the management of e-waste. However, the implementation of a specific formal and consistent incentive flow methodology for practical purposes has not been extensively examined. This paper proposes a study on the potential application of blockchain technology for incentivization schemes in e-waste collection. The motivation for this research stems from the successful implementation of similar incentivization schemes in e-waste management, as demonstrated in previous studies [23], and the subsequent works of [24–27]. In light of the data showing that a blockchain-based system that tracks e-products from the time they are first conceived all the way to their eventual decomposition into e-waste, and eventual recycling back into raw materials, generates interactions across numerous organizations [28] in which the risks associated with e-waste are mitigated, and the economy as a whole becomes circular [29]. Considering this, the techniques proposed by the current research aim to enhance e-waste real-time tracking, which would enable authorities to monitor the long-term impact of blockchain-based incentivization schemes on e-waste collection.

3. Methodology

The present study employs the design science research methodology [30,31] as its applicable research methodology. The rationale for implementing this particular methodology is based on the observation that the current state of e-waste collection follows a sequential process that begins with the manufacturer and ends with the consumer. The task at hand pertains to the development and evaluation of the pipeline-process aimed at tackling a strategic e-waste collection initiative. The efficacy of the proposed solution is contingent upon the technique presented, given that the research problem has been identified and expounded upon in Section 1.

3.1. Conceptual Design

The main technique under this current study is the incentivization scheme. The proposed incentivization scheme is founded on the vector space approach and implemented in a blockchain smart contract platform that keeps track of the gathering and recording of e-waste via smart contracts. The smart contract incentivizes both individuals and businesses/agencies for their efforts to collect and organize e-waste. The incentives are dispensed in the configuration of digital tokens, which are exchangeable for commodities or amenities; for this specific case, Ethereum was used. The rationale behind the adoption of Ethereum pertains to the prevalent utilization of its intrinsic digital currency, Ether (ETH), for the purposes of tokenization and crowdfunding. The platform affords developers the opportunity to generate their own tokens and execute initial coin offerings (ICOs) or initial exchange offerings (IEOs) as a means of procuring capital for their initiatives [20].

The operational procedure of e-waste collection operates by having individuals and businesses/agencies alike engaging in the retrieval of e-waste, which can then be transported to designated facilities for proper disposal. The center or controlling unit is responsible for the collection of e-waste, and carries out the process of verifying and weighing said waste. The issuance of incentives/tokens entails the registration of authenticated e-waste in a blockchain system, followed by the allocation of digital tokens to either individuals or enterprises. The number of disbursed tokens is contingent upon the weight of the e-waste associated with the role of collection of the e-waste. The utilization of blockchain technology guarantees both transparency and security, thereby establishing a resilient safeguard against deceitful actions. The platform facilitates real-time monitoring of e-waste collection, thereby enabling authorities to assess the efficacy of the program.

3.1.1. Incentive Generation for the Incentivization Scheme

This study proposes an incentive-based approach that utilizes blockchain technology to precisely monitor the disposal of electronic products, with the aim of mitigating the environmental impact of e-waste. The crucial aspect of the model lies with the incentivization scheme for incentive generation. However, the general approach of the incentive generation model (see Figure 1) dwells on "Role based" as the practical application of the tasks involve.

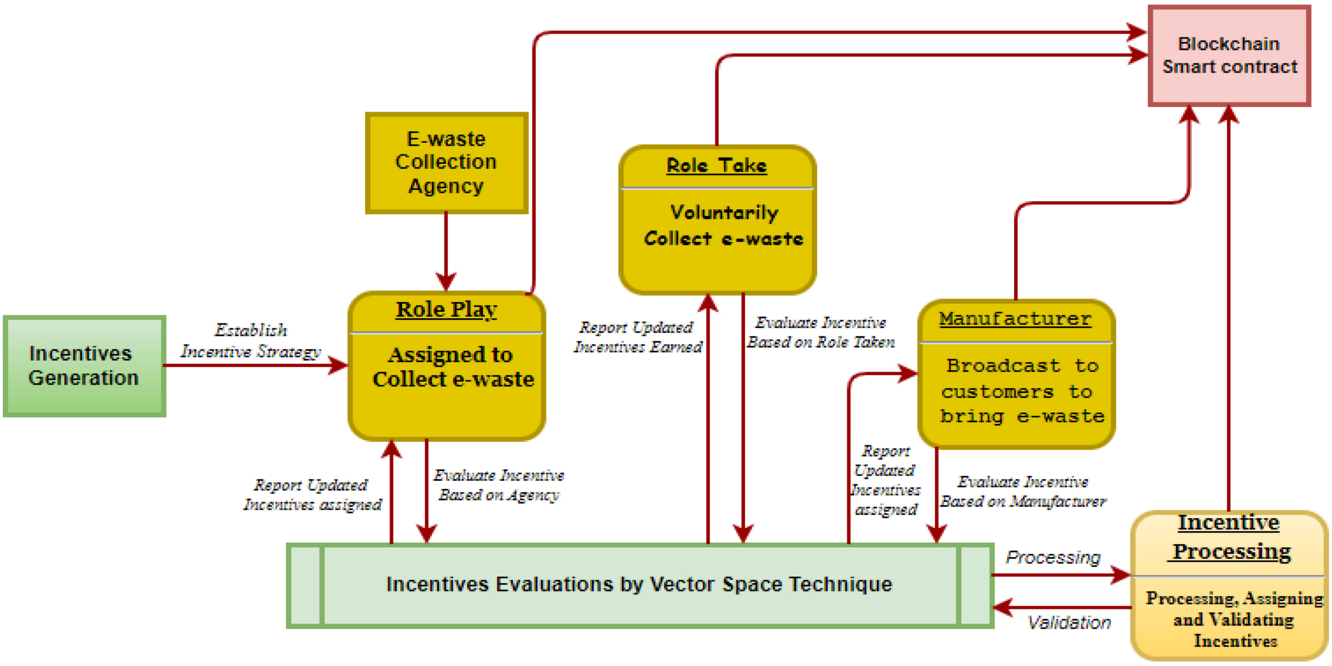

Figure 1. The general approach of incentive generation.

The major component of the concept lies with "E-waste collection agency", "The e-device's manufacturers EPR policy", "The Role-based approach", "The incentive generation", and "Incentive processing". The e-waste collection agency, "The e-waste controlling incentive processing unit", and "the manufacturers of electronic device" are all responsible for defining and assigning tasks for the collection of e-waste. These are all independent bodies, but can coordinate to set out tasks for e-waste collection and assigning incentives.

The term "role-based" is defined operationally as the specific functions and responsibilities of individuals or agencies involved in the collection of e-waste, which can be expressed through either "role-playing" or "role-taking", or a combination of both. The management and monitoring of incentives related to the collection of e-waste can be facilitated through the implementation of keeping the records inspired by blockchain smart contract technology. A reliable tool is typically required for individuals or agencies to effectively gather and monitor e-waste records over an extended period of time. The implementation of blockchain technology has the potential to facilitate the perpetual documentation of this transactional activity, which is linked to incentivization.

The operational definition of "Role-taking" dwells on the voluntary task of organizing and collecting e-waste. This is motivated by the decision to undertake a particular role, which is contingent upon the unique requirements of the individual or the situational context in which it is being assumed. The present research also considers role taking for incentives as the voluntary engagement of an individual in the collection of e-waste. When contemplating incentives, it is crucial to consider the unique preferences and requirements of the individual tasked with performing the activity. The motivational factors of individuals may vary, with some being inclined towards financial incentives, and others being more inclined towards recognition.

Role-playing (assigned task), on the other hand, is also operationally defined as a practice that pertains to the assignment of tasks to individuals or organizations involved in the organizing and collecting of e-waste. The present study also considers "role played for incentives" as the act of an agency which can be a supplier of retailers or an independent agency assigning tasks related to the collection of e-waste, along with its corresponding incentives. Offering incentives for a particular role can aid in aligning individual and organizational objectives, and foster a sense of accountability towards the assigned tasks.

The allocation of tasks for incentivization, as posited by this research, should also fall within the purview of electronic device manufacturers, who may consider implementing relevant policies in this regard. The effectiveness of incentives can also be influenced by the manner in which a task is allocated. Assigning tasks with well-defined expectations and objectives increases the likelihood of successful completion and a positive response to incentives. It is crucial to guarantee that tasks are allocated in a just manner, and that rewards are distributed impartially to prevent any feelings of bitterness or decrease in motivation.

The effectiveness of incentive strategies cannot be determined by a universal formula [32]. However, a thorough analysis of the specific individual, task, and organizational variables involved can facilitate the identification of successful incentive approaches. That is why the processing of incentives in each scenario will vary due to the distinct objectives of the respective tasks. The implementation of a blockchain-based recording and monitoring system involves the assignment of specific roles and corresponding incentives for each task, which are associated with the concepts of role-playing and role-taking. Individuals who assume specific roles and engage in role-playing activities have the potential to effectively gather e-waste materials, and subsequently dispose of them in designated locations. The role of agencies involved in e-waste collection is defined and described as role-playing. Additionally, manufacturers have the ability to establish an EPR policy framework, which designates the responsibility of managing e-waste to the manufacturers of electronic devices.

The integration of the e-waste collection agency, the EPR policy of e-device manufacturers, the role-based approach, the incentive generation, and the incentive processing units collectively provide the necessary information to the blockchain. Each individual block within the blockchain will comprise a set of "data" and its corresponding "hash". The sequence of events pertaining to the collection of e-waste can be compared across all associated tasks.

3.1.2. The Vector Space Incentivization

A vector space is a mathematical structure that consists of a set of vectors and two operations, vector addition and scalar multiplication [33]. Vectors are typically represented as ordered n-tuples of real numbers, where n is the number of dimensions or components in the vector [34]. The operations of vector addition and scalar multiplication allow for the manipulation and combination of vectors, and form the basis for many mathematical concepts and applications [35]. The concept of a vector space is a fundamental one in mathematics, and has many applications in many fields, which is why this study is adopting it for establishing an incentivization scheme. The properties of a vector space are governed by a set of axioms, which specify the behavior of vector addition and scalar multiplication [36]. These axioms include closure under addition and scalar multiplication, distributivity of scalar multiplication over vector addition, and associativity of vector addition and scalar multiplication [37]. Additionally, a vector space must contain a zero vector, which is the additive identity element, and each vector must have an additive inverse. Vector spaces can be finite-dimensional or infinite-dimensional, depending on the number of dimensions or components in the vectors [38]. Finite-dimensional vector spaces are more familiar and easier to visualize, but infinite-dimensional vector spaces have important applications in analysis [39]. The concept of a vector space provides a powerful and flexible framework for representing and manipulating vectors.

In this study, the vectors are conceptual and assigned to be "Incentives", and the space is the "Role-based in collection of e-waste". The incentivization of a vector space is defined by a set of axioms that describe the properties and structure of the space ("Role-based in collection of e-waste"). These axioms further specify the behavior of vector addition and scalar multiplication. Crucial to this is "Closure under vector addition", which dwells on the sum of any two vectors in the space. This goes along with other properties such as "Associativity of vector addition", which describes the various order in which vectors are added. Therefore, it suggests that each way of mapping the incentive and role does not affect the result.

Consider a case where a, b, and c are involved; it would then be a + (b + c) = (a + b) + c and the result will not change. Similarly, a "Commutativity of vector addition" states that the order in which vectors are added does not affect the result; a + b = b + a. The phenomenon also reflects the existence of a zero vector, where a vector in the space is denoted by 0, such that a + 0 = a for all vectors in the space. Another dimension lies with the existence of additive inverses, where for every vector in the space, there is a vector –a in the space, such that a + (−a) = 0.

As was described above, the vector space model can be applied to incentives by representing different types of incentives as vectors in a high-dimensional space. Each dimension in the vector space represents a different attribute or characteristic of the incentive, such as the size, duration, type, and nature of the incentive (see Figure 2).

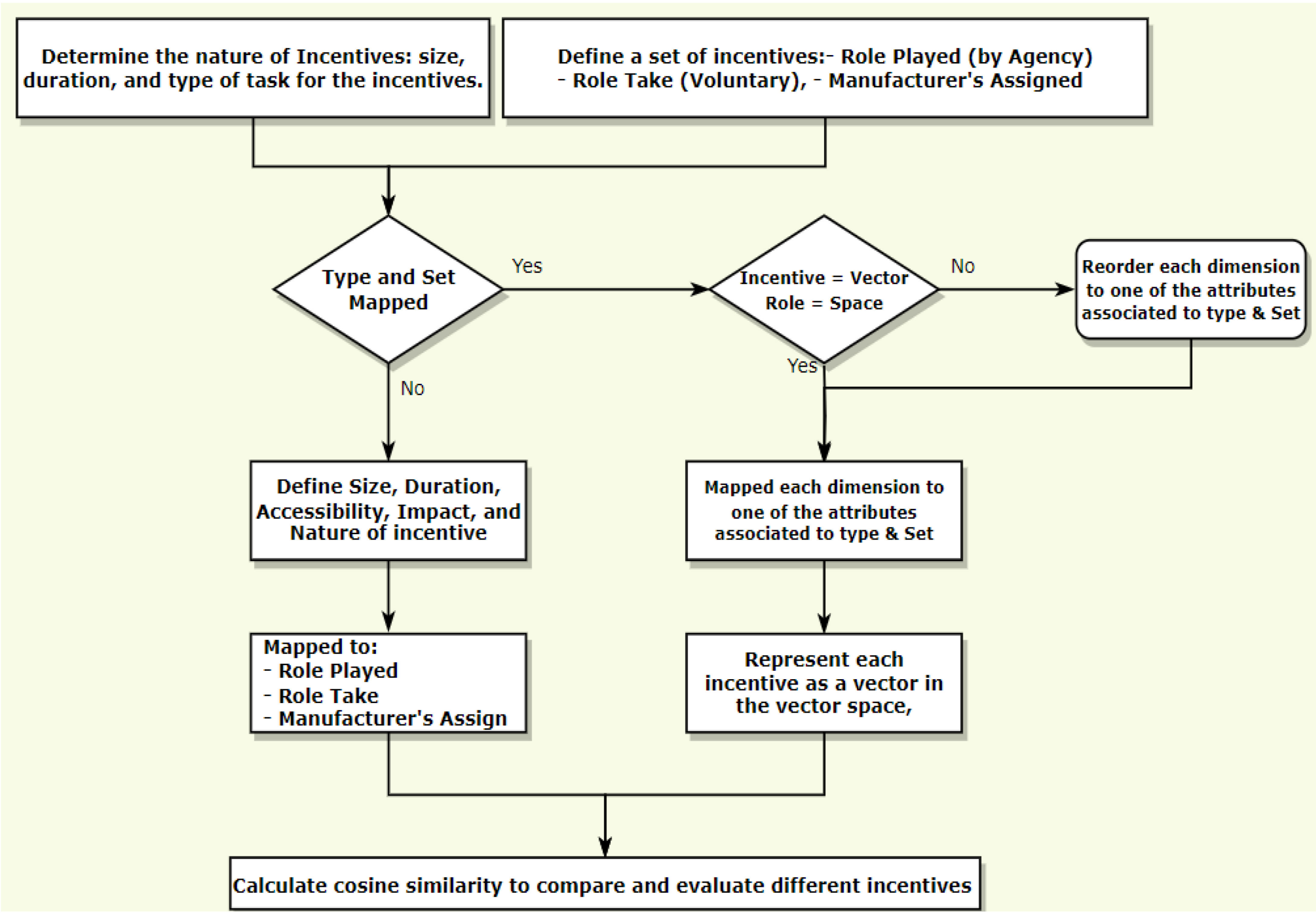

Figure 2. The vector space incentivization process.

The utilization of the vector space model in the context of incentives involves an examination of the characteristics and composition of the incentive structure. This research enables the identification of the nature of incentives and the corresponding set of incentive attributes. The incentives are characterized by tasks that are linked to size, duration, and specific activities. The set of incentives comprises three distinct categories, namely, "incentives associated with role-played", "incentives associated with role-taking", and "incentives associated with assigned tasks". Hence, by delineating the characteristics of the incentives and the prescribed incentives, it is possible to conceptualize vectors of "Incentives" that are linked to the domain of "Role-based in the collection of e-waste".

Therefore, the concept of incentive based on "Size" refers to the quantitative value of the reward or benefit provided, in relation to the magnitude of the tasks accomplished in the process of collecting e-waste. When dealing with substantial assignments, it can be advantageous to divide them into smaller, more feasible components, and provide rewards for accomplishing each component. Maintaining high levels of motivation throughout the process can be beneficial in reducing the perceived magnitude of the overall task.

The incentive structure based on "Duration" pertains to the temporal aspect of e-waste task completion, determining the length of time during which the incentive will remain applicable. Offering time-based incentives for e-waste collection that are time-sensitive can be successful. A bonus or additional recognition could be given, for instance, if the assignment is completed within a specific amount of time.

The categorization of incentives based on "Type" denotes that the reward is contingent upon the completion of a particular category of tasks pertaining to the gathering of e-waste. Incentives can also be tailored to specific activities within a task. For example, if a task involves a lot of exploration of areas in which e-waste could be most available, then offering a per-coverage incentive could be motivating.

The concept of incentives as related to "Accessibility" pertains to the degree of ease with which the incentive can be accessed in relation to the entirety of tasks associated with the collection of e-waste. Tasks that are easily accessible (e.g., can be completed remotely or from home) could be incentivized with flexible work arrangements or other perks.

The present study examines the impact of incentives on the performance of e-waste collection, as indicated by "Impact". This particular scenario facilitates the computation of incentive similarities, thereby enabling the comparison and assessment of diverse incentives. Incentivizing performance can help ensure that tasks are completed to a high standard. This could involve bonuses for achieving certain benchmarks, or recognition for exceptional work.

Upon defining the attributes for each incentive, the subsequent step involves representing each incentive as a vector within the vector space. In this context, each dimension of the vector corresponds to one of the attributes. Each dimension in the vector corresponds to the degree or level of a particular attribute for the incentive.

The utilization of the aforementioned concept can be exemplified through the following scenario. Considering that an incentive is produced by the vector space:

$$[1000, 6, 1, 0.8, 0.5]$$

The aforementioned suggests that the initial dimension denotes the magnitude of the incentive, which is USD 1000. The second dimension pertains to the duration of the incentives, which spans over a period of 6 months. The third dimension signifies the category of incentive, which is either information and communication technology (ICT) and telecommunications e-waste, or household/industrial e-waste, or both, represented by 1, 2, and 3, respectively. The fourth dimension represents the degree of accessibility of e-waste, which is 80%. Lastly, the fifth dimension denotes the anticipated effect of the incentive on performance, which is a 50% increase in the collection. Analogously, additional stimuli may be expressed as vectors in a comparable manner, and similarities between diverse incentives may be computed utilizing a similarity metric, such as cosine similarity. This approach facilitates organizational comparison and evaluation of various incentives, enabling the selection of those that are optimal for both individual and organizational objectives.

The application with regard to mapping the vector space can be specific if all of the tasks involved in the concept are associated with the collection of e-waste; we can assign numeric values to each factor and calculate the output as follows:

- A = 5 (collecting e-waste may require carrying heavy items, so the size of the task is relatively large).
- B = 3 (depending on the location and amount of e-waste, the time required to complete the task may vary, but it is not very time-consuming).
- C = 2 (specific activities may involve sorting and separating different types of e-waste).

- D = 4 (accessibility may vary depending on the location of the e-waste and the means of transportation available).
- E = 4 (performance can be measured by the quantity and quality of e-waste collected).
- F = 2 (incentives can be given based on the size and quantity of e-waste collected).
- G = 3 (individual preferences can be taken into account to some extent, such as assigning tasks to team members based on their physical abilities and interests).
- H = 4 (assigning tasks based on accessibility and quantity of e-waste can result in better incentives).
- We can then use the mapping M to create effective incentive strategies. For example:
- Incentives can be given based on the size (A) and quantity (E) of e-waste collected (F, A and F, E).
- Task assignments can be made based on accessibility (D) and quantity (E) of e-waste (H, D and H, E).
- Individual preferences (G) can be taken into account when assigning specific activities (C) related to e-waste collection.
- Incentives (F) can be given based on the overall performance (E) of the team in collecting e-waste.

The output will depend on the specific values assigned to each factor and the incentive strategies implemented. However, using the concept of vector space allows for effectively mapping incentives to task performance factors, with which we can motivate and reward individuals or teams for collecting e-waste efficiently and effectively.

3.2. The Smart Contract E-Waste Collection Formulations

Smart contracts are self-executing computer codes that conduct specified actions when specific conditions are satisfied in the real world [40]. Smart contracts for e-waste collection will increase coordination among the involved stakeholders. Blockchain and smart contracts make it easier to track the origin and volume of e-waste collected, transported, and reused throughout the process [7]. The justification of adopting smart contracts lies with their ability to set up promises/agreements that are specified in digital form, as well as the protocols that the parties and stakeholders involved in the collection of e-waste will be used to fulfill these promises. Smart contracts can also automate the workflow of the collection of e-waste by initiating the subsequent step when specific criteria are fulfilled.

In general, the formulation of the smart contract technique lies with the initialization of the following:

- The incentives characterized by tasks that are linked to: size, duration, and specific activities.
- The set of incentives under three distinct categories, "incentives associated with role-played", "Incentives associated with role-taking", "Incentives associated with assigned tasks".
- The delineating characteristics of the incentives.
- The prescribed incentives, which are initiated under 3 different initial scenarios.
- Individual (voluntarily).
- Agencies (set tasks).
- Manufacturers (assigned tasks).

The circumstances associated with the flow of the incentivization technique require a set of incentives to be defined and grouped by the roles played, role-taking, and assigned task, as adopted from the vector space technique presented. From Algorithm 1 below: let S be the set of incentives offered, which are grouped by role played, role-taking, and assigned task. The research represents:

S = {x | x is an incentive, grouped by role played, role-taking, or assigned task}.

This can further establish that the subsets of S can be based on the different categories, where for incentives based on role played, it is defined as a subset of S:

S1 = {x ∣ x is an incentive based on the role played}

This expresses the incentives in S1 that are established based on agency defined tasks, which are either exceeding agency collection of e-waste targets, or not. Similarly, for incentives based on role-taking, it is defined as a subset of S where:

S2 = {x ∣ x is an incentive based on willingness to take tasks}

This establishes that incentives in S2 are those associated with anyone who is willing to participate voluntarily in the collecting of e-waste with additional responsibilities, based on consistently demonstrating a willingness to take on new challenges. Finally, for incentives based on assigned task, it can be defined as a subset of S where:

S3 = {x ∣ x is an incentive based on specific tasks assigned by manufacturers}

This is typically in line with EPR policy, where an incentive in S3 might include a reflection of a complete task of collecting e-waste ahead of schedule or under budget, or recognition programs for performing the tasks consistently to deliver high-quality work on assigned tasks.

3.3. The Incentivization of the Smart Contract E-Waste Collection

Incentivization refers to the act of providing a reward for a particular behavior or performing a certain task. This can also be seen as an act of imposing a penalty for the failure to exhibit that behavior or to perform that task [41]. In certain scenarios, incentives can serve as potent instruments for incentivizing individuals or organization to undertake specific actions. On occasion, incentives can have an adverse effect and lead to a reduction in motivation, rather than a boost or an avenue to address this imbalance [42].

This study establishes that utilization of the vector space model in the computation of incentive strategies for performing e-waste collection tasks, taking into account diverse factors such as task magnitude, duration, particular actions, availability, and achievement, is crucial. The justification of this lies with the correlation between the variables associated with the weights for each incentive. Through the application of weightages to the distinct factors associated with each task, a comprehensive incentive score can be computed, thereby facilitating the identification of the optimal incentive approach for each task. This methodology has the potential to assist organizations in optimizing their incentive program, and enhancing the overall performance of their teams.

The presented scenario pertains to the development of an incentive plan for e-waste collection duties, taking into account diverse factors associated with task performance and individual inclinations, as presented in Algorithm 1. The vector space model is utilized to represent various factors associated with task, performance, and incentives, and to determine the significance of each incentive factor by assessing its impact on task completion.

The three distinct tasks that exhibit varying attributes pertaining to dimensions, duration, particular undertakings, availability, and efficacy were initialized in the "Ensure" section of Algorithm 1. The determination of the overall incentive strategy for each task can be achieved by computing the weightage assigned to each incentive factor from line 25 to 35. Line 1 to 24 set out all of the components associated with assigning the weight. This presents potential benefits for entities or groups seeking to encourage the collection of e-waste, and enhances its efficiency by considering various task attributes and personal inclinations.

Algorithm 1: Incentivization

Require: S = *{x | x is an incentive offered*: *grouped by role played, role-taking, or assigned task}*
Ensure: *S1 = {x | x is an incentive based on the role played}*
S2 = {x | x is an incentive based on willingness to take tasks}
S3 = {x | x is an incentive based on the completion of specific tasks or projects}

```
IncentiveSet {
  S1, S2, and S3,
    } // Define the types of incentives
  IncentiveClass {
      size, duration, specific_activities, incentive_type
        } // Define the characteristics of incentives
// Map the set of incentives for each initial scenario
   IncentiveMap {
      Individual: [
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        ...
        ],
      Agencies: [
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        ...
      ],
      Manufacturers: [
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        {size: ... , duration: ... , specific_activities: ... , incentive_type: ... },
        ...
      ]
  }
// Initialize the incentives
function initializeIncentives() {
  for each scenario in IncentiveSet:
    for each incentive in scenario:
      // Define the prescribed incentives for each incentive
      prescribedIncentive = ...
      // Delineate the characteristics of the incentive
      incentive = {size: ... , duration: ... , specific_activities: ... , incentive_type: ... }
    end for
  end for
}
```

3.4. Computing the Incentive Score of E-Waste Collection

Algorithm 2 presents the computation of the incentive scheme for e-waste collection using the vector space model. The initiation of the calculation establishes sets and subsets pertaining to the task associated with the collection of e-waste, specifically those related to task and incentive weights. This is followed by the creation of a mapping mechanism to establish connections between these tasks, and the computation of an incentive score for each task by the assigned weightage for each incentive activity, presented from line 4 to line 8 of Algorithm 2. The solution, which has the potential to be extended to express the incentive score for each task, involves establishing the activities within the tasks and subsequently computing the total incentive score map for each task.

The values assigned to A[i], B[i], C[i], D[i], and E[i] from line 11 to 20 of Algorithm 2 correspond to the respective activity associated with the tasks, which in turn represent the weightages allocated to each activity pertaining to incentives. The determination of these weightages is based on the correlation between the activities related to incentives (F, G, H) and the activities related to task performance (A, B, C, D, E), as presented from line 21 to line 31 of Algorithm 2.

The percentage of task *i* that has been accomplished is determined by the values of A[*i*], B[*i*], C[*i*], D[*i*], and E[*i*], as represented by the task completion percentage. The incentive scores for task *i* have been determined by assigning weightages to each activity associated with incentives. The aggregate incentive score for a given task *i* is determined by adding up the incentive scores associated with each factor that pertains to incentives.

Given a scenario where the sets and subsets for e-waste collection activities are defined as: Set S = {A, B, C, D, E, F, G, H}, Subset T = {A, B, C, D, E} (activities related to tasks).

Subset I = {F, G, H} (dimension of the incentives). Create a mapping M that links the dimension of the incentives in I to the activities related to tasks in T: M = {(f, t) | f ? I, t ? T}.

Assign weightage to each incentive for a certain task: A = 20%, B = 30%, C = 10%, D = 10%, E = 30%. For each task, calculate the incentive score using the mapping and weightage. For each factor f? I: calculate the incentive score for this factor as t * weightage, where t is the value of the corresponding factor in T. Add up the incentive score for all factors f in I to obtain the total incentive score for the task.

Algorithm 2: Computing the incentive score

Require: *a set for each tasks {}*
Ensure: *weighted average assign a score {}*

```
Task_completion_percentage[i] = A[i]*0.2 + B[i]*0.3 + C[i]*0.1 + D[i]*0.1 + E[i]*0.3
  List←K1 ={a | O < O<n}
  //Calculate the incentive score for each factor related to incentives:
  Incentive_score_F_A[i] = F_weightage_A * A[i]
  Incentive_score_F_B[i] = F_weightage_B * B[i]
  Incentive_score_F_C[i] = F_weightage_C * C[i]
  Incentive_score_F_D[i] = F_weightage_D * D[i]
  Incentive_score_F_E[i] = F_weightage_E * E[i]

  //Calculate the total incentive score for each task:
  Total_incentive_score[i] = Incentive_score_F_A[i] + Incentive_score_F_B[i] +
Incentive_score_F_C[i] + Incentive_score_F_D[i] + Incentive_score_F_E[i]
# Define sets and subsets for e-waste collection factors
S = set(['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H'])
T = set(['A', 'B', 'C', 'D', 'E'])
I = set(['F', 'G', 'H'])

# Create a mapping that links factors in I to factors in T
M = {('F', 'A'): 0.2, ('F', 'B'): 0.3, ('F', 'C'): 0.1, ('F', 'D'): 0.1, ('F', 'E'): 0.3,
    ('G', 'A'): None, ('G', 'B'): None, ('G', 'C'): None, ('G', 'D'): None, ('G', 'E'): None,
    ('H', 'A'): None, ('H', 'B'): None, ('H', 'C'): None, ('H', 'D'): None, ('H', 'E'): None}

# Assign weightage to each incentive factor
weightage = {'A': 0.2, 'B': 0.3, 'C': 0.1, 'D': 0.1, 'E': 0.3}

# Define tasks with their corresponding factor values
tasks = {'Task 1': {'A': 50, 'B': 60, 'C': 20, 'D': 10, 'E': 80},
         'Task 2': {'A': 10, 'B': 20, 'C': 60, 'D': 20, 'E': 70},
         'Task 3': {'A': 30, 'B': 40, 'C': 10, 'D': 60, 'E': 40}}
      }
  }
}
```

3.5. Incentivization of the Smart Contract E-Waste Collection

The subsequent operation, which occurs after the formulation of the incentivization strategies, is the implementation of the incentivization. This operation is tied to the actions that take place within the blockchain smart contract. A ledger record based on the smart contracts for all e-waste collection system-related transactions and operations for full auditability is proposed. The smart contract blockchain technology allows for the development of an e-waste collection system that incentivizes both consumers (users) and businesses (agency) to dispose of their e-waste in an eco-friendly manner. This study sets out the operation by first establishing that:

Z = Set of all parties involved in smart contract e-waste collection.

M = Set of parties involved in managing the smart contract.

C = Set of parties involved in the collection of e-waste.

R = Set of parties involved tracking of products in the e-waste.

With the help of these sets, we are able to establish the following roles for the various parties engaged in smart contract e-waste collection:

$$Z = M \cup C \cup R \tag{1}$$

According to Equation (1), the set Z, which denotes all of the participants in the smart contract e-waste collection, is equivalent to the union of the sets M, C, and R. In light of this information, it can be deduced that each and every participant in the smart contract e-waste collection is either a member of the set M, the set C, or the set R. For that reason, the operations of M = {smart contract controlling unit which can be hosted by agencies for e-waste collections or the manufacturers of the e-devices who can also be the smart contract auditor}: this set represents the parties responsible for creating, developing, and auditing the smart contract. Whereas, C = {e-waste, e-waste collectors}: this set represents the parties responsible for the collection of e-waste. Their operation is presented in Algorithm 3 from lines 25 to 47. R = {set of parties involved in tracking of products in the e-waste.}: this set represents the parties responsible for the monitoring of e-waste.

By defining these sets and their elements, we can clearly define the roles for the parties involved in smart contract e-waste collection using mathematical set theory.

3.6. Smart Contract E-Waste Collection Implementation and Deployment

Smart contracts are utilized for the purpose of e-waste collection through the deployment of autonomous computer programs that execute predetermined functions in accordance with pre-established directives. For the execution, significant resources are necessary; however, the general flow process of the implementation is presented in Figure 3. The first stage of the process depicted in Figure 3 consists of the user being given the opportunity to register in order to supply their information, after which a block and an account will be generated for them. The user may fall under the category of individuals who are interested in collecting e-waste, or may hold the position of manufacturer or supplier of the e-devices or retailers. Both of these roles are possible. Other types of applications include operating as a controlling center for e-waste collection. Each of their responsibilities will be defined, and the addresses of their Ethereum wallets will be indexed to those roles. After that, the entirety of the process will proceed according to the cycle shown in Figure 3.

Algorithm 3: Smart Contract E-Waste Collection

Require: *Z = Set of all parties involved in Smart Contract E-Waste Collection.*
Ensure: *M = Set of parties involved in managing the smart contract.*
C = Set of parties involved in the collection of e-waste.
R = Set of parties involved tracking of products in the e-waste.

```
Initialization
    // operation involving the roles for the parties involved
    enum Role {User, Agency, Manufacturer}

    // operation involving the structure of the data
        struct E_Waste {
         address collector;
           uint weight;
        bool isCollected;
    }
Create
        // operation involving mapping to store the E-Waste data
            mapping(address => E_Waste[]) public eWasteCollection;

        // Define the function for the user to submit their e-waste for collection
                function submitEWaste(uint weight) public {
                    // Add the e-waste to the user's collection list
                        eWasteCollection[msg.sender].push(E_Waste({
                            collector: msg.sender,
                        weight: weight,
                isCollected: false
                }));
        }

        // Define the function for the agency to assign collectors for e-waste collection
            function assignCollector(address user, uint index, address collector) public {
                // Ensure that only agencies can call this function
                    require(msg.sender == Role.Agency);
                        // Get the user's e-waste at the specified index
                            E_Waste storage eWaste = eWasteCollection[user][index];
                        // Ensure that the e-waste is not already collected
                            require(!eWaste.isCollected);
                // Assign the specified collector to the e-waste
                    eWaste.collector = collector;
            }

        // Define the function for the manufacturer to collect e-waste they produced
            function collectManufacturerEWaste() public {
                // Ensure that only manufacturers can call this function
                    require(msg.sender == Role.Manufacturer);
                    // Collect all e-waste produced by the manufacturer
                        for (uint i = 0; i < eWasteCollection[msg.sender].length; i++) {
                            E_Waste storage eWaste = eWasteCollection[msg.sender][i];
                        if (!eWaste.isCollected) {
                            eWaste.collector = msg.sender;
                                eWaste.isCollected = true;
    }    }    }
```

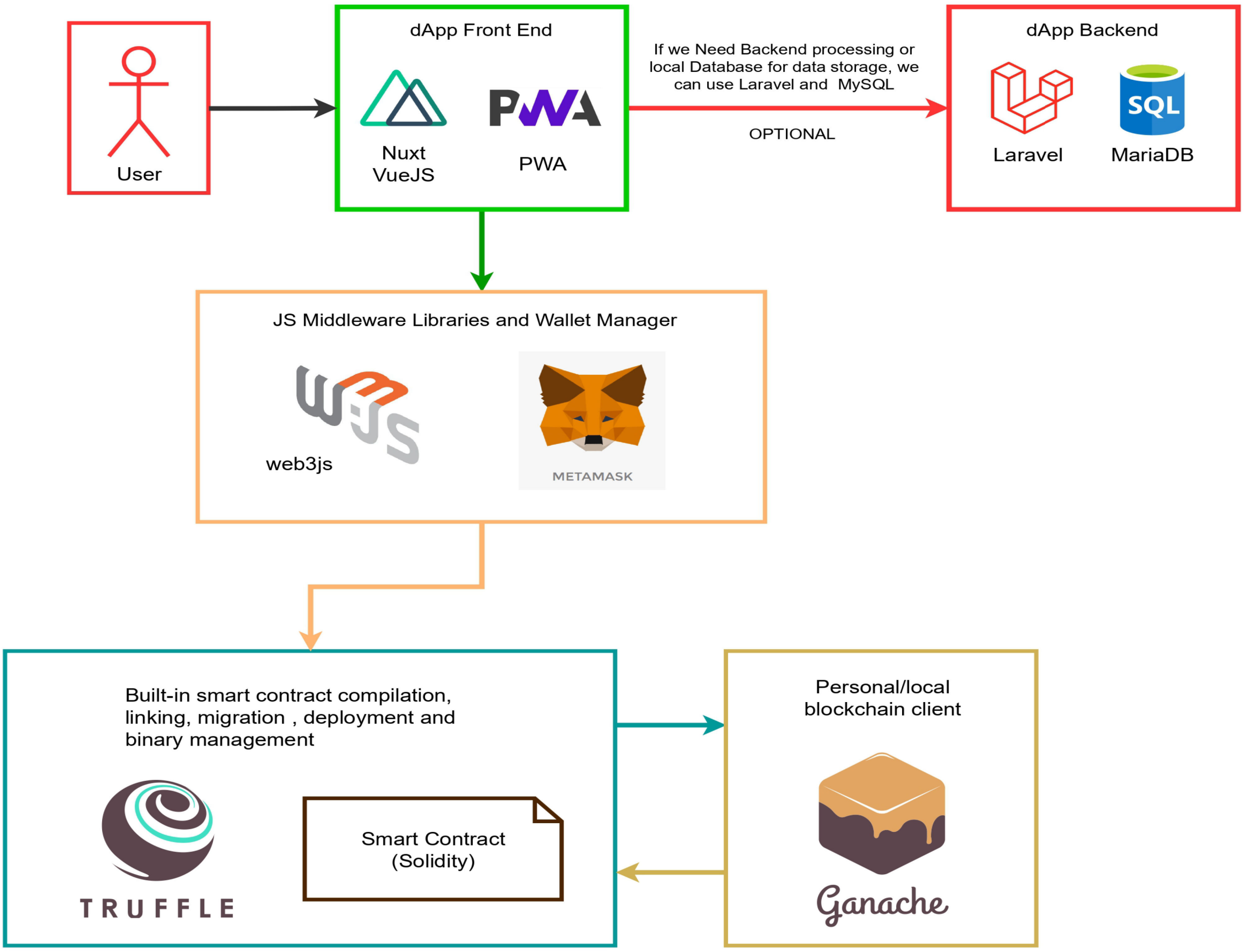

Figure 3. Smart contract e-waste collection implementation and deployment.

One of the crucial tools used in the development is Truffle. Truffle is an application framework for creating DApps on the Ethereum blockchain [43]. ConsenSys developed it and introduced it to the public in 2015. Truffle offers a set of tools that streamline the creation of a working smart contract, from compilation to deployment to testing. The Solidity programming language is used to create smart contracts on the Ethereum blockchain, and Truffle was built to be compatible with it [44]. Smart contracts may be easily created, compiled, and deployed thanks to the integrated development environment. Additionally, automated tests for smart contracts can be written quickly and easily thanks to Truffle's integrated testing infrastructure. Truffle's many plugins and connectors make it simple to use with other tools and frameworks in the Ethereum ecosystem [45], in addition to its basic functionality. It is compatible with a wide range of front-end frameworks, including React and Angular, and widely used Ethereum client libraries such as Ganache. Truffle is an excellent resource for Ethereum programmers since it provides both a user-friendly environment for coding, and a set of potent tools that make it simpler to create decentralized applications (DApps) on the Ethereum network.

To those familiar with Ethereum and its associated smart contracts, a remix is a web-based integrated development environment (IDE) for developing, testing, and deploying these contracts on the Ethereum blockchain. Remix is a web-based open-source tool that offers a suite of tools to simplify the development and testing of smart contracts [46]. Remix provides a simple environment in which to write Solidity code, the language used to generate smart contracts on the Ethereum network. In addition, it has a testing framework for automating the execution of unit tests and integration tests on smart contracts, as well as a compiler for compiling and debugging Solidity code. Remix also has a number of plugins and connections with other tools and services, such as MetaMask for handling Ethereum accounts and dealing with the blockchain, and the Swarm network for hosting and distributing decentralized applications (DApps). Remix has become an integral part of the Ethereum development ecosystem because it is a robust and adaptable tool for creating and deploying smart contracts on the Ethereum blockchain.

For those working with Ethereum, Ganache provides a local blockchain environment that may be used to simulate how a network operates [47]. Developers can test and deploy their smart contracts locally on this network without ever connecting to the main Ethereum network. In order to execute smart contracts on the Ethereum network, Ganache is constructed on top of the Ethereum virtual machine (EVM). Whenever Ganache is launched, it will generate an instance of a blockchain to operate locally. This blockchain has the same characteristics as the public Ethereum blockchain, but it is localized to your computer only. Creators of applications can use Ganache to set up user accounts, mine blocks, and release smart contracts. The blockchain's transaction logs, network utilization, and contract events may all be viewed in real-time via the user interface (UI). The ability to simulate network conditions such as latency and packet loss, as well as manipulating time and block numbers, are just a few of Ganache's many helpful capabilities for testing and debugging smart contracts. Overall, Ganache is a potent tool for Ethereum development, providing a secure and safe environment for developers to swiftly prototype and test new versions of smart contracts and applications.

3.7. Evaluation of the Smart Contract Implementation

After the smart contract has been deployed, its implementation consists of launching the program. The application is ready and now available. Figure 4 depicts the first launch surface that employs both MetaMask and CORS to enable users to register for a particular account. The MetaMask wallet can connect to the Ethereum blockchain, and the CORS protocol defines the protocol used between a web browser and a server to determine if a cross-origin request is allowed. As shown in Figure 4, the menu provides access to the numerous e-waste programs currently in operation. The "Account Details" for each account will be displayed once it has been launched, as depicted in Figure 4′s right-hand side. The smart contract can generate an entirely new account.

The electronic e-waste data is collected from every manufacturer and then linked to the e-waste's details. The process of tracking the data that records transactions for the entire system begins once all e-waste details are added to the smart contract and registered. The smart contract platform allows its users to monitor system updates in real time. After a successful signup, a new account record will be created in the database using the user's MetaMask wallet address and the details supplied by the user. However, when a user tries to have a next login after the initial creation of account, the DApp website verifies the user's identity using the wallet address obtained via MetaMask submitted during registration. Users without the manufacturer role in the system are unable to access the "Registered e-waste" details, which is used to add new items to the block.

In order to clear the implementation, the MetaMask-imported key will be utilized, the password will be furnished, and the user will be prompted to verify their selection in the MetaMask dialogue box. Both of these actions will be executed subsequent to the user receiving a prompt to perform them.

The manufacturer's account will enable the inclusion of new e-waste into the smart contract. Upon completion of the processing, the relevant information will be appended to the manufacturer's account, thereby enabling the manufacturer to subsequently access the account by logging in.

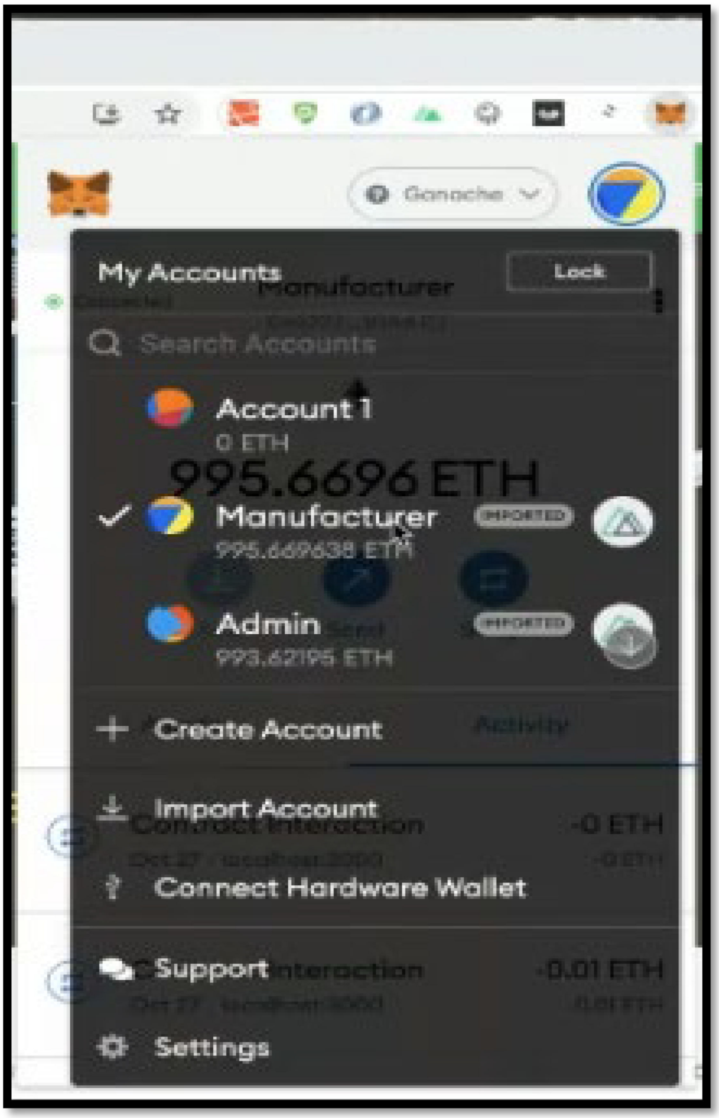

Figure 4. Smart contract account access and creation.

The term "Product" is utilized to denote e-waste in the domain of smart contracts. The manufacturer's products, denoted by the "my product" icon, will exhibit the specific product that has been registered on the website. The manufacturing enterprise's capacity to generate a wide array of commodities is reflected in the inventory of said commodities available in their account.

By means of the e-waste collection system, users can submit a request to exchange their e-waste with another user. In order to proceed with this step, it is necessary to have access to the wallet addresses of both the user and the recipient, the precise time at which the transfer occurred, the product identification number, as well as the initial time of the contractual agreement.

Accepting calls for transfer is requisite for the contract. The individual who initiates the contractual agreement bears the responsibility of transferring their Ethereum cryptocurrency to the designated wallet linked to the contract. Upon the delivery of the product to an e-waste management facility, the individual who initiated the transaction will receive the Ethereum cryptocurrency back into their digital wallet. Simultaneously, it initiates the procedures intended to notify the receiver that the transfer process has been initiated.

Upon the introduction of a new product by a company, it shall be featured in the "create new product" section, which is denoted by an associated icon. Upon inputting the designated wallet address as the recipient of a transfer, the user will receive a prompt requesting their confirmation of the acceptance of the funds.

The process of utilizing a smart contract's transfer function once it has been called. The act of acquiring permission and then exercising the ownership function leads to the production of a new item in the track data structure. This entry helps to log the transfer of ownership, and is a result of the action of exercising the ownership function.

The forthcoming occurrences include the verification of the enrollment of a new manufacturer and the commencement of wallet production. The aforementioned statement is succeeded by multiple sequences of operations. The critical factor pertains to the sequence of occurrences that commences with a new producer, and progresses through intermediaries, vendors, and ultimately consumers.

The transaction menu displays comprehensive information regarding all transactions that have taken place between the manufacturer and the supplier. Consequently, the aforementioned components comprise "Product Transfers In", "Product Transfer Out", "Attempt Login Logs", "Your transfer Amount to E-waste", and the "My Incentive List". Ultimately, the user must navigate to the product list, select a product, and subsequently click on it in order to finalize the transfer. Upon defining the supplier's address in MetaMask, users are now required to obtain the supplier's address in order to transfer ownership of the product.

After obtaining the supplier's address, the user will input said address along with the initial locked amount of cryptocurrency held in a smart contract. The user will then proceed to select the transaction type, which in this instance is a transfer from the manufacturer to the supplier. Subsequently, commence the procedure of transferring possession of the item from the manufacturer to the supplier by selecting the "confirm" option to initiate the transfer of ownership from the former to the latter. Thereafter, await the supplier's acceptance of the transfer.

The requisite knowledge pertaining to the procedural aspects of transferring ownership of a product from the producer to the vendor, subsequent to the confirmation of the transaction, is deemed essential at this stage.

It is necessary for the supplier to first accept the transfer before beginning the process of transferring the funds to the retailer. In the supplier's account, at the supplier login interface, since the supplier is already registered, it can provide the login details. The supplier should provide the password and confirm login into the account.

i. The summary of the events at the Manufacturer Scenery.
ii. Display "My Product" menu and list of products.
iii. Display "Create New Product" icon.
iv. Display upcoming events: registration of a new manufacturer and production of a wallet.
v. Display the chain of events starting from a new manufacturer and ending with customers.
vi. Display the transaction menu with details of all transactions.
vii. Transfer ownership from manufacturer to supplier:
    a. Navigate to "My Product" list.
    b. Choose a product and click on it.
    c. Get the address of the supplier.
    d. Insert the supplier's address, initial locked amount, and select the transaction type as transfer from the manufacturer to the supplier.
    e. Click "Confirm" to initiate the transfer of ownership from the manufacturer to the supplier.
    f. Wait for the supplier to accept the transfer.
    g. Log the details of the transaction.

The agencies that are involve in the collection of e-waste are referred to as "Suppliers" and "Retailers" in this current study. Under the guise of role-playing as described in Section 3.1.2 and in Figure 1, either "Suppliers" or "Retailers" can propose the task of collecting e-waste. Table 1 present the summary of the event activities.

Table 1. Summary of the smart contract event activities.

Agency 1 (Supplier)	Agency 2 (Retailer)
Login with login details	Login with login details
Display "My Product" menu and check for pending products	Display "My Product" menu and check for pending products
Confirm acceptance of the pending product	Accept the pending product
Hand over ownership of the product to the retailer:	Transfer ownership of the product to the customer:
a. Navigate to "My Product" list	a. Navigate to "My Product" list
b. Choose the product and click on it	b. Choose the product and click on it
c. Get the address of the retailer	c. Get the address of the customer
d. Insert the retailer's address	d. Insert the customer's address
e. Click "Confirm" to initiate the transfer of ownership from the supplier to the retailer	e. Click "Confirm" to initiate the transfer of ownership from the retailer to the customer
f. Wait for the retailer to accept the transfer	f. Verify the transaction details

In the context of this research, "any individual" or "person" that is actively engaged in collecting e-waste is referred to as the customer who participates in e-waste collection. As presented in Section 3.1.2 and Figure 1, this falls under the category of "role taking", that is, someone that voluntarily collects e-waste. Their smart contract state is therefore summarized here, along with a summary of the events that have occurred.

Login with login details.

Transfer the product to a customer or e-waste center:

a. If transferring to e-waste center:
    i. Select "Customer to Waste Center".
    ii. Proceed to login with admin login details.
b. If transferring to another customer:
    i. Get the address of the customer.
    ii. Insert the customer's address.
    iii. Click "Confirm" to initiate the transfer of ownership from the customer to the other customer.
    iv. Verify the transaction details.

From the smart contract's perspective, the admin is the "controller" who is responsible for ensuring that all e-waste collecting activities are carried out as agreed upon. The administrator is responsible for the processing unit and the distribution of associated incentives. As such, the following is a summary of the events leading up to the present status of the admin smart contract:

Login with admin login details.

Display the options available at the e-waste center:

a. Participants.
    i. All Participants in a Normal view.
    ii. All Participants in a Stacked view.
b. All Registered Product in a Normal view.
c. Detail of a Single Registered Product in a Normal view.
d. Detail of a Single Tracked Product.
e. Sending Reminder.
f. Confirmed the Product that reached E-waste canter.
g. Need Confirmation.
    i. Display products that need confirmation.
    ii. Confirm the product that reached the e-waste canter.
h. Log the details of the transaction.

Upon arrival at the e-waste center, a product undergoes a confirmation process, during which all transaction details are updated. Following this, the smart contract is triggered to initiate the acceptance process of the product at the e-waste center. The next is the most important stage that involve assigning the incentives associated with the tasks (see Figure 5).

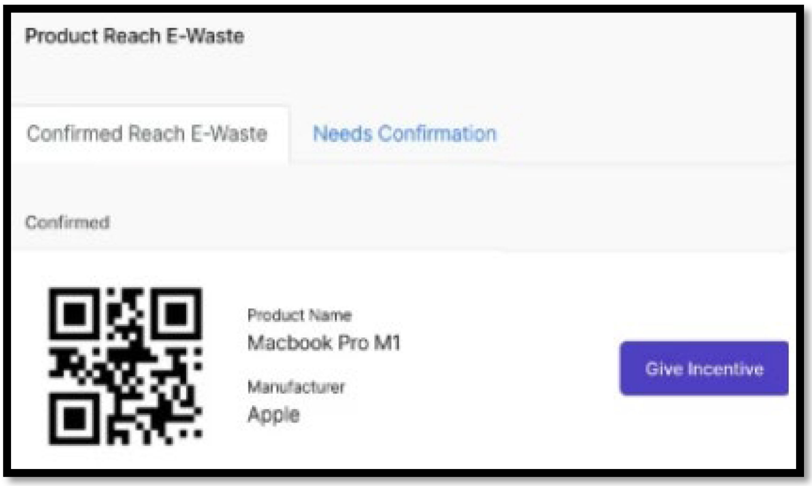

Figure 5. Smart contract incentive initiation.

Associate incentives will be given out based on the product that is ultimately validated at the e-waste center (see Figure 6). Until the item is delivered to the e-waste command center, the incentive will not be activated. It is handed to everyone, from the manufacturer to the agencies and individuals involved in the execution of the task. The incentivized function of the smart contract is invoked from within, resulting in the transfer of the appropriate amount of Ethereum to the wallets linked with the accounts of all of those entities. All parties whose product transfers were hampered due to the Ethereum in the agreement are likewise released.

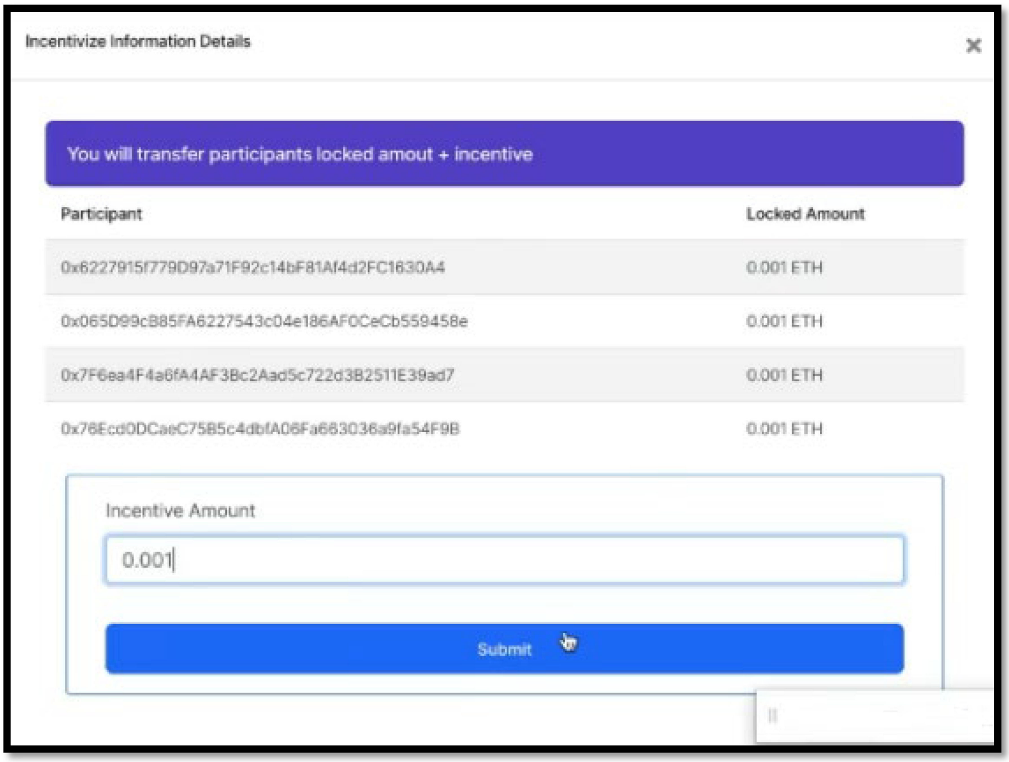

Figure 6. The product that is confirmed at the e-waste center and the collection of incentive.

The smart contract can only be accessed through the unique admin account, which also serves as the contract's creator. The administrator has access to all product records and can follow the product's ownership chain from its creator to the present day. The administrator can also discover the whereabouts of any out-of-date products that have not been brought to the e-waste center, and provide that information to the current owner.

4. Principal Findings and Interpretation

In light of the growing environmental impact of e-waste, there has been a surge in interest in the collection and monitoring of such waste. As a result, this study seeks to conduct an empirical investigation into the incentivization scheme for e-waste collection, utilizing the Blockchain as a basis for analysis. This scheme's objective is to incentivize individuals and organizations to gather e-waste by providing digital tokens as a reward.

Figure 7 presents the potential results of incentives that may be taken into account for various scenarios. The allocation of numerical values in a particular scenario, wherein the factors influencing the concept to be incorporated in the smart contract, is contingent upon the specific context and objectives of the e-waste collection undertaking. The present study's implications pertain to a scenario wherein a group of ten individuals are assigned to gather e-waste from a residential locality. The team shall receive a predetermined set of assignments to accomplish within a specified duration, and the achievement of each task shall be evaluated as a proportion. The system registration process is carried out by the e-waste smart contract controller/administrator. Subsequently, the procedure will be executed in the following manner:

A = Size of performing task: the size of each task can range from small (1%) to large (10%). We can assume an average task size of 5%, so A = 5.

B = Time for performing task: each task will have a specific time limit for completion. The time for a task can range from short (5 min) to long (1 h). We can assume an average time of 30 min, so B = 5. C = Specific activities of a task: the specific activities involved in each task can be categorized as easy (1%) or difficult (5%). We can assume an average difficulty of 3%, so C = 3.

D = Accessibility of the task: the accessibility of each task can range from easy (1%) to difficult (5%). We can assume an average accessibility of 2%, so D = 2.

E = Performance of a task: the performance of each task can range from poor (50%) to excellent (100%). We can assume an average performance of 80%, so E = 80.

F = Role played for incentives: the role played by each team member in the incentive program can be categorized as low (1%) or high (5%). We can assume an average role of 3%, so F = 3.

G = Role taking for incentives: the role taken by each team member in the incentive program can range from low (1%) to high (5%). We can assume an average role of 2%, so G = 2.

H = Assigning a task for incentives: the assignment of each task for better incentives can range from low (1%) to high (5%). We can assume an average assignment of 4%, so H = 4.

Figure 7. The different types of incentives associated by function.

To create effective incentive strategies, we need to map the factors related to incentives (F, G, H) to factors related to task performance (A, B, C, D, E), based on the mapping M. This is the direct vector space implementation. Furthermore, we can use a weighted average to assign a score to each mapping, where the weight of each factor is based on its relative importance. For example, we can assign a weight of 30% to A, 20% to B, 20% to C, 15% to D, and 15% to E. Then, we can calculate the score for each mapping as follows:

$$(F, A) ? 0.3 * 5 + 0.2 * 5 + 0.2 * 3 + 0.15 * 2 + 0.15 * 80 = 19.55\%$$

$$(F, B) ? 0.3 * 5 + 0.2 * 5 + 0.2 * 3 + 0.15 * 2 + 0.15 * 80 = 19.55\%$$

$$(F, C) ? 0.3 * 5 + 0.2 * 5 + 0.2 * 3 + 0.15 * 2 + 0.15 * 80 = 19.55\% \ldots$$

The provided mappings can also offer a structure for computing the incentive rewards for task completion, taking into account various variables. The mapping (F, A) offers incentives that are contingent on the magnitude of the task, whereby a smaller task is associated with a 25% incentive, a moderate task is associated with a 50% incentive, and a substantial task is associated with a 100% incentive. The mapping (G, E) offers incentives that are contingent upon individual task performance preferences. Specifically, suboptimal performance is associated with a 25% incentive, average performance is associated with a 50% incentive, and exceptional performance is associated with a 100% incentive.

The mappings have the potential to allocate tasks based on various factors such as magnitude, duration, particular undertakings, and convenience, and subsequently offer appropriate rewards. As an illustration, the allocation of a minor assignment that is readily accessible and comprises straightforward activities could potentially yield a 25% incentive, whereas a major assignment that is challenging to access and involves intricate activities could potentially yield a 100% incentive.

This follows the proposed vector space technique; the mappings offer a methodical strategy for providing incentives for tasks and considering various factors that could impact task execution and drive. Note: in Figure 7 and Tables 2 and 3, the following applies: A = size of performing task; B = time for performing task; C = specific activities of a task; D = accessibility of the task; E = performance of a task; F = role played for incentives; G = role taking for incentives; H = assigning a task for incentives.

Table 2. Assigned incentive values and their description.

Mapping Factor	Description	Assigned Value
F, A	Incentives based on the size of the task	7
F, B	Incentives based on the time for performing the task	9
F, C	Incentives based on specific activities within the task	8
F, D	Incentives based on the accessibility of the task	6
F, E	Incentives based on the performance of the task	10
G, A	Taking into account individual preferences for task size	7
G, B	Taking into account individual preferences for task time	6
G, C	Taking into account individual preferences for specific activities	8
G, D	Taking into account individual preferences for task accessibility	5
G, E	Taking into account individual preferences for task performance	9
H, A	Assigning tasks based on size for better incentives	6
H, B	Assigning tasks based on time for better incentives	8
H, C	Assigning tasks based on specific activities for better incentives	7
H, D	Assigning tasks based on accessibility for better incentives	5
H, E	Assigning tasks based on performance for better incentives	9

Table 3. The incentive calculation weight and the resulting incentive value.

Factor	Assigned Value	Incentive Weight	Incentive (F(Factor))
A	8	3(8)	24
B	5	3(5)	15
C	7	3(7)	21
D	6	3(6)	18
E	9	3(9)	27
F	3	N/A	N/A
G	2	N/A	N/A
H	4	N/A	N/A
Total			105

Based on Algorithm 2, Table 2 provides a thorough list of the mapping factors, together with the values that have been allocated to them, and an explanation of each mapping factor. It is not the behavior of the individual that is measured, it is the tasks that are measured. The mapping demonstrates how each aspect pertaining to incentives (F, G, and H) can be linked to mapping factors pertaining to task performance (A, B, C, D, and E) in order to develop effective incentive systems.

Table 3 present the incentive calculation weight, and the resulting incentive value for each factor. The notation "N/A" denotes the absence of an incentive calculation formula for factors F, G, and H, as they do not exert a direct influence on task performance. The aggregate value of incentives is determined by adding up the individual incentives for each factor, resulting in a total of 105 in this instance. The tabular representation offers a lucid and succinct approach to illustrating the data and computations presented in the initial inquiry.

Similarly, assuming that a task is executed with complete efficiency, whereby all facets of the task are executed flawlessly, a score of 10 will be awarded for each element. Conversely, if a task is not executed at all, a score of 0 will be granted for each element (see Table 4). The allocation of values to the various factors in the mapping process can be achieved by utilizing the previously mentioned scale, and is solely the responsibility of the e-waste smart contract controlling center.

Table 4. Key comparisons addressing the application of blockchain technology to e-waste management.

Author(s)	Objective	Platform of Implementation	E-Waste Management	Incentives	Key Finding
McGrenary [16]	Develop blockchain-based solution for e-waste	Blockchain ledger	Trade in e-waste for digital	Not proposed	Blockchain-based solution for e-waste
Dua et al. [7]	Utilized (5G) and blockchain technology for e-waste	Smart contract	Multiple stakeholders participating	Proposed but not assigned	Smart contract's incentive function established
Chaudhary et al. [19]	Develop blockchain-based waste management for industry	Smart contract	Monitor and track the movement of e-waste in real-time	Not proposed	Noncompliance with the established regulations for efficient e-waste treatment can be tracked
Sambare et al. [20]	Survey waste management using blockchain	Blockchain	Waste management in general	Not utilized by many researchers	Ethereum is best across multiple sectors of waste management
Bedi [21]	The use of blockchain in e-waste management	Smart contracts	Collection and recycling	Not proposed	Enhanced coordination among multiple stakeholders in the supply chain of e-waste
Sahoo and Halder [23]	Developed an e-waste management system	Smart contract	Life cycles of electronic products	Not proposed	Tracking of the complete life cycles of electronic products

Table 4 provides a condensed summary of some important previous research studies regarding the use of blockchain technology in the context of the management of electronic waste. The utilization of blockchain technology in e-waste management and the development of various incentivization approaches have both been investigated based on the existing research that is available in the public domain. To the best of our knowledge, we could not find prior research that has developed a technique for assigning incentives to e-waste collection. Dua et al. [7] proposed the implementation of incentives, but did not provide any provision on how the incentive would be assigned.

5. Future Research Directions and Limitations

The results of this study have the potential to guide future studies in the development of incentive structures that promote user engagement and facilitate modifications in behavior. Comprehending the incentives, inclinations, and attitudes of users can facilitate the creation of efficacious incentive structures, such as token-based frameworks that encourage individuals and enterprises to engage in the gathering of e-waste. Notwithstanding the findings of the present study, which suggest that blockchain-based incentive mechanisms for e-waste collection may provide a viable solution, it is imperative to take into account the future research avenues and constraints identified in this paper. One of the key areas for future research pertains to the scalability of blockchain-based incentive programs in order to effectively manage the increasing amount of electronic waste being produced. It is recommended that forthcoming research give precedence to scalable blockchain architectures that possess the ability to manage significant quantities of e-waste collection and incentive programs across multiple dimensions.

Another implications of the findings for future research and potential applications dwells on the optimization of e-waste collection operations to heavily rely on the interoperability of blockchain networks and platforms. Effective implementation of an e-waste collection incentive program requires well-defined governance structures and regulations. The widespread adoption of blockchain-based systems necessitates the consideration of various legal and regulatory frameworks, including but not limited to liability, responsibility, and data privacy. Therefore, future research should evaluate the variables that will influence the adoption of blockchain-based incentive mechanisms for the collection of e-waste. Future research should also investigate the affective and behavioral responses of individuals towards e-waste collection initiatives that employ blockchain technology. This approach has the potential to enhance the design of incentives that effectively incentivize individuals to participate and modify their conduct.

Some limitations of the current study lie with the efficacy of e-waste collection incentives in guaranteeing the appropriate use for its management. Thus, it is imperative that forthcoming research endeavors to explore techniques for incorporating the complete value chain, spanning from the collection phase to the recycling phase. Although the implementation of blockchain-based e-waste collection incentivization schemes exhibits potential, several obstacles must be addressed before achieving widespread adoption and optimal utilization. The concerns encompass matters such as scalability, interoperability, governance, user conduct, plausible constraints, and so many others.

In general, the capital procured via an initial coin offering (ICO) is predominantly allocated toward the advancement of the project and essential business activities. Nonetheless, a limitation or constraint of this research is the intended utilization of the ETH procured via the ICO as the primary incentive distribution. In order to ensure the ongoing sustainability of the incentive pool, it may be necessary to introduce an alternative digital token in the event that the allocated ETH from the initial coin offering is exhausted or depleted. This measure would enable the continued allocation of incentives, as the present study has established a framework for such allocation.

An additional limitation of this research pertains to the requirement of adhering to guidelines for the creation of new tokens utilizing the ERC20 protocol in an alternative scenario. Henceforth, it is recommended that forthcoming research or future research should focus on devising a systematic approach to establish regulations pertaining to the generation of the tokens.

6. Conclusions

This study has demonstrated that the utilization of case-based scenarios and a weighting scale scheme to determine incentives for e-waste collection represents a potentially effective strategy for the management of e-waste. The findings of this study indicate that the incentive structure for e-waste collection is not uniform, but rather determined by a weighting scale that considers the various tasks and activities associated with the collection process. The aforementioned methodology could potentially offer a more intricate and adaptable means of motivating the gathering of e-waste, as it has the capacity to account for the diverse levels of exertion and intricacy associated with distinct facets of the collection procedure. The method proposed for computing incentives for e-waste collection, which involves tailoring the approach to individual cases and incorporating a system of task and activity weighting, holds significant importance for a number of reasons. The present study demonstrates that the aforementioned approach acknowledges the intricate and fluctuating nature of e-waste collection endeavors. The process of collecting e-waste encompasses a variety of undertakings and operations, including but not limited to categorization, conveyance, and elimination, each of which presents distinct obstacles and prerequisites. The utilization of a case-based scenario methodology allows for the customization of incentive calculations to suit the particular conditions of the collection endeavor. This ensures that the incentives are equitable, and precisely correspond to the exertion and resources demanded. Moreover, the utilization of a weighting scale system facilitates a more intricate computation of motivators. The utilization of fixed-value incentives may result in an inaccurate representation of the worth of various tasks and activities, potentially resulting in unjust remuneration for individuals engaged in e-waste collection. Through the allocation of a weight or value to individual tasks, the calculation of incentives can be customized to the precise demands of each task, thereby guaranteeing equitable remuneration for those engaged in the collection of e-waste. The present study applies this methodology in practical contexts, utilizing blockchain smart contracts and creating an app to establish unambiguous protocols and processes for distributing rewards according to case-specific circumstances and a system of weighted scales. The effective implementation of the new approach towards e-waste collection will necessitate adequate training and support for the individuals involved, to ensure their comprehension and proficiency in its application.

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