Intelligent Automation & Soft Computing
DOI: 10.32604/iasc.2023.033879
Article

Tech Science Press

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Bayes-Q-Learning Algorithm in Edge Computing for Waste Tracking

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Received: 30 June 2022; Accepted: 14 October 2022

Abstract: The major environmental hazard in this pandemic is the unhygienic disposal of medical waste. Medical wastage is not properly managed it will become a hazard to the environment and humans. Managing medical wastage is a major issue in the city, municipalities in the aspects of the environment, and logistics. An efficient supply chain with edge computing technology is used in managing medical waste. The supply chain operations include processing of waste collection, transportation, and disposal of waste. Many research works have been applied to improve the management of wastage. The main issues in the existing techniques are ineffective and expensive and centralized edge computing which leads to failure in providing security, trustworthiness, and transparency. To overcome these issues, in this paper we implement an efficient Naive Bayes classifier algorithm and Q-Learning algorithm in decentralized edge computing technology with a binary bat optimization algorithm (NBQ-BBOA). This proposed work is used to track, detect, and manage medical waste. To minimize the transferring cost of medical wastage from various nodes, the Q-Learning algorithm is used. The accuracy obtained for the Naïve Bayes algorithm is 88%, the Q-Learning algorithm is 82% and NBQ-BBOA is 98%. The error rate of Root Mean Square Error (RMSE) and Mean Error (MAE) for the proposed work NBQ-BBOA are 0.012 and 0.045.

Keywords: Binary bat algorithm; naïve bayes; supply chain; edge; medical wastage

1 Introduction

The medical waste management system is an important decision-making problem to protect our environment. If medical waste is not disposed of properly, it creates a high risk to the health condition of human beings and also spoils the environment [1]. Medical waste management is used to manage waste from health centers, transportation, and disposal of medical waste, and its processing cost is high. This paper presents an efficient medical waste management system using an efficient Naive Bayes classifier algorithm and Q-Learning algorithm in decentralized edge computing technology with a binary bat optimization algorithm (NBQ-BBOA). It reduces the cost of transportation, minimizes the time in processing, has reliable data speed, high security, and transparency, is auditable for the solution of the supply chain, and provides cheap medical equipment waste management. The Ethereum-based decentralized storage is used to store large amounts of information in a secure manner and transfer data through the supply chain of medical equipment and manage the medical waste system.

Monitoring of the generation of medical waste from health care centres or hospitals and compliance of health care centres using edge computing technology can efficiently handle the medical equipment waste. The medical equipment data and transactions of usage data are stored on the edges and are accessible to the physicians or staff in the health care centre through the supply chain. The decentralized storage of edge computing increases security, trust, and easily accessible data [2–4]. The category of medical wastage in the aspects of hazardousness includes infectious medical wastage, general medical waste or non-hazardous, pharmaceutical, and chemical wastage [5]. The disposal of pharmaceutical waste is traditionally carried out by burning or non-burning methods. This method of disposal of waste contains 15% hazardous waste and the remaining 85% is considered general waste [6]. A huge amount of pharmaceutical waste is found in streams, waterways, and groundwater, which affects the climate and water [7]. The main contribution of this paper is,

1. Implementing an Ethereum edge computing-based method for tracking the medical equipment supplier and disposal of medical equipment wastage using a supply chain.
2. Develop a smart contract with naïve Bayes and Q-Learning algorithms in the supply chain.
3. Implementing decentralized storage provides more security, trustfulness, and transparency.
4. Developing a binary bat optimization algorithm

The paper has been organized as follows: Section 2 describes the literature review, Section 3 implements an effective medical waste management system, Section 4 discusses the experimental results, and Section 5 concludes the paper with future directions.

2 Review of Literature

The World Health Organization (WHO) defines pharmaceutical wastage as including unused medicines, expired vaccines, and spilled items that are disposed of properly [8]. Nowadays, the wastage of pharmaceuticals has increased in huge numbers because of the overproduction of medicine, the increased number of patients, and the poor health conditions of humans. This leads to an increasing wastage level of expired medicine or medical equipment, unused medicine, and the cost of disposal of medical equipment [9]. This paper proposes managing medical equipment waste using edge computing technology in the supply chain.

In the health care field, edge computing technology securely tracks medical equipment and medicines from manufacturer or distributor to health care center. The coinage computing approach tracks and traces the medicines through the supply chain method. It performs the operations of handling manufacturers, pharmacies, distributors, and drug in-takers. These transactions are stored in edge computing to identify the supplier or manufacturer of medical equipment [10]. To provide assurance of drug safety, purchasing medical equipment from an authorized person and maintaining the quality of medical equipment [11] is necessary.

In the paper [12], the authors introduce the smart waste management system in which the waste producer's service cost is charged based on price estimation. It also includes IoT for monitoring and collecting data about the location of the waste bin and measuring the quantity of waste collected in the bin. The electronic waste management system was implemented using an Ethereum-based system which includes compliance and guidelines for the disposal of waste in electrical and electronic equipment (EEE). The main services of EEE are as a manufacturer, distributor, and consumer of medical equipment. Using smart contracts, we can report and record the disposal of EEE waste to the waste collector [13]. Table 1 shows a survey of literary works on the waste management system.

Table 1: Survey on literature

Author name	Technique
Abdallah et al. (2021) [14]	A multi-objective optimization model for strategic waste management
Valizadeh et al. (2021) [15]	Hazardous infectious waste collection in COVID
Tirkolaee et al. (2021) [16]	The fuzzy multi-trip location-routing problem for medical waste management
Tirkolaee et al. (2021) [17]	sustainable medical waste collection and transportation model for pandemics
Mohsenizadeh et al. (2020) [18]	Bi-objective MILP; Municipal solid waste management with cost minimization and emission.
Tirkolaee et al. (2020) [19]	A robust optimization technique for urban-based waste
Yu et al. (2020) [20]	A multi-objective mathematical method for hazardous waste management
Rathore et al. (2020) [21]	Multi-objective MILP and particle swarm optimization algorithm in solid waste management
Kargar et al. (2020) [22]	medical waste management in the epidemic outbreak of the novel coronavirus (COVID-19).
Laura Wood (2020) [23]	Global Medical Waste Management Market-COVID-19
Asefi et al. (2019) [24]	The heuristic method in solid waste management.
Asefi et al. (2019) [25]	VRP with fleet heterogeneity in Integrated SolidWaste Management
Gergin et al. (2019) [26]	Artificial Bee Colony Algorithm for Healthcare Waste Disposal
Osaba et al. (2019) [27]	bat algorithm for solving a medical goods distribution problem with pharmacological waste collection

There are many techniques used in wastewater management, but the prediction accuracy is still not satisfactory to authorities. Medical equipment wastage analysis needs an intelligent learning platform. So in this work, we use Naïve Bayes with Q-learning, which is comparatively better than other techniques.

3 Proposed Environment Waste Management Methodology

Managing medical equipment suppliers and medical wastage is done in this work by an efficient Naive Bayes classifier algorithm [28] and Q-Learning algorithm [29–32] in decentralized edge computing technology with binary bat optimization algorithm (NBQ-BBOA). The architecture of the proposed work is given in Fig. 1. The process of this proposed work is divided into four components. They are; Registration authority, Ethereum edge computing with smart contracts and decentralized storage [33], medical waste management in the supply chain [34–37] finally, implementation of proposed work in the edge computing technique.

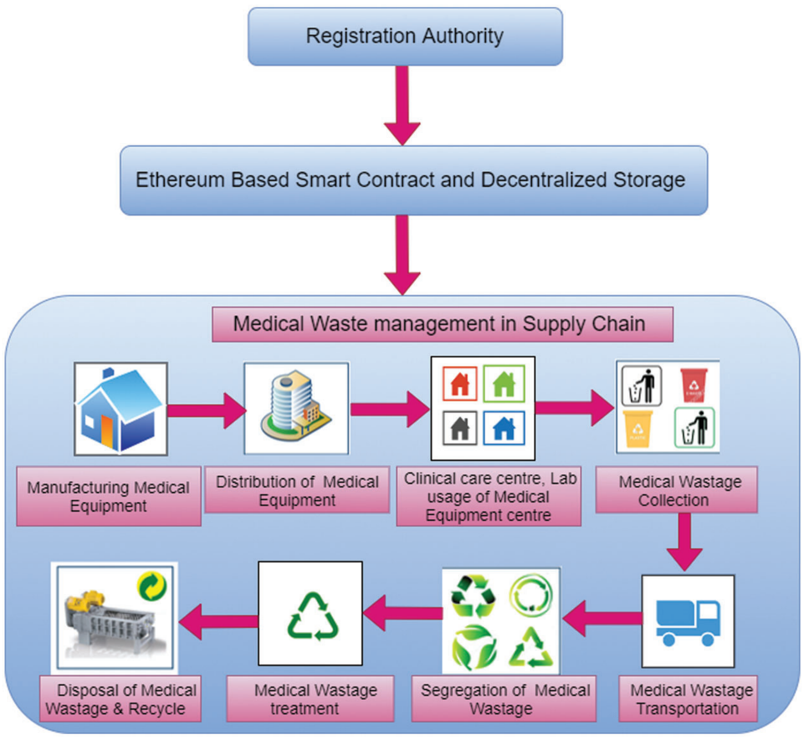

Figure 1: Architecture of medical wastage tracking

3.1 Registration Authority

Drug and medical equipment suppliers registered their roles and license in the supply chain of medical waste delivery management systems [38–41]. And also, they should comply with rules and regulations. If the supplier is non-complying with the rules and regulations, then their license will be suspended by the registration authority [42].

3.2 Smart Contract

A smart contract is an agreement between a medical equipment supplier and a medical center or healthcare professional in the form of rules. They run on edge computing, so they are stored on a public database and cannot be changed [43–49]. We implement three major contracts in this work, including the registration smart contract, medical equipment orders smart contract, and medical waste handler smart contract. All these smart contracts are implemented in the supply chain of the medical waste management system. Fig. 2 shows the sequence diagram of three smart contracts with the supply chain [50–54].

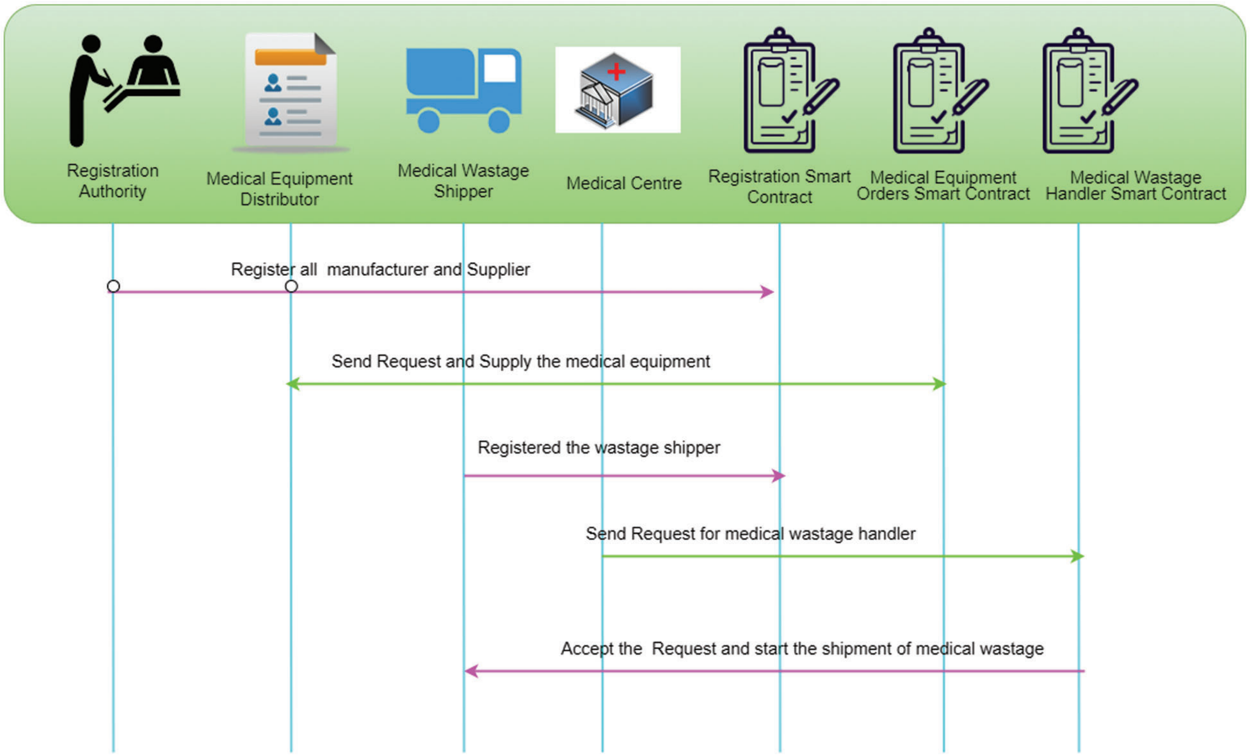

Figure 2: Sequence diagram of smart contracts

Distributed Storage

Medical equipment details and their requirements for treatment and medical waste details are stored in the distributed storage system on the edge computing ledger. To overcome the issue of scalability in edge computing, in this work, distributed storage is used.

3.3 Medical Waste Management in Supply Chain

In the medical waste management system [55,56], each distributor and health care centre is involved in the supply chain with monitoring, tracing, handling, and shipment of waste without spoiling the environment. The key components of the supply chain [57] in medical waste management are manufacturing medical equipment, distribution of medical equipment, medical centres, collection of medical waste, and segregation of medical waste [58].

3.3.1 Manufacturing of Medical Equipment

The medical manufacturer is used to manufacture the currently needed medical equipment and store the details of the equipment name, cost, manufacturing date, and details of the manufacturer in the edge nodes. The manufacturer finds a trusted supplier of raw materials and places the order for raw materials. Then they manufacture the medical equipment. Manufacturers should genuinely display the license details of medical equipment publicly.

3.3.2 Distributor of Medical Equipment

The responsibility of medical equipment distributors in the supply chain is to take a survey about the demand for medical equipment in the medical field, purchase the medical equipment from the registered manufacturers, and supply it to the registered healthcare centers. The distributor must have a valid license to purchase and supply medical equipment.

3.3.3 Health Care Centre

Healthcare centres purchase medical equipment from manufacturers or distributors. After using it, the waste is stored in the storage room safely. The waste handlers segregate the waste and pack it safely in a separate bag.

3.3.4 Medical Wastage Transportation

The collected medical waste from the health care centre is shipped to the medical waste treatment centre for recycling and disposal.

3.4 Implementation of Effective Waste Management System

The smart contract implementation in the supply chain includes the registration smart contract, medical equipment orders smart contract, and medical waste handler smart contract. This work implements the Naive Bayes classifier and Q-Learning algorithm for placing orders for the most in-demand medical equipment. It implements a binary bat optimization algorithm (NBQ-BBOA) to get the optimized solution. This algorithm is implemented in four different concepts: placing the medical equipment order; updating the requirements of medical equipment; sending requests for transporting the waste and monitoring and storing the medical waste safely.

3.4.1 Naïve Bayes Algorithm

The Naive Bayes classifier is reliable and handles various concepts ineffectively. In the Naïve Bayes algorithm, prior probability is calculated by using the probability of demand for medical equipment based on its market demand. For example,

$$P(A = COVID) = (NasalSwabs,\ \ surgicalmask,\ gloves,\ \ handsanitizer)$$

This probability is used for future prediction of manufacturing medical equipment. This algorithm predicts the demand for medical equipment based on the maximum value among the groups in Eq. (1)

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \tag{1}$$

where A and B are the probability of demand for medical equipment. $P(A|B)$ is posteriority demand of B. A that is a requirement of medical equipment after confirmation is proved. Now Bayes is represented as in Eq. (2)

$$P(b|A) = \frac{P(A|b)P(b)}{P(A)} \tag{2}$$

where A is the group variable and A is the demand for the medical equipment of several items needed.

Algorithm 1: Placing the Medical Equipment Order using Naïve Bayes

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Input: Medical Equipment Ethereum address, Quantity in demand, Medical Equipment name.

Output: Order is placed.

Step 1: **If** *sender is not Distributor or manufacturer* **then**

Step 2: Display "Invalid distributor"

Step 3: End

(Continued)

Algorithm 1: (Continued)

Step 4: Else

Step 5: If *Sender is Registered and valid License number* then

Step 6: For *every demand*

Step 7: For *every medical Equipment*

Step 8: Evaluate $P(b|a_1.\ a_2,\ \ \ldots\ldots a_{n)\propto}\ P(b);\ \prod_{i=1}^{m} P(a_i|b)$

Step 9: Evaluate $P(a_i|\ b_i)$.

Step 10: Evaluate $P(a,\ b)$

Step 11: End For

Step 12: End For

Step 13: For *every medical Equipment*

Step 14: Evaluate Posterior probability

Step 15: Calculate the demand in the market using $P(a) + Pwhich\ (b) = 1$

Step 16: End For

Step 17: Generate Order ID, *Ethereum address for sender*, *receiver*, *MedicalEquipmentName*, *EquipmentEthereumAddress*, *QuantityofRequestedMedicalItem*

Step 18: Place the order successfully.

Step 19: Display an error message and return to the previous state of the contract.

The procedure of Algorithm 1 is implemented to place an order for medical equipment requests from the health centre. It needs the sender to provide the Ethereum address of the manufacturer or distributor with the required quantity of medical equipment and also the name of the medical equipment. Algorithm 2 represents the distribution of medical equipment to the health care centre.

Algorithm 2: Distribution of Medical Equipment

Input: Ethereum Address for Medical Equipment's Order, Demand Quantity.

Output: Distribute Medical Equipment

Step 1: IF *sender is not Distributor or Manufacturer* **THEN**

Step 2: Display ‘‘*The sender of medical Equipment is not authorized*".

Step 3: End

Step 4: ELSE

Step 5: IF *Health centre and sender are Registered with a valid License* **THEN**

Step 6: IF Book == MedicalItem **THEN**

Step 7: Set Book to 0.

Step 8: Read *quantity of AvailableItem in StockRegister*

Step 9: IF *AvailableItem* $\geq$ *RequestedQuantity* THEN

Step 10: *AvailableItem = AvailableItem-RequestedQuantity*

(Continued)

Algorithm 2: (Continued)

Step 11: *QuantitySold* = *RequestedQuantity*.

Step 12: End

Step 13: ELSE

Step 14: Display "*Not enough medical items in the Stock*"

Step 15: End

Step 16: End

Step 17: ELSE

Step 18: Display "*Another Request of medical item for process*".

Step 19: End

Step 20: End

Step 21: Else

Step 22: Display *display an error message* ; *return to the prevofious state of contract*.

Step 23: End

Step 24: Display "Send notification about the sending of the medical equipment to the health centre using the Ethereum address of Distributor or manufacturer, Quantity Sold, Ethereum address of health centre.

Step 25: Reset Book to Item.

Step 26: IF *Medicalitem Available* == *NULL* **then**

Step 27: Reset the medical equipment order smart contract.

Step 28: End

Step 29: End

Algorithm 2 describes functionalities of selling the medical equipment to the health care centre based on their demand. The Selling process is done only to the registered manufacturers and distributors.

3.4.2 Q-Learning Algorithm

The highlights of Algorithm 3, Optimal Policy, are directly addressed in Q-Learning. The learning rate is set at a value between 0 and 1. If the set value is 0, nothing is learned and never updates the Q-values. If the set value is 1, a learning process occurs. The agent of the Q-Learning algorithm controls the consumption of medical waste in the health centre. The agent observed the state of each medical waste in the house and took action, estimating the immediate reward. In this way, an agent observed the maximum reward.

Algorithm 3: Sending a request for shipment of the medical waste using Q-Learning

Input: Ethereum Address for Medical Equipment's Order, Demand Quantity.

Output: Distribute Medical Equipment

Step 1: Randomly initialize $Q(transportid,\ wasteid)$

Step 2: *for* $i = to1$ *to* N // number of medical waste items

Step 3: Initialize *transportid*

Step 4: Select *ac* from *transportid* using policy Q

(Continued)

Algorithm 3: (Continued)

Step 5: Take action *wasteid* and monitor $max_{ac'}\ Q\left(transport',\ \ wasteid^{all}\right)$, for all wastages

Step 6: $Q_{i+1}\ (transportid,\ wasteid) \leftarrow Q(transport,\ wasteid) + \alpha[r + \gamma Q_i(transportid,\ \ wasteid^{max}) - Q_i(transportid,\ wasteid)]$

Step 7: $i \leftarrow i + 1;\ step\ 3$

Step 8: $Q_{i+1}(transportid,\ wasteid) = Q(transportid,\ wasteid)$

Step 9: Return Q_{i+1}.

3.4.3 Binary Bat Optimization Algorithm

The binary bat optimization algorithm performs the task in the discrete search space. The search space of the Binary Bat Algorithm is restricted to 0's and 1's. To find the optimal solutions, the algorithm chooses potential outcomes from Naïve Bayes and Q-Learning algorithms in medical waste management. The transfer function of Binary Bat algorithm is given in Eq. (3):

$$BB(ve_i^k(t)) = \frac{1}{1 + e^{-ve_i^k(t)}} \tag{3}$$

Here, i is the particle and $ve_i^k(t)$ indicates the velocity of the corresponding wastage at t iteration. Transfer function applied in Eq. (3) and its updating position is given in Eq. (4) and in Eq. (5)

$$ve_i^m(t) = \left|\frac{2}{\pi}\arctan\left(\frac{\pi}{2}ve_i^m(t)\right)\right| \tag{4}$$

$$x_i^m(t+1) = \begin{cases} x_i^m(t)^{-1} ifrand < Vl\left(ve_i^m(t)\right) \\ x_i^m(t) ifrand \geq Vl\left(ve_i^m(t)\right) \end{cases} \tag{5}$$

$x_i^m(t)$ is position and $ve_i^m(t)$ represents velocity of i^{th} medical wastage at t^{th} iteration in m^{th} dimension.

Algorithm 4: Monitoring and storing waste data related to the current location and state of the medical waste using Binary Bat algorithm (Proposed)

Step 1: Initialize *transport ID as bat population*, $rand(0\ or\ 1)$*Current Location*, *WasteID*, *sensor data of waste equipment*

Step 2: Define $status\_wasteshipmentwastesship_i$

Step 3: Initialize *transportid* , *wasteid*

Step 4: Place the order for medical equipment using Algorithm 1

Step 5: Distribute the medical equipment to the needed places using Algorithm 2.

Step 6: Disposing the medical wastage safely using Algorithm 3.

Step 7: while $(t\ <\ Max.no.\ of\ \ iterations)$ do

Step 8: Adjusting $wastesship_i$ and updating *status_wasteshipment*

Step 9: Calculate $transfer\_function(wasteid)$ using Eq. (3)

Step 10: Update $Current - Location$ of transportation tousing Eq. (4)

Step 11: **if** $(rand\ >\ wasteid\ )$ **then**

(Continued)

Algorithm 4: (Continued)

Step 12: Randomly choose best solution $(transport - best)$

Step 13: Replace *SensorsStateData* with new sensors of $(transport - best)$.

Step 14: **end if**

Step 15: Randomly generate a new *sensorreadings* by flying of bat.

Step 16: if (rand $< wasteid$) &$MedicalItem < transport - best$ then

Step 17: Accept the new *sensorreadings*.

Step 18: Increase *transportid* and reduce *wasteid*

Step 19: end if

Step20: Arrange the bats according to rank and highlight the current *status_wasteshipment* $(transport - best)$

Step 21: end while

The highlights of Algorithm4 are the actions performed by sending requests to get the medical equipment and having the registered distributor send the medical equipment to the required places. After using the medical equipment, waste is collected and safely disposed of. Before uploading the waste, the system verifies the current status of the waste shipment. After this verification is completed, it allows the transporter to periodically upload the waste shipment's location through the chain waste container's state until it reaches the waste disposable unit.

4 Results and Analysis

Many pieces of medical equipment are designed for single use only. In that case, dispose of it immediately after its use. The medical waste generated from health care centres, medical laboratories, and hospitals must be handled carefully because it may spoil the environment. This medical waste needs to be recycled or disposed of in an efficient manner. In this work, an efficient approach is implemented in the supply of medical equipment to the health care centre using a supply chain concept and also disposes of the medical wastage. This work is based on three smart contracts and implements the Nave Bayes algorithm and Q-Learning concept integrated with the decentralised storage of Ethereum edge computing technology in the disposal of medical waste. These algorithms are analysed using performance metric measures of sensitivity, specificity, and accuracy. Positive likelihood, negative likelihood helps to analyse medical waste management, calculate the root mean square error (RMSE), which is given in Eqs. (6)–(15). An IoT-based survey and ideology for medical data collection were learned.

$$Sensitivity = \frac{TP}{TP + FN} = \frac{Number\ of\ True\ positive\ assessment}{Number\ of\ all\ positive\ assessment} \tag{6}$$

$$Specificity = \frac{TN}{TN + FP} = \frac{Number\ of\ True\ Negative\ assessment}{Number\ of\ all\ Negative\ assessment} \tag{7}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} = \frac{Number\ of\ true\ correct\ assessment}{Number\ of\ all\ assessment} \tag{8}$$

$$Positive\ Likelihood(PL) = \frac{Sensitivity}{1 - Specificity} \tag{9}$$

$$Negative\ Likelihood(NL) = \frac{1 - Sensitivity}{Specificity} \tag{10}$$

$$MAE = \frac{1}{N}\sum\nolimits_{i=1}^{n}\left|\propto_i - \propto_i^{'}\right| \tag{11}$$

$$RMSE = \sqrt{\frac{1}{n}\sum\nolimits_{i=1}^{n}\left|\propto_i - \propto_i^{'}\right|} \tag{12}$$

$$precision = \frac{TP}{TP + FP} \tag{13}$$

$$recall = \frac{TP}{TP + FN} \tag{14}$$

$$F1 - Score = \frac{2*precision*recall}{precision + recall} \tag{15}$$

Table 2, shows that performance metric measures of medical wastage management algorithms.

Table 2: Performance metric measures

Algorithm	Sensitivity	Specificity	PLR	NLR
Naïve bayes	86.3%	78.8%	12.87	0.18
Q-Learning	89.6%	90.4%	11.34	0.14
NBQ-BBOA (Proposed)	93.8%	95.2%	10.22	0.043

The Table 2 for the sensitivity rate of the NBQ-BBOA (Proposed) algorithm (93.8%) is better than Naïve Bayes (86.3%) and Q-Learning (89.6%). NBQ-BBOA outperforms other algorithms with a specificity of 95.2%. For PLR value, proposed work NBQ-BBOA has better performance at 10.22. In the NLR rate, NBQ-BBOA got 0.043 compared with Naïve Bayes and Q-Learning. Fig. 3 shows that accuracy in the execution of proposed work.

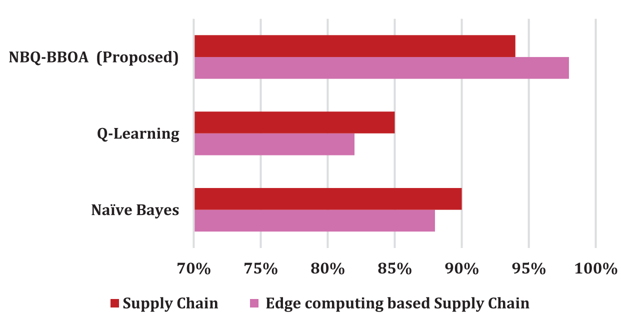

Figure 3: Accuracy

For implementing the accuracy rate with the concept of edge computing based in supply chain and without edge computing-based supply chain are evaluates and our proposed algorithm gives the better accuracy. Table 3 shows that comparison of our proposed work with existing parameters in wastage concepts.

Table 3: Comparison of existing concept with NBQ-BBOA

Author name	Type of wastage	Transportation rules	Traceability feature	Decentralized storage system	Supply chain
Lamichhane et al. [12]	Domestic wastage IoT based block chain	No	yes	No	No
Gupta et al. [13]	E-wastage	No	yes	No	Forward supply chain
Omar et al. [29]	Wastage of COVID medical item	No	yes	Yes	Forward supply chain
Tao et al. [30]	Municipal solid wastage	No	No	No	No
NBQ-BBOA (Proposed)	Medical wastage	Yes	Yes	Yes	Yes

Table 3 shows the benefits of our proposed work compared with existing concepts in the Ethereum-based decentralized storage method for handling the large-sized medical waste management system. And also, it shows that fast access provides security and automatic execution of smart contracts. Fig. 4 shows the F-score of Naïve Bayes, Q-Learning, and NBQ-BBOA (Proposed) algorithms.

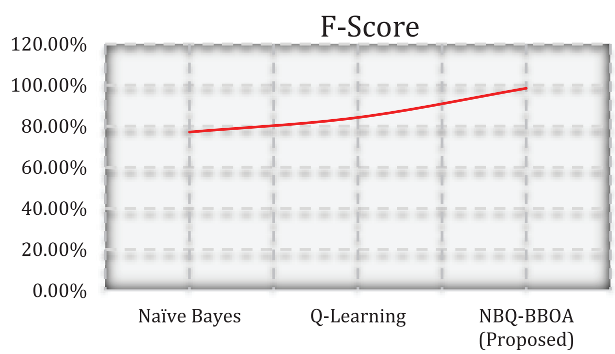

Figure 4: F-Score

In the evaluation of F-score value our proposed work gives better performance than existing algorithm. Using Eqs. (8) & (9), Table 4 shows that performance prediction of error rate.

From Table 4, it seems that our proposed work provides better improvement in terms of performance in the area of prediction in the error rate. Table 5 shows that computation time in (ms) is needed for doing the sequence of operations in the medical waste management system.

The above Table 5 shows the computation time taken for doing a sequence of operations in the medical waste management system. Our proposed work shows that less computation time is spent in executing a sequence of operations.

Table 4: Performance prediction of error rate

Algorithm	RMSE	MAE
Naïve bayes	0.422	0.377
Q-Learning	0.391	0.289
NBQ-BBOA (Proposed)	0.012	0.045

Table 5: Time taken in sequence of operation

Operation name	Naïve bayes	Q-Learning	NBQ-BBOA (Proposed)
place order request for medical Equipment	0.82	0.56	0.32
Supply of medical equipment by Distributor/Manufacturer	0.78	0.43	0.28
Send request to place transportation for pick up wastage	0.62	0.31	0.12
Transportation of medical wastage to wastage treatment facility centre	0.65	0.35	0.15

5 Conclusion

This paper aimed to develop an efficient medical waste management system in the supply chain using edge computing technology. The proposed NBQ-BBOA provides reliability, high security, transparency, and auditable solutions for supply chain and waste medical equipment management when compared with the existing algorithm. From the result, we concluded that our NBQ-BBOA produces a better system for supply chain and medical waste management systems. The Nave Bayes algorithm has an accuracy of 88%, the Q-Learning algorithm has an accuracy of 82%, and the NBQ-BBOA algorithm has an accuracy of 98%. The RMSE and MAE error rates for the proposed work NBQ-BBOA are 0.012 and 0.045, respectively. The computation time for performing the sequence of operations in the medical equipment wastage management system in our proposed work NBQ-BBOA got less computation time. In future work, the development of this waste management system will be implemented with a meta-heuristics algorithm. The limitation of the study is that Q-learning takes more time initially, which has to be considered for future research.

Acknowledgement: Authors would like to thank for the support of Taif University Researchers Supporting Project number (TURSP-2020/10), Taif University, Taif, Saudi Arabia.

Funding Statement: Taif University Researchers are supporting project number (TURSP-2020/10), Taif University, Taif, Saudi Arabia.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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