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Critical Care Medical Expenses And Affordability: An AI-Based Prediction Model

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Abstract:
Background: *The advances in the medical field and pharmaceutical sciences year on year have enhanced the human life span in developed and developing countries. A major factor that has contributed is the advancements in medical technologies, especially in the area of AI. However, these technologies are limited to treatment and care once the problem has been diagnosed. The Prediction of medical problems and the cost related to the treatment is an area where one draws a lot of unknowns. This study attempts to bridge this gap of unknowns using AI technology, especially for the section of people who cannot afford the high cost of critical care, using crowdfunding sources.*
Materials and Methods: *This study has used MIMIC III data to train the model to predict the duration of total stay in the ICU. The cost of the stay, along with other predictors, was input to the trained KIVA crowdfunding model to predict if the individual was eligible for a loan to meet his/her critical care medical expenses. In the study, data selection, data preparation, selection of features, and their correlation to results were done to ensure proper results from the AI-trained model. Several AI algorithms were used to ensure a proper fit for the business solution. A business interface was developed to connect the functioning of the two AI-trained models.*
Results: *using the study and the application developed, the solution was able to predict the number of days of stay in ICU and also calculate the cost of the critical care for the stay. We also successfully overcame the challenge where the cost of ICU stay varies from country to country and within a country, from region to region. The result from crowdfunding an AI-trained model was able to predict the frequency of repayment of the loan, and also the EMI*
Conclusion: *The challenges faced by the medical fraternity vis-à-vis the patient's financial affordability are multi-dimensional. Our study and model, though small, have laid down the foundation whereby one can venture into the other dimensions. There is a need to understand the technical and business aspects of the problem and build models using existing AI-based technologies to find the solutions*
Keywords: *ICU, MIMIC, KIVA, Crowdfunding, AI-trained model, cost-prediction*

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I. Background

Last hundred years, we have seen the average lifespan grow by 70-80%. Primarily, the advances in the medicalfield and pharmaceutical sciences year on year have enhanced the human life span in developed and developing countries. A major factor that has contributed is the advancements in medical technology. However, these technologies are limited to treatment and care once the problem has been diagnosed. MRI, Ultrasound, Laparoscopy, and Robotic Surgery are some examples of it. The Prediction of medical problems and the cost related to the treatment is an area where one draws a lot of unknowns. As of the last Decade, the advent of Artificial Intelligence (AI) has helped prediction of Lung Cancer using imaging of Biopsy Tissues, Heart Diseases using lifestyle factors,etc., and more. These Predictions of major diseases are still in very formative stages and will become more and more accurate as the AI technology advances. However, from a patient's point of view, in the area of critical care, how long the treatment takes and the question of cost and affordability will remain unanswered at best. Critical Care and Treatment, irrespective of developed or developing countries, is expensive. Treatment for Cancer, heart diseases, knee replacement, hip joint replacement, and brain Tumor removal are some of the most expensive treatments. In developed and developing countries, the rich and some upper-middle-income groups can afford the Medical Insurance coverage for such expenses. However, when it comes to developed, developing, and poor countries, the middle-income, lower-middle-income, and low-income strata of people find it difficult to bear the medical expenses. More shocking for them is the unknown associated with such situations as the duration of the treatment and the cost linked with it. Some of the key costs are

- Stay in the ICU or NICU
- Medical Surgery
- Medical Professional Expenses
- Pre and post-care expenses
- Medication

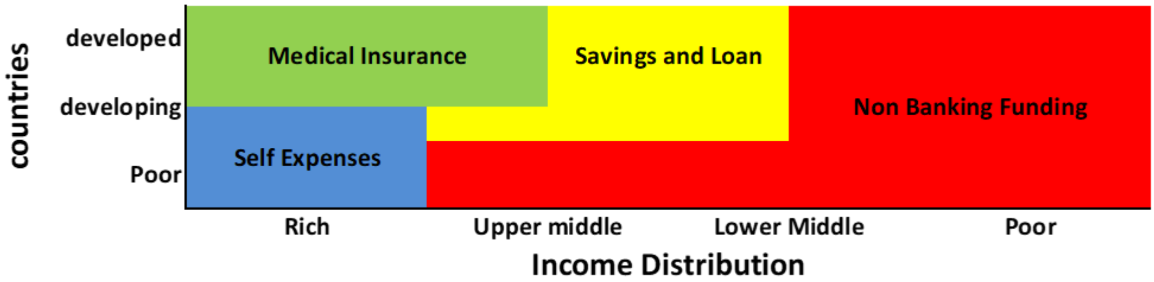


Chart 1 – Medical Expenses of Critical Care vs. Economic strata of the populace

Chart 1 shows a breakup of how people of different income groups are dealing with the Sudden and unknown medical expenses across developed to Poor Countries. The Rich and upper-middle-income families generally can afford the medical expenses by taking medical and health insurance. The worst hit in the spectrum are poor or low-income families who have to depend on either government assistance or non-banking finance companies. Very often, the delay in arranging finances results in human mortality.

India, like many other countries, is also part of the phenomenon where the cost of healthcare is rising. Access to health care and expenditure on it vary across countries. India has a huge population and a proportionately larger health care sector, which is a source of employment for many. The healthcare industry consists of hospitals, medical colleges, private nursing homes, clinical trials, telemedicine, medical tourism, and health insurance. India's healthcare systems, both public and private,are the major contributors to the country's GDP and have recorded a threefold increase, growing at a CAGR (Compound Annual Growth Rate) of 22% to reach 372 billion USD, according to a 2022 economic survey. This survey also reports a public expenditure of 2.1% of the GDP on healthcare. India's healthcare market is valued at USD 98.98 billion and is expected to grow at a CAGR of 8% from 2024 to 2032, with a projected value of 193 billion USD by 2032. With the current trends of rising costs of medical care, ageing population, and an increase in health care requirements, can technology help? Is there a solution that can help medical establishments to accurately predict the cost of medical treatment (for example, being number of days of stay in the ICU)? Is there a non-banking finance company that can predict if the loan can be provided to the patient or his/her family to cover the cost of critical care? Can we use AI tools to resolve this paradigm?

Objective - The Objective of this paper is to analyze and find an AI solution that can address the fundamental question of the cost of critical care duration and affordability across the income spectrum of populace. This paper attempts to build an AI model along with solution to predict the days a person will be admitted to ICU using ML/DL algorithms and then pass the cost of ICU stay to another AI ML/DL algorithm to predict whether the individual is eligible for funding for his/her medical expenses from a non-banking financial company such as crowd funding.

II. Literature Review

Critical care, as per Meghan Prin and Hannah Wunsch [1], forms one of the most expensive components of the cost and has been improving over the years. The availability of beds, doctors, and support staff varies from hospital to hospital and country to country. Bruyneel et al [2] studied the ICU costs and analyzed the various costs associated with each day of ICU stay in Belgium. The cost can be broken down into three categories, namely – Personnel, equipment and Medication, and Hospital expenses. The comparison showed the costs vary from hospital (Private and government-assisted) to hospital and country to country.Narendra N Khanna et al [3]in their article have shown the linear link between predictors and the outcome using Machine Learning algorithms. Furthermore, their research and analysis on imaging from CT Scans, MRI using Gray scale and Deep learning algorithms like Convolution Neural Networks (CNN) can extract features for the prediction of the level or stages of such diseases as Lung or other Cancers. These levels can be used for **predicting the number of days of stay in ICU,** the treatment,etc, during critical care and thereby **calculating the potential cost of the treatment**. Yin New Aung et al[4] in their paper attempted to determine the cost and length of stay in the ICU and the factors that influence the duration of the stay. Using the case mix system, they analyzed the discharge summaries of patients to determine the length of stay (LOS) and thereby calculate the cost of ICU. One of the key conclusions of their paper was that ICU cost was a major component of the entire critical care cost. Many more studies have indicated that irrespective of the diagnosis or treatment, the ICU cost per day and LOS drive the critical care cost overall. Key Coleman [5] in his publication "Lowering health care costs through AI – The Possibilities and Barriers" discusses that AI can or may help reduce the treatment cost of patients because of features like early detection. However, such lowering of cost will be disease-specific and not across the entire health care system. He advocates the use of Large Language Models (LLM), Machine Learning (ML), Artificial Neural Networks (ANN), and Generative AI tools for early detection and Prediction. He also emphasizes a body where government, agencies, and independent Medical regulators assess the use of AI models. Serap Bedir [6], Wahl B et a l[7] in their papers have explored the rising cost of health care and use of AI models to predict the exact cost of the critical care component of health care. The AI models have been used in medical care, but this remains limited to developed countries. Use of such technologies in resource-poor nations is very limited. However, things are changing.

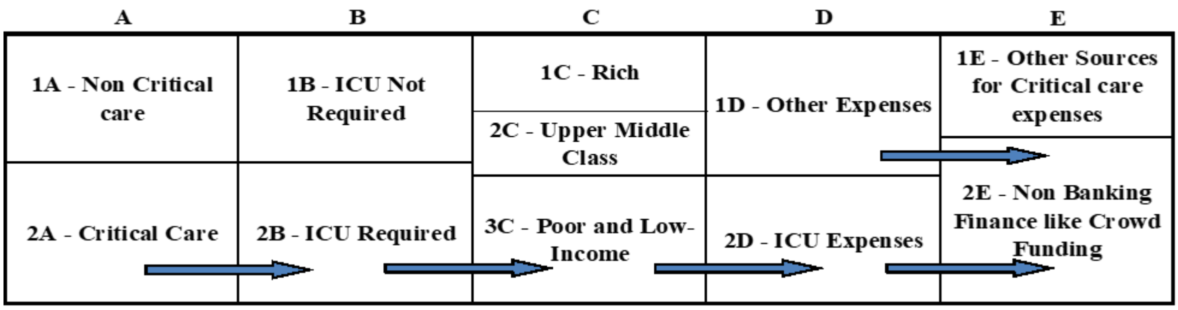
III. Materials And Methods

Scope - This paper attempts to identify and banks on an AI model to answer the question of the "Unknown" in the medical scenario. For our case, we have limited our study to the Red area on Chart 1 and have taken only the cost of ICU Stays. Further, using the crowdfunding Sources data and feeding the AI model, we have predicted whether the individual is eligible for a loan to meet his/her medical expenses for critical care. We used MIMIC III data to train the model to predict the duration of total stay (Length Of Stay (LOS)). The cost of the stay, along with other predictors, was input to the trained KIVA crowdfunding model to predict if the individual was eligible for a loan to meet his/her critical care medical expenses.

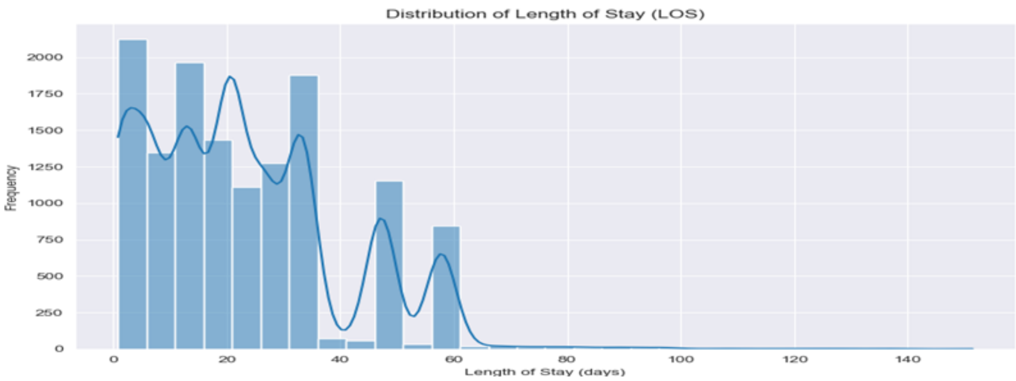
MIMIC III is a large, publicly available database developed by the MIT Laboratory for Computational Physiology. It contains detailed, de-identified health-related data associated with over 60,000 ICU admissions between 2001 and 2012 at the Beth Israel Deaconess Medical Center in Boston, Massachusetts. This is a large source of Open data which contains a history of patients who have been admitted either once or more than once for critical care.

KIVA is a nonprofit organization that operates a crowdfunding platform for microloans, aimed at expanding financial access to underserved communities around the world. It connects individual lenders with borrowers who need small loans to improve their lives, often in developing countries. Health and Medical-related categories are one of the sectors this organization provides loans.

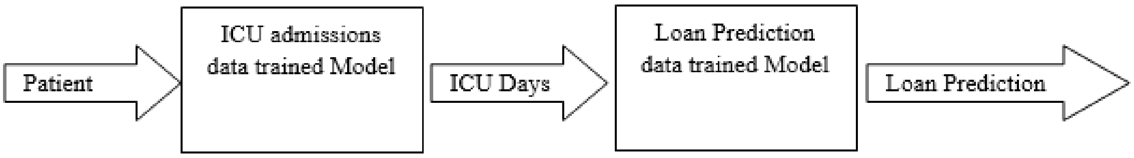
Using these two data sources and AI ML/DL Algorithms, prediction models were trained. This method does not cover all medical care scenarios. The diagram below explains the complete medical scenarios and the scope of our study and model.



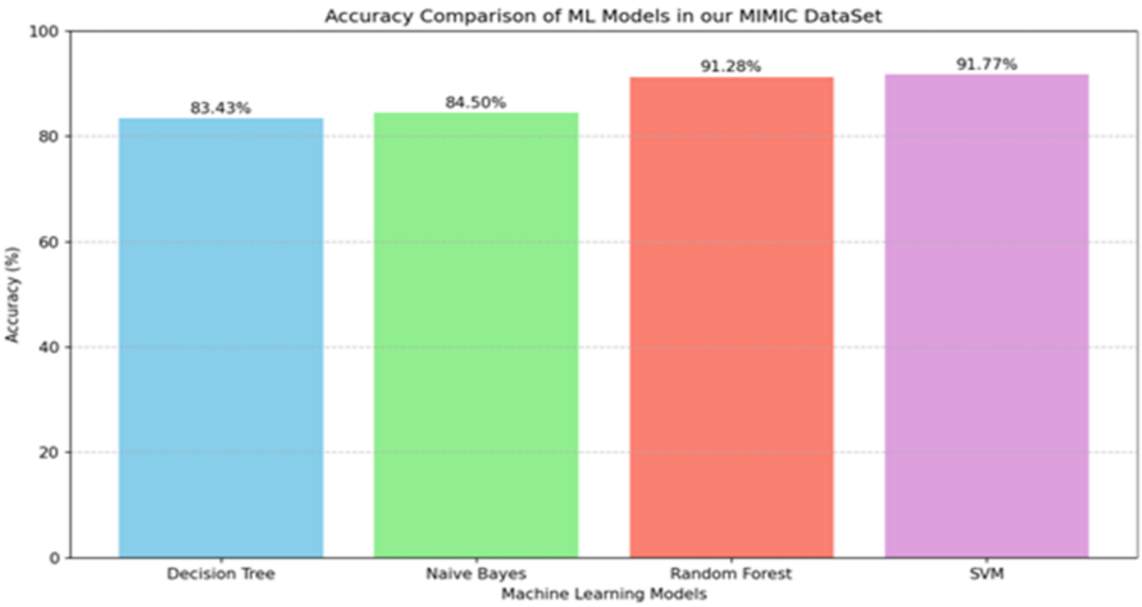
The Blue arrow indicates the path 2A-2B-3C-(1D&2D)-2E, which is covered in the model. All other paths are not covered in the model. In this case, we did a statistical analysis of the relevant MIMIC III data, and our results we depicted in terms of LOS as shown below.



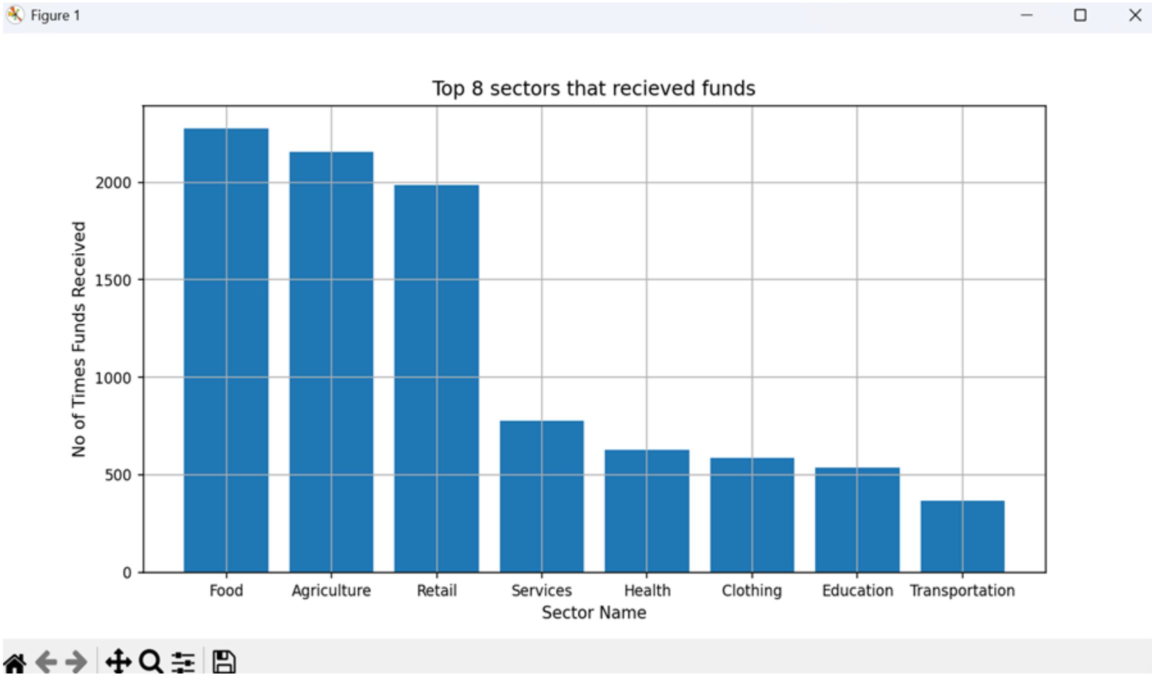
However, the AI model developed lays down the foundation to calculate the medical care (Critical as well as non-critical) expenses.The diagram below provides a fundamental concept of the method we used to calculate the LOS, which was then passed to the next AI model, where the expenses of the critical care are calculated and the model predicts if or not the patient will get a loan for his/her medical treatment.



It is the decision of the medical professionals whether ICU admission is required and is based on the medical condition of the patient, medical tests conducted like X-RAY, Blood test, etc. The input to the AI-trained model in this case is post this activity, where the medical professional has already decided that the patient needs ICU admission. Based on the condition of the patient, the medical professional decides the ICU and ward where the patient will get his/her treatment. Additionally, the age and gender of the patient is taken into account to decide the LOS. Based on this information provided by the Medical professional, and the age and gender, the AI-trained model predicts the Length of stay in the ICU for the patient. For training purposes, we split the dataset in the ratio of 80 (X) and 20 (Y). Different models were trained using the four algorithms - Decision Tree, Naïve Bayes, Random Forest,and SVM. Statistical metrics (F1 Score, ROC (Area under the curve), Accuracy, balanced accuracy,etc) were used to evaluate the Models. The matrix elements denote the True Positives (TP) and True Negatives (TN), which helped us decide on the Algorithm model we wanted to use.The approach also included the AI ML/DL algorithm, where the accuracy was highest and the error probability was the lowest.



The error probability in the Random Forest and decision tree was found to be the lowest among the four algorithms. The time to run was the smallest in the case of the Decision Tree Algorithm KIVA Crowdfunding has data primarily from poor to developing countries where the organized banking sector is limited. Further, the loans given out cater to the poorer sections of society, which is primarily the target of our research and model. This data caters to loans in various sectors like Food, Agriculture, retail, and services etc. Health care is the top sectorafter these four categories,which is catered for by the Kiva Crowdfunding as shown in the following chart.



In addition, the statistical analysis of the data in the four quartiles is shown below.

--- Statistical Information ---

	id	funded_amount	partner_id	term_in_months	lender_count
count	10022.000000	10022.000000	9812.000000	10022.000000	10022.000000
mean	888.414987	920.355219	151.726152	14.222012	26.125823
std	1055.159065	1099.532702	62.383451	8.649208	29.320673
min	0.000000	50.000000	9.000000	1.000000	0.000000
25%	300.000000	300.000000	112.000000	8.000000	9.000000
50%	525.000000	550.000000	145.000000	14.000000	17.000000
75%	1025.000000	1050.000000	183.000000	14.000000	32.000000
max	12925.000000	12925.000000	343.000000	137.000000	408.000000

In this case the evaluation of AI DL algorithms resulted in ANN Algorithm being the best fit for our features selected.

S/No	EPOCH	Accuracy (%)
1	Epoch-1	56.47
2	Epoch-2	96.61
3	Epoch-3	98.80

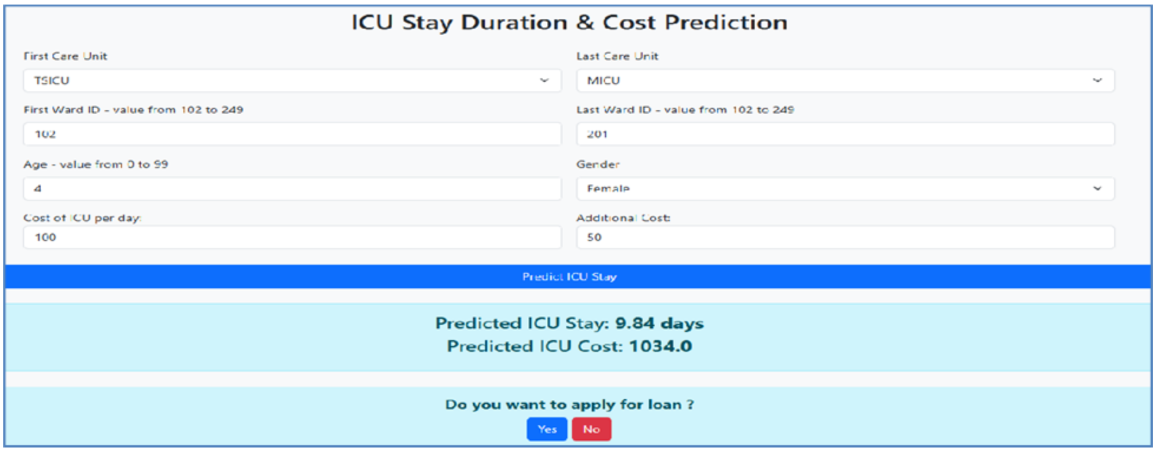
Exclusion criteria - The non-critical care component and costs have been excluded from this study

Challenge and Solution- The cost of ICU has been calculated as the number of days or length of stay in ICU (LOS). The cost per day of ICU varies from country to country and within countries, varies from region to region, and hospital to hospital. At present, we do not have the dataonthe ICU cost per day of various hospitals. Apart from ICU cost, three other costs become part of the critical care cost. The three costs are Medical professional costs, Medications, and Hospital expenses. It is safe to assume that these three costs are dependent on LOS. To overcome this challenge, in the web front end, we have provided an input field where the user can enter the "cost of ICU per day (CP)". Another field to cover other costs is also an editable fieldin the web front-end called "Additional cost (AC)". The formula for totalcost is then as Total Cost = (predicted LOS * CP) + AC

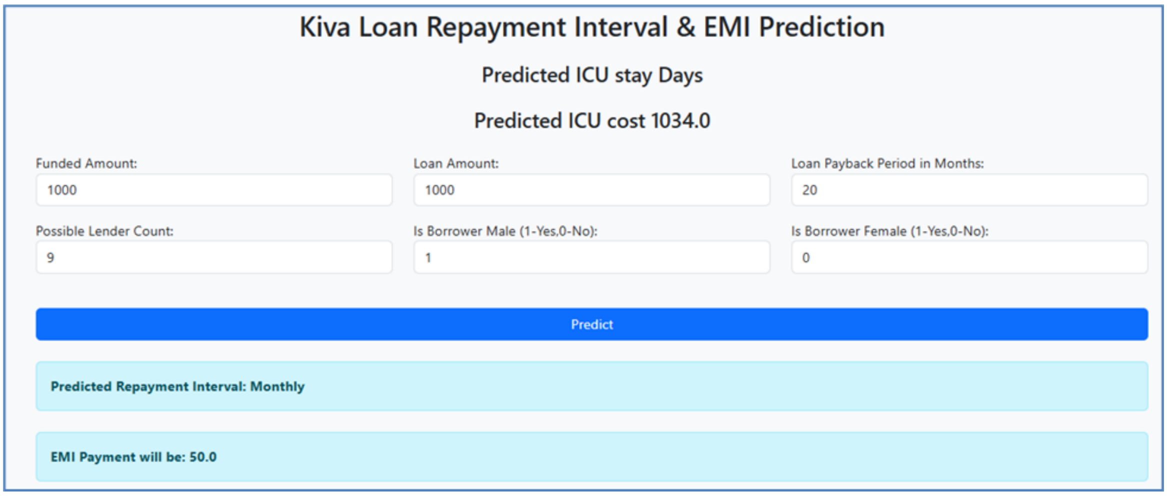
Methods–The entire model to predict LOS and loan feasibility was done using two pages in the Web front-end. The results of the first prediction of LOS were fed into the KIVA crowdfunding AI Model. The final result was either that the loan was approved or rejected. If the repayment frequency was weekly, monthly, or Bullet, the logic further calculated the Loan EMI. An irregular payment frequency was assumed as rejection of the Loan. The entire solution was dependent on the robust interface between the two AI models, and the manual entry of CP and AP made the overall model capable of implementing it in any geographic location.

IV. Results

In both models developed, we completed the feature analysis and the correlation between each feature, the predicted result, and its effect on other features. In the case of MIMIC data, the LOS was impacted by the ICU and the ward. Additionally, age and gender correlation showed the effect on LOS prediction. Learning from the exercise was the right choice of data, the strategy for cleaning the data, and also the approach for filling in the missing values. In our case, the dimensions of cost were immense, as the AI model only predicted the LOS. This challenge was recognized upfront, and a solution was arrived at from the very beginning.



Above is an input process where a four-year-old girl is admitted to the ICU. The ICU cost per day (CP) is 100 units, and the additional cost (AC) is 50 Units. AI model prediction is that the ICU stay will be 9.84 days, and the calculated cost is 1034 units. This is then fed to the KIVA crowdfundingAI-trained model as depicted below



Here, nine lenders have agreed to loan 1000 units for 20 months. The borrower is a male. The KIVA AI model predicts that the loan payback frequency will be monthly, and EMI payments will be 50 Units per month.

V. Conclusions

Predicting the length of Stay in the ICU and calculating the cost associated with it is a real challenge for medical establishments today. Each case of medical emergency requiring ICU stay is different. Even if we can predict the LOS and the cost, the next challenge for the poorer section of people is to arrange the funds. Our attempt in this study was to find a simple business solution to the challenge that the poorer section of people face in this regard. The Study and the AI models have helped us understand the basic concept of developing business applications using AI, ML, DL, and the available Algorithms. Also, it is very critical to link business problems with a business interface, whereby more than one trained model can be connected to solve a real-life business problem. As in this case, we connected the outcome of MIMIC prediction with the input of crowd crowd-funding KIVA AI trained model.

This entire exercise has also helped us better understand how the AI-supportedbusiness application becomes robust, scalable, and flexible if the feature selection and correlation to the outcome are evaluated properly. This can be accomplished if the data preparation, including data correction and completing the missing data, is done properly.

Future Work & Discussion- The challenges faced by the medical fraternity vis-à-vis the patient's financial affordability are multi-dimensional. Our study and model, though small, have laid down the foundation whereby one can venture into the other dimensions. There is a need to understand the technical and business aspects of the problem and build models using existing AI-based technologies to find the solutions.

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