

Fuzzy Expert System for Bank Loan Approval

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Abstract

Background: Bank loan approval is one of the important pillars of the banking system; it is the process of approving or denying a loan to companies or individual customers by the bank. The approval process has a lot of parameters to be taken into consideration, which is ambiguous in nature; hence, bank loan approval required special knowledge to be executed. **Aim:** Due to the ambiguity of the approval process, we proposed the use of a fuzzy expert system which proved to handle such ambiguous problems to help banks easily and accurately make decisions on bank credit approval. This proposed fuzzy expert system will help banks in making accurate decisions easily even in the absence of the domain expert on credit approval based on the knowledge of an expert in the field. **Method:** The proposed fuzzy expert system was developed using a fuzzy tool in MATLAB software and it has two stages, where the first stage decides on three output parameters which are repayment, ability manage, and risk. Total asset, credit repayment, 18% earning, business stability, credit missed, asset/debt ratio, bond rating, and dollar to Naira ratio are the input parameters for the first stage of the system. The second stage of the system used the output parameters values of the first stage as its input parameters to make the final decision on whether to approve the credit or not. **Results:** Using 0.938, 0.583, 0.715, 0.88, 0.104, 0.897, 0.842, and 0.856 membership degree for total asset, credit request (loan amount), 18% earning, business stability, asset/debt ratio, bond rating, and dollar to naira ratio respectively as an input to the first stage of the system, the resultant output were 0.625, 0.367, and 0.25 for repayment, ability manage, and risk respectively, and those were feed to the second stage and result in 0.656 loan membership degree which means the loan can be approve to the customer.

Keywords: Loan Approval, Banks, Decision Making, Ambiguity, Fuzzy System

1. Introduction

Bank loans are needed in cases where financial resources are insufficient compared to inflation. Inflation generally occurs with the increase in the prices of all goods in the economy. The decrease in purchasing power with the increase in inflation is among the factors that negatively affect society. Although the increase in inflation causes purchasing power to decrease, bank loans emerge as a savior to meet the needs. Bank loan; It is used for reasons such as inflation, political situation, financial insufficiency, or investing. Bank loan is also important to startup, they needed a lot of money for their business expenses to stabilize the huge expenses with the less profit they are getting as a startup entrepreneurs (Patnaik, 2020).

Banks operating their services accurately influence the economic development and daily life activities of peoples (Astamal & Rahimi, 2019a). While banks are lending, according to different needs; Changing interest rates vary depending on the reasons such as the loan limit, the number of installments, and the delay in the loan payment. This situation may differ between banks. The person requesting a loan from the bank chooses the bank and applies according to these conditions. The bank, on the other hand, checks whether the customer applying for the loan complies with certain procedures. Within the bank procedures, the customer; There are factors such as economic status, reliability, stability, equity amount, credit history, business stability, collateral factor, total assets, total liabilities, type of production, investment, and number of businesses owned. It also reveals that performing credit analysis and authorization for the implementation of these procedures depends on more than one factor. Together with these procedures, the bank evaluates

all the possibilities that the bank will not lose. It is important for a financial industry to know how banks select people to which they can lend and whether they depend on mostly soft or hard detailed importation in their selection processes (Calcagnini et al., 2018).

Having a fuzzy system that support in making decision on an ambiguous problem is needed in making reliable decision (Nugroho & Edi Setiawan, 2016). In this research we are trying to use a fuzzy system to help in bank loan approval, making decisions in the field of loan/credit authorization is not certain, it deals with ambiguity; hence, we are proposing a fuzzy system aiming that will help in accurate and reliable decision system on bank credit. When we consider the procedure inputs, fuzzy systems are needed to evaluate all possibilities. With the fuzzy systems, credit approval of the bank has been made easier. Therefore, with the developing technology, it is inevitable that we want to get fast and easy results in every stage of our lives. Since the bank loan has many procedures, there are also uncertainties. The credit analysis and approval process make this process a complex structure due to its ambiguity and the existence of many different rules. Fuzzy systems are needed to simplify this complex structure and to make operations easier because it deals with any form of ambiguous problems (Dote, 1995).

The remaining section of the paper is arranged as follows: Section 2 reviews and compares the related bank credit authorization approaches in the literature. Section 3 introduces the proposed expert system. Section 4 provides and discusses the results. Finally, we conclude in Section 5.

2. Related Works

Credit authorization is one of the most important arms of the banking system that deals with uncertainty, hence, making a decision is not that easy, the researchers in the literature have shown different methods and approaches to this problem solutions, there exist many researchers finding in the literature regarding the bank credit authorization. Authors (Menekay, 2016) proposed an expert system that helps in either bank credit will be granted to a firm or not, the knowledge of a human expert in the field of bank credit authorization is used in developing the knowledge base of the system, they developed two stages of credit assignment where the first stage provide the evaluation of firm about repayment, management, and risk concerning repayment possibilities, those evaluation factors are used in the second stage to decide either to approve the credit or not.

In (Menekay & Ma'Aitah, 2017) the paper presents a customer's data investigation and how it can be broken down and utilized by an expert system, in their research a reliable decision system is developed to help in credit authorization, and human expert plays a vital role in their research, the knowledge of the expert is model using fuzzy inference engine to create the knowledge base of the expert system that makes the final decision on bank credit approval.

In (Aristei & Angori, 2021) authors use eleven euro country's data period from 2014 to 2019 to analyze the loan need and credit probabilities ratio, accounting, and unobserved heterogeneity dependencies. Their research shows that small businesses with a lack of public support and credit history find it difficult to get bank credit, whereas those that have once obtained the credit find it easier to access the bank credit. They also stated that firm access to credit is directly linked to firm-level characteristics and country-level credit market factors.

In the paper (Mahmoud et al., 2008) authors proposed an expert system and an easy-to-use interface for evaluating and supporting the decision on bank credit approval, in their research, they used two methods in acquiring the knowledge to be used by the expert system for efficiency, correctness, and effectiveness of their system, the first method is acquiring the knowledge from a human expert in the field of bank credit, and the second method is the enhancements and some modification to the knowledge acquired in the first method to reach the final system.

In (Astamal & Rahimi, 2019b) authors proposed a structural model for determining and categorizing credit application by factorial analysis and then the use of an expert fuzzy system. Due to the lack of a proper system for facilities allocation, the authors found that banks face several problems including bank credit allocation. Data from the Maskan bank of East Azerbaijan in Iran is used for validating the customers. The model is tested and compared the result with the

bank credit expert result in the field of credit authorization and found that their model is more efficient in deciding whether the credit will be approved or not.

Authors (Nugroho & Edi Setiawan, 2016) proposed a web-based bank credit automated system to help in decision-making on credit approval to eligible firms with minimal errors. The authors found out that it is difficult to track blacklisted customers that cannot be granted credit across the branches of the bank in the current system; a customer may be on a black list which means that the customer will have no access to any credit facilities from the bank, but due to non-integrated system of the banks a customer in the black list in a particular bank branch may move to other branch and apply for credit and get it without been identified as a black listed customer, hence, the authors created a web-based system using waterfall model to integrate all customer’s data into one system that can be shared across all the branches of a bank so that bank credit can only be provided to eligible customers.

Authors (de Andrés et al., 2020) use a statistical model to find the gender gap in bank credit access, they used data from over 80,000 Spanish new companies from the year 2004 to 2014, and they found that the probability of getting credit from a bank by the female entrepreneur is significantly lower than their male peers leading the same industry. The authors also found by analyzing the data that a company run by a female entrepreneur is about 10% less likely to request credit than a company run by a male entrepreneur.

The paper (Gaganis et al., 2021) introduced a multicriteria decision tool using the SMAA-Fuzzy FlowSort method for bank credit ratings, the method allows to decide on an uncertain problem, hence, it helps the expert working in the field of bank credit authorization to make a more reliable decision on granting credit to only eligible customers.

In (Roy & Shaw, 2021) authors proposed a hybrid decision system for credit scores using the fuzzy best-worst method (BWM) for weighting the factors and fuzzy techniques for order preferences by similarity to the ideal solution (TOPSIS) that is used for borrower’s evaluation, their proposed model was empirically analyzed to show its utility. The authors found that the most important parameters for sustainable credit scoring are environmental, social, and financial sustainability.

The paper (Bakurova et al., 2021) introduced a decision-making system using an ontology model, authors use OWL language to store the bank documents that will be used in the decision-making system, and protégé editor is used in the research to develop the ontology. Their model will help the banks to decide on credit to a firm, and it also helps in providing an early warning signal to the banks for credit to the non-eligible firm. The model also helps to mitigate the credit risk of the bank. The system is developed to support credit decisions in Ukraine’s banking institutions.

Many research on the field of bank loan approval have been done by researches as mentioned using different techniques ranging from decision system using ontology model (Bakurova et al., 2021), SMAA-Fuzzy flowsort method (Gaganis et al., 2021) for bank credit rating and others mentioned above. But those researches were done base on loan approval to the firm or company not for an individual bank customer and this is an important research gap that needed to be covered, hence we are addressing it in this paper. As in (Menekay, 2016) that proposed an expert system to makes decision on a firm/company bank credit approval only, there is need to have an expert system that evaluate a particular customer on the bank loan approval as well. Hence, we proposed a fuzzy expert system that helps in making decision on bank loan approval for a particular customer. Different parameters like 18% earning of a customer credit and asset-debt ratio of the customer were considered to decide on whether the loan will be approved or not to the customer by the bank.

Table 1: The Summary Table for Comparison of this Research and Researches in the Literature

Authors	Year	Method/Technology	Aims/Results
(Menekay, 2016)	2016	Expert System	Developed a system to help in bank credit approval/disproval for a firm/company.
(Menekay & Ma’Aitah, 2017)	2017	Expert System	Developing a reliable system to be used in deciding credit approval.

(Aristei & Angori, 2021)	2021	Probabilistic Method	Help to analyze and grant bank credit in eleven-euro countries.
(Mahmoud et al., 2008)	2008	Expert System	Developed an interface that uses an expert system in evaluating and supporting decision-making on credit approval.
(Astamal & Rahimi, 2019b)	2019	Factorial Analysis with Fuzzy Expert System	Developed a model that determined and categorized credit approval applications,
(Nugroho & Edi Setiawan, 2016)	2016	Automated Web-Base System	A system that helps in granting bank credit to only eligible customers regardless of which branch they are applying from.
(de Andrés et al., 2020)	2020	Statistical Model	Developed a model for the gender gap in accessing bank credit.
(Gaganis et al., 2021)	2021	SMAA-Fuzzy-FlowSort Method	A system that helps in deciding on bank credit rating.
(Bakurova et al., 2021)	2021	Ontology Model	Developed an ontology model that will help in making bank credit decisions in Ukraine's banking institutions.
(Roy & Shaw, 2021)	2021	Fuzzy-best-worst method (BWM) and (TOPSIS)	Developed a hybrid system that helps banks in credit scoring decisions.
This Research	2023	Fuzzy Expert System	Developed a fuzzy expert system to help in bank loan approval/disproval for a customer easily and more accurately even with the absence of an expert in the field.

3. Methodology

3.1 Research Design

The main aim of this paper is to design a fuzzy system that can be used to decide whether to approve a loan or not to a customer. Deciding on a problem of loan approval requires lots of parameters and expertise to be taken into account; the decision is not certain so, using Boolean logic to make a decision will not yield an appropriate outcome, since the decision to be made is not certain, fuzzy logic is good to be used in such problems. The designed fuzzy logic system in this paper is divided into two stages, the first stage uses total assets, credit request, 18% earning, business stability, credit missed, asset/debt ratio, bond rating, and dollar TL ratio as its input, and repayment, ability manage, and risk as to its output. The second stage of the system uses the output of the first stage which is repayment, ability management, risk as to its input, and credit as the output. Below shows the block diagram of the expert system.

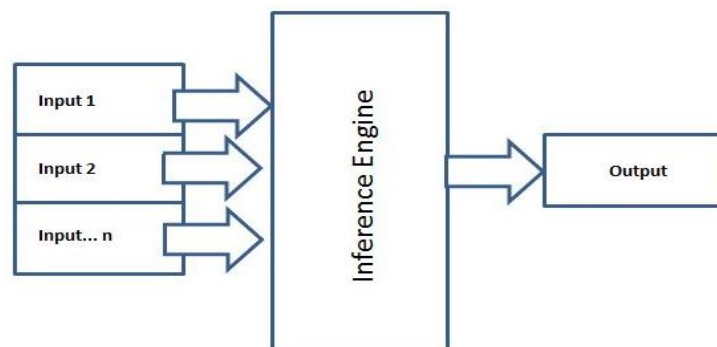


Figure 1: Block Diagram of the System

3.1.1 Input Variables

Input variables are the variables the system used as its input, and what will be fuzzified by the inference engine. The table below shows the range of each input variable for both stage 1 and stage 2 of the system and their linguistic terms.

Table 2. Input Variables Linguistic Term Names

No.	Variables Name	Min	Max	Term Name
1	Total Assets	0	1	Low High
2	Credit Request	0	1	Low High
3	DollarNgRatio	0	1	Abnormal Normal
4	18% Earning	0	1	Less More
5	Business Stability	0	1	Low Medium High
6	Credit Missed	0	1	Less More
7	Assets/Debt Ratio	0	1	Low Medium High
8	Bond Rating	0	1	Low High

3.1.2 Output Variables

Output variables are the variables the system produces as an output, and what will be the result of fuzzification by the inference engine. The table below shows the range of each output variable for both stage 1 and stage 2 of the system and their linguistic terms.

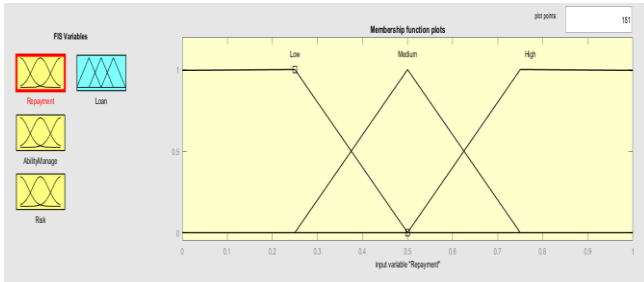
Table 3. Output Variables Linguistic Term Names

No.	Variables Name	Min	Max	Term Name
1	Repayment	0	1	Low Medium High
2	Ability Manage	0	1	YES NO
3	Risk	0	1	Low Medium High
4	Credit	0	1	Not Approve Approve

3.1.3 Membership Function

A membership function is defined for any values of input variable associated with the degree of membership of the linguistic terms. All terms of the linguistic variables are shown in one graph. In this research work we have used triangular membership function to describe the mapping between inputs variables and their degree of membership in the

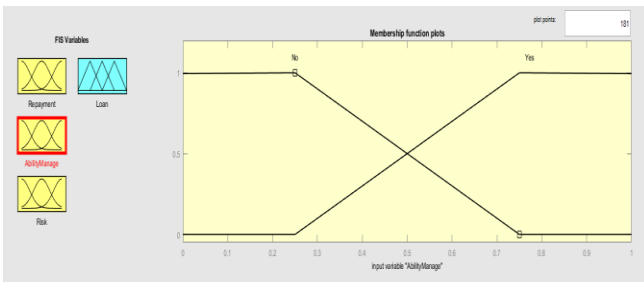
range of 0 and 1. Below are the figure plots of the member function of some of the input and their analytical representation of the linguistic terms.



$$\mu_{Low}(x) = \begin{cases} 0, & x > 0.5 \\ \frac{0.5 - x}{0.25}, & 0.25 \leq x \leq 0.5 \\ 1, & x < 0.25 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} \frac{x - 0.25}{0.25}, & 0.25 \leq x \leq 0.50 \\ \frac{0.75 - x}{0.25}, & 0.50 \leq x \leq 0.75 \\ 0, & \text{Otherwise} \end{cases}$$

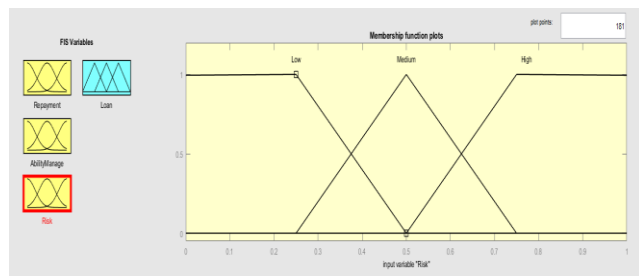
$$\mu_{High}(x) = \begin{cases} 0, & x < 0.5 \\ \frac{x - 0.5}{0.25}, & 0.50 \leq x \leq 0.75 \\ 1, & x > 0.75 \end{cases}$$



$$\mu_{NO}(x) = \begin{cases} 0, & x > 0.75 \\ \frac{0.75 - x}{0.50}, & 0.25 \leq x \leq 0.75 \\ 1, & x < 0.25 \end{cases}$$

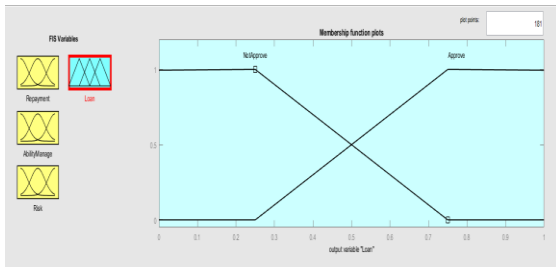
$$\mu_{YES}(x) = \begin{cases} 0, & x < 0.25 \\ \frac{x - 0.25}{0.50}, & 0.25 \leq x \leq 0.75 \\ 1, & x > 0.75 \end{cases}$$

$$\mu_{Low}(x) = \begin{cases} 0, & x > 0.5 \\ \frac{0.5 - x}{0.25}, & 0.25 \leq x \leq 0.5 \\ 1, & x < 0.25 \end{cases}$$



$$\mu_{Medium}(x) = \begin{cases} \frac{x - 0.25}{0.25}, & 0.25 \leq x \leq 0.50 \\ \frac{0.75 - x}{0.25}, & 0.50 \leq x \leq 0.75 \\ 0, & \text{Otherwise} \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, & x < 0.5 \\ \frac{x - 0.5}{0.25}, & 0.50 \leq x \leq 0.75 \\ 1, & x > 0.75 \end{cases}$$



$$\mu_{NotApprove}(x) = \begin{cases} 0, & x > 0.75 \\ \frac{0.75 - x}{0.50}, & 0.25 \leq x \leq 0.75 \\ 1, & x < 0.25 \end{cases}$$

$$\mu_{Approve}(x) = \begin{cases} 0, & x < 0.25 \\ \frac{x - 0.25}{0.50}, & 0.25 \leq x \leq 0.75 \\ 1, & x > 0.75 \end{cases}$$

3.1.4 Fuzzy Rules

The functionality of this system suddenly defends fuzzy rules. Fuzzy rules are the expert knowledge modeled in the application of interest (Bai & Wang, 2006). The fuzzy rules are the decision-maker that our system used. Our system has different input variables with different terms used for each, the fuzzy rules are nothing but the combination of all possible occurrences that may result in the change of our target output by using the “and” operator, which makes sure that our terms evaluate to true for a specific decision of output to happen. The syntax of the rules is IF (input variable) THEN (output variable). The fuzzy rules are for both stages one and two of the expert system, rule 1 to 9 are for the first stage of the system which accesses the repayment, ability manage, and risk of the firm and then gives results to stage two for final decision. Rules 10 to 15 are for the second stage of the system which makes the final decision on either the bank should approve the loan or not using the output results of the first stage of the system (repayment, ability manage, and risk) as input. In the second stage rules, we used the following acronyms.

H: High

M: Medium

L: Low

Y: Yes

Rule 1: IF (TotalAssets is High) AND (CreditRequest is Low) THEN (Repayment is High)

Rule 2: IF (TotalAssets is High) AND (CreditRequest is High) THEN (Repayment is Medium)

Rule 3: IF (TotalAssets is Low) AND (CreditRequest is Low) THEN (Repayment is Medium)

Rule 4: IF (TotalAssets is Low) AND (CreditRequest is High) THEN (Repayment is Low)

Rule 5: IF (CreditRequest is Low) AND (18%Earning is Less) THEN (AbilityManage is YES)

Rule 6: IF (CreditRequest is High) AND (18%Earning is Less) THEN (AbilityManage is YES)

Rule 7: IF (CreditRequest is Low) AND (18%Earning is More) THEN (AbilityManage is NO)

Rule 8: IF (CreditRequest is High) AND (18%Earning is More) THEN (AbilityManage is NO)

Rule 9: IF (BussinessStability is High) AND (CreditMissed is Less) AND (Asset/DebtRatio is High) AND BondRating is High) AND (DollarNgRatio is Normal) THEN (Risk is Low)

Rule 10: IF (Repayment is H) AND (AbilityManage is Y) AND (Risk is L) THEN (Credit is Approve)

Rule 11: IF (Repayment is M) AND (AbilityManage is Y) AND (Risk is L) THEN (Credit is Approve)

Rule 12: IF (Repayment is H) AND (AbilityManage is Y) AND (Risk is M) THEN (Credit is Approve)

Rule 13: IF (Repayment is M) AND (AbilityManage is Y) AND (Risk is M) THEN (Credit is Approve)

Rule 14: IF (Repayment is H) AND (AbilityManage is Y) AND (Risk is H) THEN (Credit is NotApprove)

Rule 15: IF (Repayment is M) AND (AbilityManage is Y) AND (Risk is H) THEN (Credit is NotApprove)

4. Results and Discussion

4.1 Simulation Results

The controller takes the input variables and uses the rule base for the appropriate result, below is the sample test in the MATLAB working system, the testing data start with putting the input variable values that is the fuzzification level and then gives an output that is to say defuzzification level, many tests have been run to see how the system works. Figure

2 and figure 3 are the sample simulation results for stages 1 and 2 of the system respectively. Figure 2 shows the first stage of the expert system simulation window where the sample input values were given for the system to decide on repayment, ability to manage, and risk of approving the loan. The total asset, credit request (loan amount), 18% earning, business stability, asset/debt ratio, bond rating, and dollar to naira ratio of 0.938, 0.583, 0.715, 0.88, 0.104, 0.897, 0.842, and 0.856 respectively were given as an input to the first stage, the resultant output of the system for this input values were 0.625, 0.367, and 0.25 for repayment, ability manage, and risk respectively.

Figure 3 shows the second stage of the expert system where which uses the output results of the first stage of the system as its inputs. The second stage uses linguistic variable values of 0.625, 0.367, and 0.25 for repayment, ability manage, and risk from the first stage and makes the final decision, the output of the second stage result in the credit approval with a membership degree of 0.656 for the mentioned inputs. This result shows that the requested loan by the firm can be approved by the bank without any doubt of risk, if to say that the credit approval shows a membership degree of less than 0.5, then the bank should not approve the loan because there is a high risk of repayment by the firm requesting the loan based on the loan requirement parameters provided by the firm or an individual’s looking for the loan.

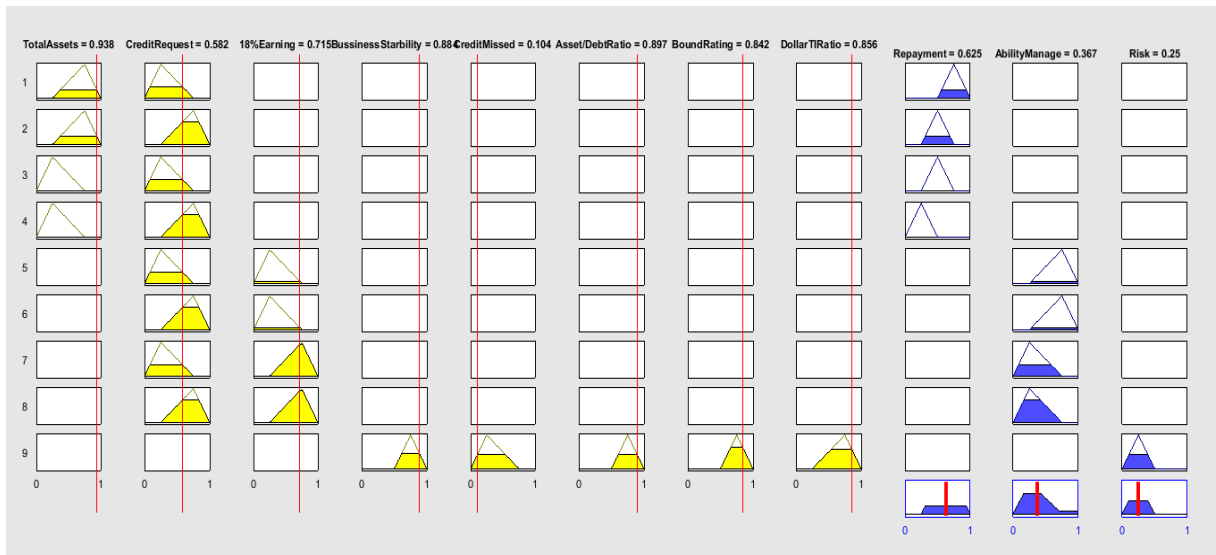


Figure 2: Stage 1 Sample Simulation Result

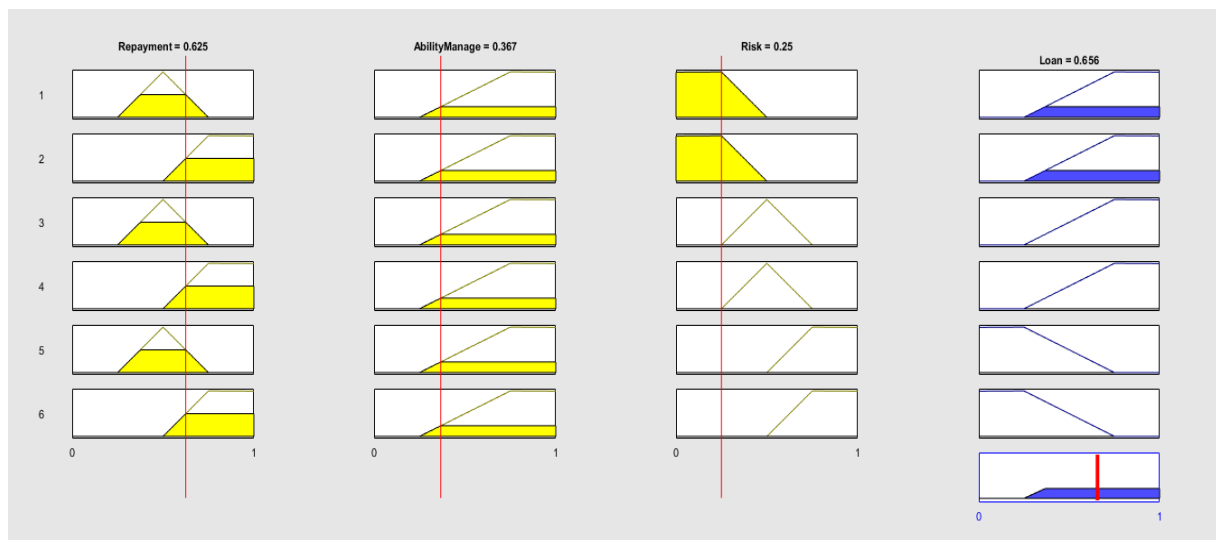


Figure 3: Stage 2 Sample Simulation Result

4.2 A 3D Simulation of Inputs with Outputs Variables

A graph is one of the best ways to demonstrate the relationship between variables; a 3D graph is used in this paper to show the relationship between the input variables and the output variable. Below are graphs showing the relationships between the output variables and the input variables of the following from the second stage of the system which is the stage that makes the final decision on whether the requested credit by the customer/firm will be approved or not.

- a) Input variable (Total Assets and credit Request) with output variable (Repayment).
- b) Input variable (18% Earning and Credit Request) with output variable (Ability Manage)
- c) Input variable (Asset/Debt Ratio and Business stability) with output variable (Risk)
- d) Input variable (Risk and Repayment) with output variable (Credit)

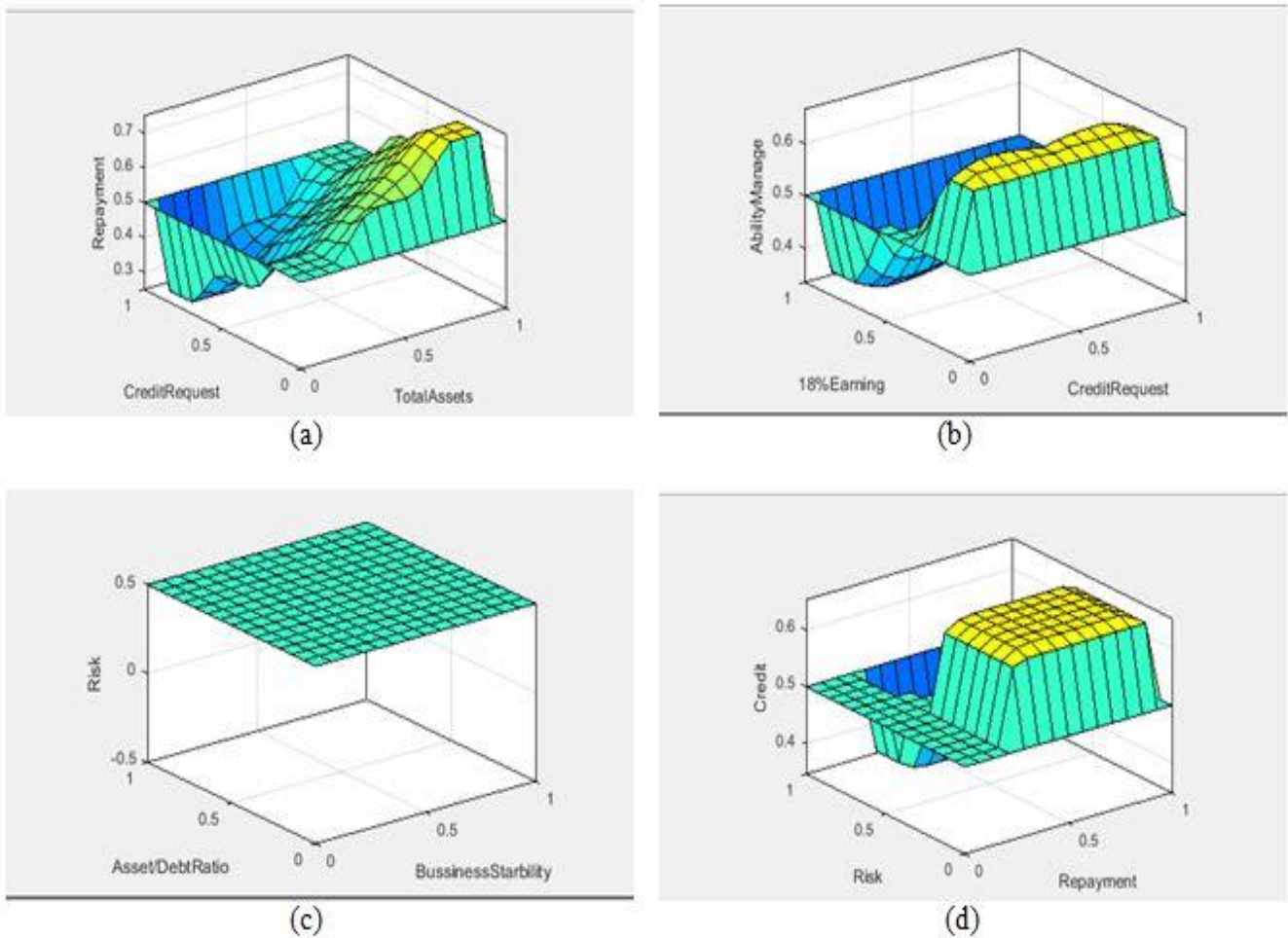


Figure 4: 3D Simulation graphical Representation of stage 2 of the Decision System

5. Conclusion

As the decision on loan approval by the banks is ambiguous, in this paper, we have developed a fuzzy logic system using MATLAB that checks whether a customer’s loan request can be approved or not, many linguistic variables with their linguistic term have been used as the input and output of the system. The decision that the system makes depends on the rules that are set to it which were gained from the expert in the domain of loan authorization. The membership function of some of the inputs and outputs were shown together with the simulation sample results, the sample input values were given to the first stage of the system and decide on the repayment possibilities, ability to manage the loan, and risk of giving the loan. Stage two of the system is where the final decision was made based on the risk, and ability to repay the

loan and be managed. If the output of the second stage shows a membership degree of less than 0.5 then the loan should not be approved, but if the membership degree shows a value greater than or equal to 0.5 then the bank can approve the loan without the worry of the repayment risk. The 3-Dimensional graphs were also shown in the result and discussion section of the paper which was used to show the relationship between the system input variables and their output variables. Finally, the system will intensively help the managers to simply and more accurately decide whether to approve or disapprove the firms'/customers' loan requests. The Bank credit system is one of the most important arms of the banking system, it is the activity that is going on now and then in the bank hence, there are data records for a lot of credit approval/rejection, for that the use of Machine learning with the fuzzy system is recommended in classifying the customers' loan request.

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