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Rule-based Fuzzy Logic for Implementing Disease and Risk Prediction Integrated Electronic Health Record (DRiP EHR)

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***Abstract*—Taking into consideration the importance of cloud computing for sustainable development and the Indian scenario with increasing investment in public healthcare, the paper presents a framework of Rule-Based Fuzzy logic for implementing Disease and Risk prediction integrated Electronic Health Record (DRiP EHR). As it is always said, prevention is better than cure, this is what the study aimed to deliver. The framework stresses the importance of implementing EHR and uses a novel approach of considering the severeness of symptoms for the identification of disease and predicting its percentage risk. This developed framework can be used as a CDSS (Clinical Decision Support System) by a practitioner which can help him make accurate data-driven decisions and can help the policy makers frame policies for further EHR implementation in the country and be helpful in providing low-cost quality healthcare services across the country.**

***Index Terms*— Electronic Health Record, cloud computing, risk prediction, clinical decision making and fuzzy logic.**

I. Introduction

Presently, the increasing cases of lifestyle diseases, the increasing demand for cost-effective healthcare facilities, the surge in investments in healthcare, the rise of technologies like telemedicine and the pivotal role played by the government in healthcare policy making are the key factors driving the healthcare industry in India. Though, [22] mentions 2.25 lakh crore were spent in healthcare in 2017-18 which is less than 1% of the GDP. According to [23], public expenditure on healthcare will be leaped by the government from 1.1% to 2.5% GDP in the next 4 years and to 5% in the following 5 years. This evidently shows that the nation is set on the road to progressive healthcare for every individual. For providing further enhanced facilities of healthcare in India, the healthcare industry in the country needs a fundamental change [5]. For this, technology can be used to enhance the reach of affordable, quality healthcare services [2,5].

[1] stated that well-adopted and secured cloud can lead to maximum gains for organizations like easy and ubiquitous access to data and applications and increased cost-effectiveness. The healthcare industry generates enormous amount of data from paper-based record-keeping, prescriptions, and patient-related data and medical reports [4]. This is where the requirement for Electronic Health Record (EHR) arises. An

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electronic health record (EHR) is a digital repository of a patient's prescriptions and reports, that make information availability instant and secured to authorized users. Thus it is an indispensable part of quality healthcare [9,14]. This data can be utilized to provide a holistic view for detection of advanced warnings in order to achieve disease surveillance that aids in the development of personalized patient care [26]. Considering a comprehensive disease and risk prediction method integrated with EHR can surge the quality of healthcare and reduce the cost of care drastically [9]. To address the above research gaps, the study states the following objectives:

RO1: To propose a Framework for successful implementation of DRiP EHR System

RO2: To make a decision matrix using AHP using symptoms for disease prediction

RO3: To formulate a probabilistic model using rule based fuzzy logic for assessing the percentage risk of the disease

To address the above-mentioned objectives, the paper focuses on the application of Rule-Based Fuzzy logic for implementing Disease and Risk prediction integrated EHR (DRiP EHR) to predict human disease that helps in early identification and diagnosis thus, increasing the quality of care. The paper is organized in the following sections: in Section 2 literature review congruous to this work is analyzed. Section 3 discusses the proposed framework of Rule-Based Fuzzy logic for implementing Disease and Risk prediction integrated EHR (DRiP EHR) and the methodology adopted and Section 4 then goes on to explain the execution in detail. Section 5 encapsulates the results obtained by the execution of the proposed framework. Section 6 states the conclusion and future scope. It gives a glimpse of this framework can be fitted to obtain the desired objectives at its maximum efficiency.

II. Literature Review

This section presents the analysis of the literature congruous to this work. The rigorous literature survey enabled a better understanding of the fundamentals of Health 4.0. A total of 30 papers were analyzed. They were selected by abstract reading and keyword search. This section of rigorous SLR is essential as this gives us a sound understanding of the research gaps of the current work and also shapes the direction of our further research.

A. Cloud Computing in Healthcare

Providing low cost, quality healthcare services accessible to people is a major challenge in developing countries [2]. To optimize the quality of care the costs shoot up and then the affordability becomes a barrier in providing healthcare services in a developing country like India. For low-cost quality healthcare and data-driven clinical decisions, it's necessary that we must use ICT [1,4,5,28]. But, the use of ICT in healthcare in India is low as compared to many developing countries. However, cloud computing shows promising growth in the healthcare sector in developing countries according to a survey conducted by [24]. [14] asserted that cloud supports remote diagnostics, telemedicine and treatment—helping the patient broaden the knowledge of their own condition. One such area that the research states cloud will have an impact is the delivery of health services—and the doctor-patient relationship. On a similar note, [21] emphasized on how the new paradigm of cloud computing has opened new possibilities, one of them being the healthcare sector. Taking this further, [25] discussed how the concepts of industry 4.0 can be applied to the healthcare sector for secure personalized healthcare through the tremendous use of CPS, (Edge) Cloud computing, the Internet of things, services and people. Cloud Computing has become a cost-effective and efficient alternative for physical data centers by providing data storage and other services at a cheaper price and is very economical obviating physical data centers. [9,21,29] stated that clinical decision-making beneath a big data environment is made possible due to the applications of IoT, CPS and mobile internet technologies.

B. Electronic Health Record

EHR is the vault of data regarding allergies, prescriptions, medical history, billing information, laboratory report, etc. of the patient, stored and provided securely, and multiple authorized users can accessible them. This can also save lives, streamline and organize healthcare value chain [25] and can provide accurate information for prompt clinical decisions to be taken. This data can be accessed easily and securely from virtually anywhere. As back as 2009, [30] used EHR in health information technology for clinical decision support systems to study the relationship between care quality and time. On a similar note, [1] showed that use of real time data analysis in comparison with traditional data gives more accurate results. With the purpose of to achieving these goals, latest technologies from the areas of Big Data, AI, IOT, Industry 4.0 and needs to be incorporated to generate real time interactive, cyber-physical systems. EHR reduces the frequency of medical error as it improves the clarity and accuracy of medical records while the decision-making mechanism assists the doctor to take a quicker decision [6,7,9]. One of the most difficult task in health informatics is to use EHR data in disease prediction wherein minimal amount of research is conducted. Many authors have tried and integrated risk prediction with EHR in his further works which will ease the physician work and increase the overall efficiency of the system [1,6,9,11,26]. But, none have done it for developing countries using predicting a disease and its associated risk. For example, [7] proposed a fuzzy case based reasoning (CBR) framework for early diagnosis and detection of a chronic disease to prevent further complications. While, [15] proposed a AI based model for the early diagnosis of another specific chronic disease. Also, [6,16,18] presented a framework aimed at developing clinical decision support system for another specific disease. The studies concluded with a point that these techniques can be coupled with EHR to make a robust CDSS system. Many AI techniques have been used to improve usability, the early detection and very few of them have focused disease diagnosis. But, the results are not highly accurate [7]. Fuzzy logic will enhance the measures of implementation [7]. Thus, taking into consideration the importance of cloud computing for sustainable development and the Indian scenario with increasing investment in public healthcare, it is imperative to reap the benefits to build a mechanism delivering affordable healthcare services.

III. Proposed Framework

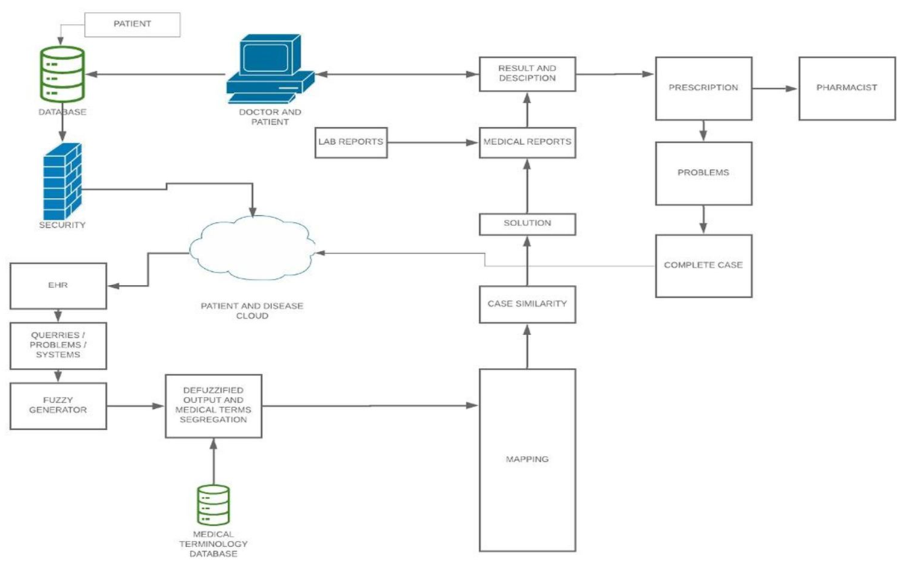

Figure 1. Proposed framework

To help in empowering the patients with knowledge of their condition and to support early diagnosis and treatment, a framework pertaining to the healthcare sector in India has been proposed. This section proposes a Analytical Hierarchy Process (AHP) [17] incorporated Rule-Based Fuzzy logic for implementing Disease and Risk prediction integrated EHR (DRiP EHR). The proposed framework is demonstrated in Figure 1. It addresses the patient-doctor relationship. The framework is divided into 4 broad areas namely, the database, front end user interface, the multi criteria decision making Analytical hierarchy Process (AHP) , and the fuzzy logic generator. The software MySQL has been used for creating the database, Visual Studio for the front end, Excel for creating template of AHP and MATLAB for the fuzzy generator.

An electronic health record (EHR) is a digital repository of a patient's prescriptions and reports. This forms the first area of the framework. As shown in Figure 1, the data of the patient is entered into the database. When a patient arrives, the doctor asks the system for a Case ID, and depending on the latest number available, the case ID is generated for the patient. This forms the primary key of the patient. The doctor takes down the patient details like name, age, gender, height and weight, which are fed to the front end which in turn gets inserted into the database under the table name 'patient' on the click of the button 'INSERT

PATIENT DATA'. Thus, a record is created. As this was a first attempt to use EHR data in disease prediction, the data of the patient considered during execution is hypothetical. However, the working model proposed considers the patients age to be in the range of 20-45.

Sr. No.	Name	Sr. No.	Name
1	HEADACHE	21	BODY PAIN
2	FEVER	22	URINE INFECTION
3	VOMITING	23	LOSS OF APPETITE
4	STOMACH ACHE	24	HUNGER
5	LOOSE MOTION	25	BLISTER
6	REDNESS OF EYE	26	MOUTH INFECTION
7	ACIDITY	27	LAZYNESS
8	RASHES	28	NON-HEALING OF WOUNDS
9	THROAT PAIN	29	INTOXICATION
10	CONSTIPATION	30	DEHYDRATION
11	COUGH	31	INFECTIONS
12	INDIGESTION	32	BLURRED VISION
13	WEIGHT GAIN	33	WEIGHT LOSS
14	DARK URINE	34	BLOODY COUGH
15	EXESSIVE SWEAT	35	ULCER
16	BP	36	NAUSEA
17	URINATION	37	WEAKNESS
18	DROWZINESS	38	CHEST PAIN
19	COLD	39	THIRSTY
20	FATIGUE		

Figure 2. Symptoms of disease

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Sr_No	NAME	SYMPTOM_1	SYMPTOM_2	SYMPTOM_3	SYMPTOM_4	SYMPTOM_5
1	JAUNDICE	FEVER	DARK URINE	VOMITING	LOSS OF APPETITE	
2	DENGUE	FATIGUE	FEVER	BODY PAIN	RASHES	VOMITING
3	TONSILLITIS	FEVER	COLD	COUGH	THROAT PAIN	
4	CHICKEN POX	FEVER	HEADACHE	RASHES	LOSS OF APPETITE	
5	TUBERCULOSIS	FEVER	COUGH	WEIGHT LOSS	WEAKNESS	
6	TYPHOID	FEVER	BODY PAIN	LOOSE MOTION	STOMACH ACHE	
7	CHOLERA	LOOSE MOTION	FEVER	DEHYDRATION	VOMITING	

Figure 3. Disease and it's symptoms

Figure 2 shows the 39 critical factors that are taken from expert opinion as the common symptoms of various diseases. They form the input of the patient. This input varies as per the condition of the patient. The doctor asks the patient about his/her condition and selects the symptoms from the drop down box and values are noted wherein the patient has to rate the severeness of the symptoms on a scale of 1 to 9 where 1 is least severe and 9 is most severe. The 'INSERT' feeds this data into the database and it is stored in the table 'calculation'. After consulting a general physician, we have collected data for 7 common diseases namely, Jaundice, Dengue, Tonsillitis, Typhoid, Chicken pox, Cholera and Tuberculosis. Every disease has its own symptoms. This data was collected and then studied and thus we compiled all of it and formed a table in the database under the name 'disease' which constitutes the names of the 7 diseases and its corresponding symptoms (Figure 3).

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

Sr_No	NAME	CURE_1	CURE_2	CURE_3	CURE_4
1	JAUNDICE	DRINK WATER	BRISK WALK	BED REST	
2	DENGUE	BED REST	DRINK WATER	USE MOSQUITO REPELLANT	AVOID WATER STAGNATION
3	TONSILLITIS	SALTWATER GARGLE	DRINK WARM WATER		
4	CHICKEN POX	MAINTAIN ISOLATION	STERILIZE UTENSILS	BURN FALLEN SCABS	
5	TUBERCULOSIS	MAINTAIN ISOLATION	CLEANLINESS	AIRY SURROUNDINGS	
6	TYPHOID	CLEANLINESS	SANITATION		
7	CHOLERA	ELECTROLYTES	CLEANLINESS	SANITATION	PROPER WASHED AND COOKED FOOD

Figure 4. Disease and its precaution

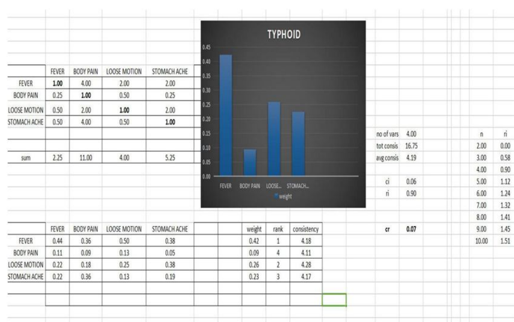

Figure 5. Weights for typhoid

Also, the aim of the approach with the disease identification is to provide remedies at a basic level and for that the diseases were further analysed and the results were collectively stored in another table in the database under the name 'prescription' (Figure 4). The task now is to identify the probable disease patient is most likely suffering from. Analytical Hierarchy Process (AHP) is a mathematical tool for problem solving [17]. It is a structured technique used by decision makers to formulate a problem, analyse it and then make decisions on the solutions obtained [17]. In our framework, we have used AHP for the determination of the weights of the symptoms for a particular disease. A number of physicians were consulted and expert opinion was also taken into consideration. A pair wise comparison matrix for every disease consisting of its symptoms is made. This comparison matrix has been solved with the AHP method to establish the relative importance of the criteria [13]. For ensuring consistency of the above result, the maximum eigen vector or relative weights are calculated. Then, the consistency index (CI) order 'n' for each matrix has been calculated using (1). On this ground, the CI and Random Consistency index (RI), the consistency ratio (CR) is computed using (2). The CI and CR are defined as follows:

$$CI = (\lambda\ max - n)/(n-1)\ . \qquad (1)$$

The consistency ratio is hence computed using the formula

$$CR=CI/RI\ . \qquad (2)$$

where RI varies according to the order of the matrix.

For each and every disease such a decision matrix is made. The excel sheets for all the 7 diseases were created and thus the respective weights were generated (Figure 5). The weights of each of the diseases is saved in the database in a table under the name of that disease. This data consisting of the weights along with the data of the diseases forms the disease cloud and the medical terminology database (Figure 1). Next part consists of the query system. Suppose D1 is Expected value of TYPHOID, D2 is Expected value of DENGUE and a, b, c, d, e be the inputs of user which correspond to weights of Symptoms of Typhoid T1, T2, T3, T4 and similarly for DENGUE be C1,C2,C3,C4. The maximum value of D is the expected Disease.

$$D1= a*T1+b*T2+c*T3+d*T4+e*0\ . \qquad (3)$$

$$D2= a*C1+b*C2+c*C3+d*C4+e*0\ . \qquad (4)$$

After clicking the ‘CALCULATE’ button, this expected value is calculated. If the patient has inputted a symptom that is not there in the pairwise comparison matrix the weight of that symptom is taken as zero. On the click of ‘NEXT’ the next form appears and when the ‘EVALUATE’ button is clicked, the name of the predicted disease appears. With this we have successfully predicted the disease the patient is suffering from. According to the weights obtained from the AHP, the fuzzy was generated for all the diseases. The symptoms are the inputs and the disease risk is the output. The range for the inputs is 0-10 and for the output is 0-100. The membership functions for the inputs and the outputs were triangular membership functions. The inputs have 3 membership functions as High (H), Medium (M) and Low (L). For the output, 5 membership functions were taken as Very Low (VL), Low (L), Average (A), High (H) and Very High (VH). With this, the rule base was generated. The doctor needs to open that fuzzy for which the disease is identified by the probabilistic model. The rules are viewed and the values of the symptoms i.e. the severeness is fed to the rule viewer. This result obtained is entered by the doctor on the form as the percentage risk predicted by the fuzzy generator. Further, on click of ‘NEXT’ button, the next form appears. On the click of ‘GENERATE’ button, the prescription for the predicted disease is generated. As we had earlier mentioned about the table prescription (Figure 4) stored in the database which consists of the cures of the 7 diseases. Thus, the same data is displayed as the disease has been successfully identified. The doctor can input the medicines in the box. Thus, the entire prescription is created. On the click of ‘NEXT’ button the last form appears. Now, on clicking ‘REPORT’ button, all the details of the patient are displayed, right from the name, age and along with the predicted disease and its risk. The ‘SAVE’ button stores this entire data in the database under the table record. Therefore, patient record is thus created and saved in the database. Thus, the disease is identified and its risk is predicted. Furthermore, on click of ‘PRINT’ button, the report is printed. Thus, this record created can be accessed by the doctor during the patient next visit. The prescription generated can be sent to the pharmacist that will display only the names of the medicines and thus preventing privacy of the patient.

IV. EMPERICAL RESULTS

So, starting with the foremost, let us consider the example of a patient who visits a general physician. The doctor asks for his details and then with this the patients Case ID is generated and his/her details are noted and thus saved in the database (Figure 6). After this, the severeness of the symptoms are noted (Figure 7). It was found that the expected value for TYPHOID was the highest and thus the system showed predicted disease as TYPHOID. Now, the fuzzy for the predicted disease which is typhoid is opened and respective values for the symptoms with reference to the values given by the patient are fed in the fuzzy rule viewer. Thus, the percentage risk is evaluated and this is our desired result.

This result obtained is entered by the doctor on the form as the percentage risk predicted by the fuzzy generator. Hence, doctor enters the value of the percentage risk predicted by the fuzzy logic controller which was ‘45%’. Figure 8 shows the disease identified as TYPHOID and thus the execution and calculation of percentage risk for the patient. On the click of ‘GENERATE’ button, the prescription for the predicted disease is generated. Thus, the precautions for TYPHOID is displayed and the doctor writes the necessary medicines for the same. Hence, the entire prescription is created. On the click of ‘NEXT’ button the last form

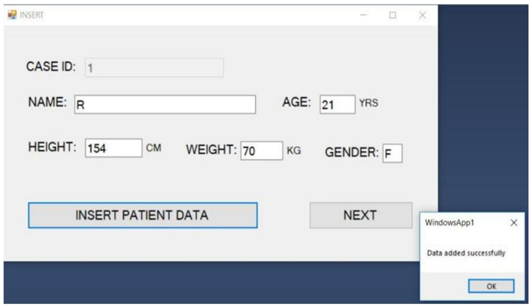

Figure 6. Patient Details

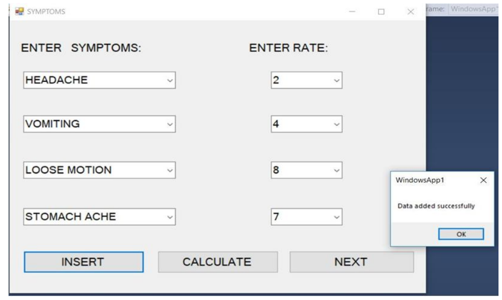

Figure 7. Severity of the symptoms of patient

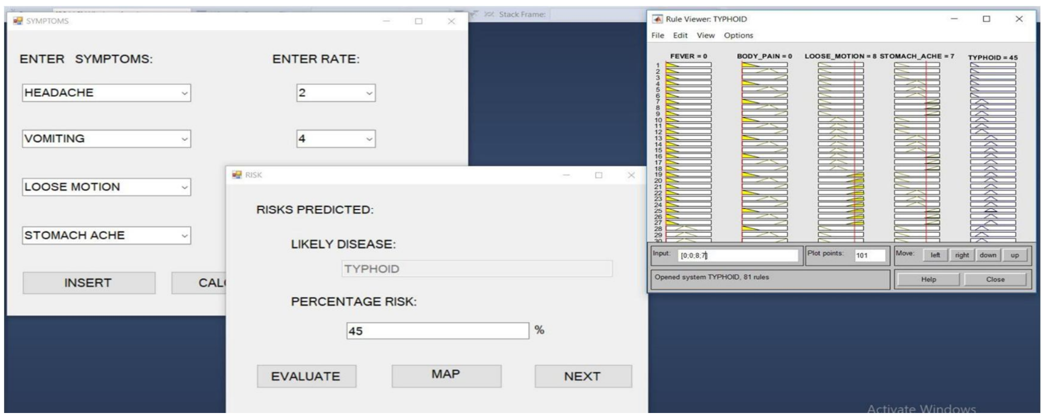

Figure 8. Disease identification and percentage risk predicted using fuzzy logic

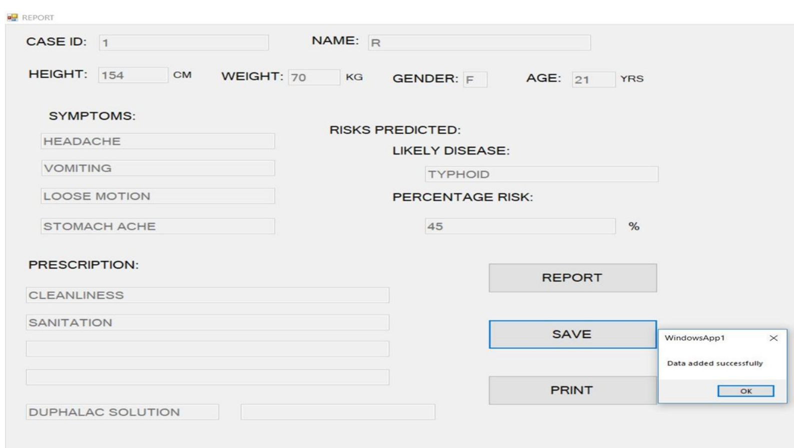

Figure 9. Full report of the patient

appears. Now, on clicking 'REPORT' button, all the details of the patient are displayed, right from the name, age and along with the predicted disease and its risk (Figure 9). The 'SAVE' button stores this entire data in the database under the table record. Therefore, patient record is thus created and saved in the database.

V. Results and Discussions

A AHP driven probabilistic model using rule based fuzzy logic for assessing the percentage risk of the disease was proposed. This is for the first time disease and risk Prediction framework is proposed and a model is build integrating it with EHR. Early identification reduces the complications one can go through in the later stages and thus increases the survival rate. Thus, even common diseases shall be cured at an early stage of diagnosis. The framework also aims at providing a safe and secure electronic health record. Thus, an one time password (OTP) system can be incorporated. Each time a patient visits the doctor, an OTP will be sent on the patients registered mobile number and inputting this OTP in the system will provide access to the record. One important aspect of the framework is case similarity mapping. As the database increases, similarity can be easily mapped for a particular disease. For every patient, the record will show that his illness has a similarity with how many patients in the database. Also, to prevent the privacy of the patient, only the number of patients will be shown and no other data will be displayed. Therefore, a vital area of application of case similarity can be the identification of epidemics in a particular area.

VI. Conclusion and Future Scope

This study provides a theoretical groundwork and a foundation for understanding the basics of Health 4.0 and also the EHR implementation in India. Academicians will benefit by further developing disease specific symptoms and their inter-relationships. The policy makers can align this framework with the Frameworks for AYUSHMAN BHARAT SCHEME and drastically reduce the cost of care while enhancing the quality of care with careful use of technology. Our results are based on the data which we use is from a physician which is bound to vary so there can be a conflict of interest. The risk prediction can be further optimized using more accurate more factors for each disease. This study can usher further research in the Healthcare Supply Chain and can be helpful in developing an ecosystem conducive for the digitization of the entire healthcare supply chain.

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