Neutrosophic AHP Method with Machine Learning Algorithms to The Priority of Maintenance in the Facility of Healthcare

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Abstract

The creation of decision-support techniques that can be used in the planned preservation and recertification ordering of healthcare facility investments is regarded as an assignment of extremely high difficulty due to the multitude of ambiguity and levels of individuality that is accessible in a decision-making procedure of this nature. This research employs a mixture of Neutrosophic logic and the Analytical Hierarchical Process (AHP) to generate a trustworthy score of hospital structure facilities depending on their varying levels of evaluation and achievement deficiencies. This is done to reduce the partiality that is related to expert-driven choices and to make the rankings more objective. This is additionally merged with the innovative use of machine learning techniques in this field, specifically: Random Forest, and Naive Bayes, to automate the process of setting priorities and making it reproducible, thereby reducing the essential for extra professional decisions.

Keywords: Machine Learning; Neutrosophic Sets; Healthcare; MCDM; AHP

1. Introduction

The effectiveness of healthcare facilities and the parts that make them up is mostly determined by the maintenance management techniques that are implemented. Facility managers are very important in the management of building operations as well as the administration of building maintenance because they can anticipate how all buildings and structures will work based on their knowledge, attitudes, and goals. However, since they were not involved in the briefing, design, or cost analysis stages of the new construction projects, their projections cannot be relied upon to accurately judge performance. Evaluation of performance is another one of those things that have to be done, seeing as how this is what determines how effective the structure that was made is. This evaluation contributes to the process of identifying the benefits and drawbacks of each facility. Furthermore, performance evaluation broadens the scope of evaluations of past and present operations, as well as future planning for the efficient operation of the organization and the successful completion of its strategic goals. Because hospitals and other medical institutions are often open around the clock, optimizing their use of space is of the utmost importance. Because a mistake may have resulted in the loss of a patient's life, the industry cannot afford to employ a "trial and error" strategy or have service failures with customers[1-2].

Therefore, the application of FM methods may be able to tackle the challenges that have been outlined above. FM is a broad term that incorporates a variety of responsibilities that vary based on the structure of an organization along with a vital activity of ongoing monitoring of the situation of an investment which is an essential characteristic of FM, and it includes periodic reports on the present circumstances, constituent residual service life, funding files for long- and short-term repairs, and estimations and suggestions for renewal. FM is a crucial function of ongoing monitoring of the circumstance of an investment vehicle which is an essential feature of FM, and it includes periodic

reports on the present circumstances, portion FM operations in the healthcare industry include things like power management, building management, and upkeep building systems, and safety and security inspections[3-4].

Multiple research on performance evaluation has been conducted in healthcare institutions. These studies can be arranged into three distinct fields of FM work performance: assessing clinical efficacy, built form and doctor's office functionality, and the advancement of constructability evaluation tools that evaluate performance characteristics. In addition, the high energy consumption of hospitals has helped save energy and compelled the establishment of energy performance metrics based on planned maintenance. Measures of care quality such as conserving energy, functioning, and maintenance management were not found to be part of a coherent framework in a previously conducted study[5-6].

The method of determining the relative worth of assets with one another within the context of an organizational structure is what we mean when we talk about "capital management." It is generally agreed that upkeep and capital renovations are the most essential roles of an asset management framework. These functions are defined by the International Organization for Standards as a combination of managerial and technical processes that are carried out to enable a building facility and its fundamental components to fulfill the function for which they were designed throughout the entirety of their lifecycle. Repairs and capital renovations are considered to be the most important roles of a portfolio administration structure. Therefore, the neglect or delayed execution of such maintenance tasks might potentially result in severe system failures that can present dangers to employees, lost revenue, or operational disruptions. These failures can harm the organization as a whole[7].

Either preventative or reactive maintenance is the conventional approach to building maintenance that is used in healthcare facilities. These approaches are employed to maintain the assets and elements of the facility. Interventions are carried out on time following a time-based schedule as part of a preventative maintenance program. Although this tactic may help to extend the useful life of the possessions, it is rather labor-intensive and calls for a significant initial expenditure for the maintenance operations to be carried out at the appropriate time. In addition, the adoption of this maintenance approach often results in the carrying out of operations that are either redundant or superfluous and which, if they were eliminated, would not affect the building assets' capacity to function reliably or effectively. It is taken into account a short-sighted and unworkable upkeep strategy because unforeseen circumstances are certainly likely in this type of maintenance program, which can find a loud noise in a hospital's activity as well as increased costs for routine conservation due to the ill-planned assets and funding level. On the other hand, condition monitoring is less expensive initially because it does not require original investment to be made. Because of this, the Joint Commission on Accreditation of Healthcare Organization developed an updated maintenance program. This program emphasized the need for more precise management and preparation of routine conservation in a hospital or clinic, taking into account the variations of asset importance and danger stages. By cutting down on the number of times time-based maintenance is performed and moving in the direction of a more proactive maintenance strategy, it is anticipated that this strategy will cut the costs and labor hours associated with operations that do not need to be performed[8-10].

Additionally, the assessment of the implications and the likelihood of the advantage mechanisms as a portion of a portfolio organization structure can act as an advantageous helping device for cities and counties, and government agencies to make unbiased comparability and order possessions with a potentially higher failure effect for the reasons of renewal. This is because the approximation of the implications and likelihood of disappointment of the investment elements is an integral part of an asset management structure. A Risk Evaluation framework is a procedure that predicts the likely repercussions and likelihood of failure. This process is sometimes referred to as a Risk Assessment. In recent years, the creation of risk assessment models as an integral element of wealth management frameworks has emerged as a critical objective in healthcare companies[10-11].

Even so, the integration of such danger evaluation nears within medical services to order the financial fundamentals has taken on a somewhat interpretive form in which specialists are required to rank the threshold values of assets according to their respective expertise and decision. This is done to order the fundamental assets. As a consequence of this, there is a possibility that the views of various specialists will diverge, and there will also be uncertainty as a result of the lack of a standardized technique for evaluating the assets and elements of hospital buildings[12-14].

As a result, the persistence of this paper is to offer a methodical approach to trying to measure the important stages for various hospital structure mechanisms based on the shortages discovered within their normal course of process, in addition to their modified propensity or disappointment history that has been encountered. This paper was created to fulfill this objective. This strategy is additionally improved through the usage of machine learning procedures, which mechanize the procedure of defining priorities and reduce dependency on further expert-based subjective procedures. As a result, the total prioritizing process is improved and becomes more consistent and dependable.

2. Healthcare Services

Because of the essential services they provide to the community, hospitals have developed into highly significant structures. The processes in the hospital building are supported by a variety of facilities and pieces of equipment, each of which operates in rotation. Patients, members of the general public or visitors, members of medical and administrative personnel, and other visitors are all distinct types of stakeholders in the healthcare system[15].

As per Loose more and Hsin, who are mentioned in it creates a dense network that needs to be looked into, the primary obstacles in administering hospital facilities are the complexity of numerous services that demand significant support and the fact that there are a lot of them. The ability of facility managers to foresee the status of the facilities based on their experiences as well as their various values, beliefs, emotions, and aspirations is a crucial function that they perform. However, despite their essential role in the healthcare system, hospitals are among the costliest settings in which to get medical treatment. Therefore, even though hospitals provide care for patients who cannot be treated anywhere else at a time when hospital treatment may still be beneficial, hospitals are increasingly concentrating their efforts on providing vital short-term care. They will only take in patients who have a critical ailment that calls for a high degree of healthcare or nursing care, or who need customized diagnoses and therapy. It is challenging to make accurate projections on the needs of hospitals in the future. The majority of facility managers do not participate in the briefing, designing, or cost-analysis phases of the creation of new buildings, which is the source of the issue. Because medical facilities often remain open around the clock, it is very important to ensure that their performance functions well. Because one mistake has the potential to end the life of a patient, the healthcare business is a highly specialized field that cannot afford to use a "trial and error" approach or have breakdowns with patients[16-18].

From the tower's front entryway to each component and space contained inside, the structure's upkeep is intimately connected to the building itself. Maintenance is defined as "a mixture of all acts carried out to keep an item in or repair it to, a people accept or standard" according to BS 3811, 1964. "combination of all technical and managerial measures, including supervision actions, designed to keep an item in, or return it to, a condition in which it can perform a specified function," was the definition that was improved by BS3811 in 1987. The concept of maintenance is subject to continuous evolution in response to shifting priorities and conditions. The primary objective of maintenance is to enhance and maintain the function of the facility, as well as its services and the surrounding area, by utilizing a methodical system and standard regulations that are required to be adhered to and accepted in the existing facility by an experienced person in charge.

According to Ahmad Riza's research from 2006, the primary considerations in building maintenance are the dimensions of the structures and the requirements of their occupants. The risk of a catastrophic failure may be mitigated by implementing an effective management approach for maintenance. Regrettably, the maintenance management techniques that should be in place are not being adequately implemented. Because there is insufficient funding for building maintenance, a strategic plan has to be formulated to deal with structures of a complex and intricate nature, such as hospitals, which include a great deal of highly important mechanical and electrical equipment. The management of a healthcare institution demands a unique approach to get better results and achieve cost savings[19-20].

There are a variety of factors that can have an impact on the performance of a hospital, including actual accommodation in comparison to planned accommodation, the age of the building, the environment in which the building is located, the managerial reserves invested, and the labor sources for implementing routine maintenance either in-house or through outsourcing. Ineffective planning on the part of management may be a contributing factor in the failure of every firm at some point. According to a report by who, it has been said that each strategic plan has to be prepared based on the vision, purpose, and objectives of the business that is developing the plan.

About the objectives and objectives of controlling maintenance in healthcare facilities, the most effective maintenance plan is, in layman's words, to keep all of the owner's assets while simultaneously enhancing the performance of those assets. There is a high failure rate among enterprises that begin the process of implementing a maintenance plan inside a hospital setting. On the other hand, the client is the best individual to judge how well something has been done. It is not an issue with costs or customers; rather, the primary concern is that maintenance is something that requires planning. However, Horner, El-Haram, and Munns believe that in the present day, building maintenance methods are more likely to be driven by financial considerations, regardless of whether they are built on scheduled or unforeseen maintenance. In addition to this, they assert that the ongoing maintenance is not being carried out by the real requirements but rather with the budgetary scenario that existed in the past.

3. Facility Maintenance Management

The effectiveness of healthcare facilities and the parts that make them up is mostly determined by the maintenance management techniques that are implemented. Facility managers are very important in the management of building operations as well as the administration of building maintenance because they can anticipate how all buildings and structures will work based on their knowledge, attitudes, and goals. However, because they were not involved in the briefing, design, or cost analysis stages of the new construction projects, their projections cannot be relied upon to accurately judge performance. Evaluation of performance is another one of those things that have to be done, seeing as how this is what determines how effective the structure that was made is. This evaluation contributes to the process of identifying the benefits and drawbacks of each facility. Furthermore, performance evaluation broadens the scope of evaluations of past and present operations, as well as future planning for the efficient operation of the organization and the successful completion of its strategic goals. Because hospitals and other medical institutions are often open around the clock, optimizing their use of space is of the utmost importance. Because a mistake may have resulted in the loss of a patient's life, the industry cannot afford to employ a "trial and error" strategy or have service failures with customers.

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4. Material and Methods

A unique classification-based automatic prioritization method for goods in healthcare institutions is presented in this work. Random Forest and Naive Bayes (NB) were the three methods that were chosen because they have a proven track record of being successful and popular in the research that came before them. The scope of this research encompasses the structure possessions that make up a healthcare institution. These architectural assets include the civil, structural, hydraulic, electrical, and sanitary sewers, as well as the components that make up each of these systems. The suggested technique is going to be used to determine the correlating importance level for the investment based on their importance or risk vigorous as well as their achievement insufficiency with reverence to their physiological and performance characteristics conditions. This will be done by comparing the asset's current state to its ideal state and comparing the two. An integration of Neutrosophic Logic and MCDM methodology has been utilized to arrive at an appropriate benchmark test for the hospital's new building materials. This was done to reduce the amount of subjectivity that was involved in the decision-making process. Figure 1 shows the suggested outline in this paper.

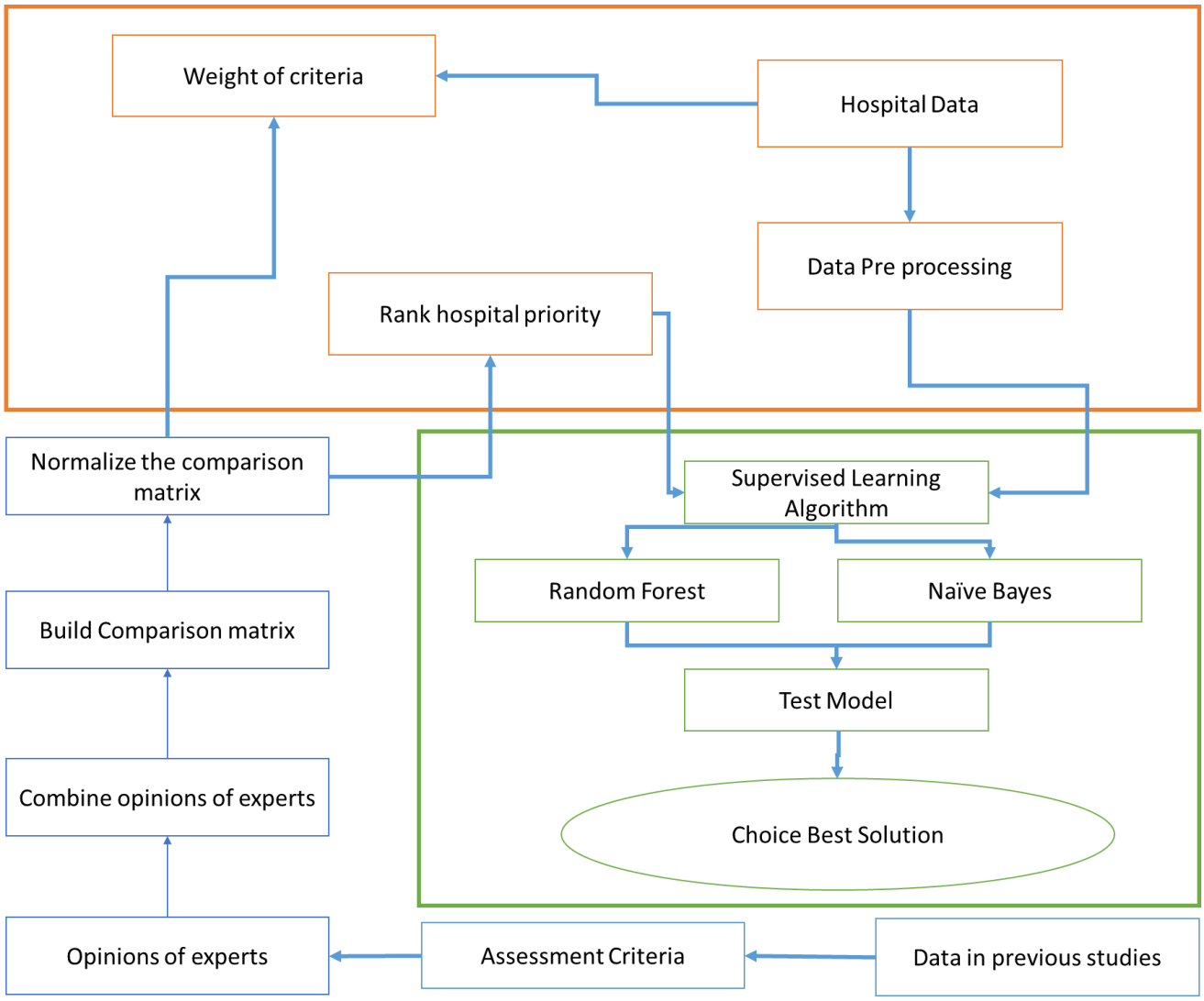

Figure 1: The proposed Framework.

4.1 The Neutrosophic-AHP Method

The N-AHP technique that has been suggested uses the procedures that are outlined below to conduct an analysis of the identified blockchain hurdles and provide a rating[21]–[24].

First, break the issue down into its parts using a hierarchy:

Establishing a hierarchy in the AHP technique that represents the aim, criteria, and options is necessary to make the issue more understandable. Within the scope of this investigation, the hierarchy of decision-making encompasses one degree of obstacles.

Second, creating a pairwise comparison matrix involves the following steps:

Using the Saaty significance scale, the specialists evaluate different components (also known as criteria) based on the relative relevance of each element Ci in comparison to Cj. When filling out the questionnaire, specialists choose a linguistic term that best conveys how critically important each component is with the others. The verbal phrase is then changed to its matching numerical value, which was previously determined (i.e., 1 to 9).

$$CR = \frac{lambda_{max} - n}{n-1} / RI \quad (1)$$

Normalize the comparison matrix.

Compute the weights of the criteria.

4.2 The Random Forest Technique

The supervised machine learning ensemble technique known as the random forest has lately garnered a lot of attention due to its increasing popularity. The foundation of a Random Forest is a decision tree, which acts as the basis classifier. In the process of creating random forests, randomization may take place in either of two methods, as suggested by the name. The first method is known as random sampling, and it involves drawing samples at random. The second method involves randomly picking qualities or features to generate decision trees. When a big quantity of data has to be categorized in terms of accuracy and correctness, decision trees are a viable choice for classification since they help logically organise the data [25-26,13].

Random Forest is the name given to the expansion of the decision tree. It constructs many decision trees and then combines them to get a forecast that is more accurate and consistent. Both regression and classification may be accomplished using Random Forest. The process of combining numerous machine learning models into one is known as "ensemble learning," and it's done to improve performance. The ensemble learning methods include random forest as one of the options. By using the random subspace approach, Ho has developed the world's first program for random forests [27-28].

The term "machine learning" (ML) refers to a collection of algorithmic frameworks that are used to teach computer systems how to learn and boost their efficiency by identifying patterns in data. ML approaches can make judgments with the least amount of interaction with people possible, and in comparison to biological brains, the computing power of technology machines is enormous. They may be broken down into three primary categories, the most common of which are supervised training, unsupervised learning, and reinforcement learning. When it comes to supervised learning algorithms, the user is the one who decides what they want the algorithm to do, and the algorithm models the correlations between the predictor factors (predictors) and the dependent variable that has already been defined [29]. As a direct consequence of this, supervised learning makes it possible to quickly solve issues involving regression and classification. RF, which was first developed by Breiman, is a well-known supervised learning approach that employs an ensemble of multiple classification and regression trees (CART) for classification, prediction, and the selection of variables. It has been put to use on several occasions across a variety of construction management domains. For example, Zhou et al. used an RF model to figure out how tunnel shape, geological features, and construction factors might all play a role in ground populations above tunnels. Zhang et al. made use of an RF technique to determine the most important factors contributing to delays in managers' making-do choices. An RF prediction model was created by Awada and colleagues to determine the chance of approval for cement pouring applications. To evaluate how outside ambient environmental conditions might impact construction productivity, Liu et al. made use of several meteorological parameters.

4.3 Naïve Bayes Technique

A supervised learning process that is a member of the family of probability different classifiers is known as a Naive Bayesian categorization. Due to the random nature of this technique, the primary advantage associated with its utilization is a low sensitivity to exceptions. As a result of this, the possibilities of skewness occurring within the prediction phase are reduced, which ultimately leads to a seems most for the data that has been provided. Because it exploits a utility function that reduces the relearning procedure of the probabilistic reasoning, this algorithm also has the benefit of requiring a smaller amount of data than other similar algorithms do to construct and build the model. This is yet another one of its many advantages. As a result, the NB method is a reliable classification tool that makes use of simple hypotheses in conjunction with straightforward methods to provide accurate predictions[30-33].

Provided that certain observations of feature events A have been made in the past, the well-established theory predicts that a specific probability level for a target event Y is likely to occur given that certain

observations of feature events A have been made in the past. The symbol A is used to denote the variable.

$$A = a_1, a_2, a_3, \dots \dots \dots \dots \dots \dots n \quad (2)$$

Therefore, a straightforward representation of the Bayesian equation by:

$$P(Y|A) = \frac{P(Y)P(A|Y)}{P(A)} \quad (3)$$

$$P(A) = \sum_{Y \in y} P(A, Y) = \sum_{Y \in y} P(A|Y)P(Y) \quad (4)$$

The Multinomial, Gaussian, and Bernoulli Naive Bayesian Classifiers are the three most common kinds of this classification method. The Multinomial type is the most common version of the NB procedures, and it is often used in circumstances in which the topographies or model forecasters are expressed in the form of generalized standards (i.e. like in rating scales 1–5). In situations when the characteristics are represented by a Boolean pattern, the Bernoulli kind of model is the one that is used for the was such. In the last step of the machine learning process, the Gaussian-based Naive Bayes algorithm is used. This algorithm is used when incessantly or non-discrete data for forecasters are provided.

4.4 Model Test

The following tests are carried out in mandate to verify the presence of the machine learning procedures in line with the real importance determined for the hospital structure possessions. The algorithm that achieves the best results is chosen to serve as the basis for the automated tool used to define priorities. There are many performance matrices used to test the model such as accuracy, sensitivity, and specificity.

5. Results and Discussions

The first thing that needs to be done to accomplish the goals that have been established is to determine the criteria and categories that will be used to assess the degrees of criticality and performing deficiency that is present in hospital building assets. The literature study that was offered earlier served as a source for the types and criteria that were used. Following the establishment of criteria, the N-AHP specialist surveying approach is used to verify and weigh the relative relevance of the requirements in question.

The present study has a total of thirty-one experts participating, all of whom come from similar professions that are pertinent to the field of healthcare building maintenance. These professionals include hospital operation and upkeep top management, maintenance workers, and government officials who are complicated with the preparation, checking and ordering of transportation structure and savings. Specialists sought to check the impact of the evaluation metrics and variables on the selection phase of healthcare construction facilities. They were also asked for allowance and priority on the supremacy of criticality and achievement defect variables on a pair-wise comparative basis.

Four groups were determined and incorporated into the measuring procedure of specialists in the areas of ability and upkeep organization of health care services to evaluate their corresponding objectives and standings in instruction to determine the levels of importance and risk related to hospital building assets. This was done to determine the risk stages that are affiliated with the hospital's new building materials. The following are the four categories that describe different characteristics of the hospital buildings' susceptibility to risk: Functional Criticality (OC), which evaluates the risks that arise as a result of the asset on an official level in addition to the historically seasoned disappointment trend of elements built on past annals and work instructions; Ecologic and Interpersonal Criticality (ESF), which is a measure of the degree of risks and severity; and Relevance of Element (SC), which consists of elements that order the relative reputation of the investment within the clinic power structure and procedure.

Let experts assess the standards to build the comparison matrix in tables 1 to 3. Then aggregate these matrices and normalized them. Then compute the weights of standards. The weights of principles are

organized as: HC1=0.52, HC2=0.201, HC3=0.229, HC4=0.043. The highest weight is the significant criteria followed by operational, then economic criteria. The least weight is the environmental criteria.

Table 1: The opinions of the first experts

	HC_1	HC_2	HC_3	HC_4
HC_1	1	(0.90, 0.10, 0.10)	(0.80, 0.25, 0.20)	(0.70, 0.30, 0.30)
HC_2	1/(0.90, 0.10, 0.10)	1	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)
HC_3	1/(0.80, 0.25, 0.20)	1/(0.60, 0.35, 0.40)	1	(0.80, 0.25, 0.20)
HC_4	1/(0.70, 0.30, 0.30)	1/(0.60, 0.35, 0.40)	1/(0.80, 0.25, 0.20)	1

Table 2: The opinions of the second experts

	HC_1	HC_2	HC_3	HC_4
HC_1	1	(0.80, 0.25, 0.20)	(0.70, 0.30, 0.30)	(0.70, 0.30, 0.30)
HC_2	1/(0.80, 0.25, 0.20)	1	(0.70, 0.30, 0.30)	(0.60, 0.35, 0.40)
HC_3	1/(0.70, 0.30, 0.30)	1/(0.70, 0.30, 0.30)	1	(0.80, 0.25, 0.20)
HC_4	1/(0.70, 0.30, 0.30)	1/(0.60, 0.35, 0.40)	1/(0.80, 0.25, 0.20)	1

Table 3: The opinions of the third experts

	HC_1	HC_2	HC_3	HC_4
HC_1	1	(0.90, 0.10, 0.10)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)
HC_2	1/(0.90, 0.10, 0.10)	1	(0.80, 0.25, 0.20)	(0.60, 0.35, 0.40)
HC_3	1/(0.60, 0.35, 0.40)	1/(0.80, 0.25, 0.20)	1	(0.90, 0.10, 0.10)
HC_4	1/(0.90, 0.10, 0.10)	1/(0.60, 0.35, 0.40)	1/(0.90, 0.10, 0.10)	1

Following the collection of all pertinent datasets related to the 394 distinct asset categories that can be found throughout 5 hospital buildings, the approach was applied to each data point that was obtained.

Subsequently, codes for Random Forest and NB examines were constructed on Embedded methods in instruction to assess their effectiveness in forecasting an appropriate importance level for clinic new building materials built on their evaluation and insufficiency stages. The results of these analyses will be compared.

A combination of Grid Search and Ten-Fold Cross-Validation was used to analyze every conceivable parameter combination to develop the most effective categorization models. This was done to acquire the largest Information Gain possible, which would indicate that the splitting and categorization system was effective.
In the first step, the random forest is applied to show the correctness of the method. The random forest achieved 0.95 accuracies.

In conclusion, it has been determined that a Grid Search technique cannot be used to develop a categorization model that is based on Naive Bayes. This is because Naive Bayes models do not include any parameters that may be tuned. As a consequence of this, taking into account the characteristics of the data features that were contained within the data sources, a GNB technique was developed, and a tag encrypting was implemented in the courses to convert the string class labels, which were Great, Moderate, and Little priority stages, into mathematical ones, which were 0, 1, and 2. The Python package known as Scikit-Label Learns Encoder was used to carry out this procedure. The NB has a 0.94 overall accuracy.

6. Conclusion

As was shown by the latest new COVID-19 epidemic, maintaining the ongoing accessibility and functionality of healthcare institutions and the properties that support them is of the highest significance. This provoked the necessity to develop more effective techniques to order the rejuvenation of healthcare possessions to express the consistently worsening situation stages of amenities in addition to the budget constraints and incomes existing to satisfy their commensurate

conservation and regeneration prerequisites. This necessitated the essential to grow more effective methods and techniques to order the regeneration of healthcare possessions. In contrast to the models that are primarily dependent on the physical situation for this intent that is found in the existing body of research, the authors of this paper devised an ordering model in which the mutable disappointment penalties of assets and the assignment reliability of those assets affect the importance level of those assets. The established model makes use of incorporation among Neutrosophic Logic and MCDM approaches, which ultimately results in an impartial and trustworthy importance level for clinic resources. In the field of asset prioritization and uses innovative machine-learning techniques were also used for the first time. This combination consisted of Random Forest and Naive Bayesian classification algorithms. This method is tested, and the algorithm that performed the best is outlined.

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