# Fuzzy Logic Approach to Credit Scoring for Micro Finances in Ghana

# (A Case Study of KWIQPLUS Money Lending)

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## ABSTRACT

This paper presents a fuzzy logic approach to credit scoring for Micro Finance.The research was necessitated as a result of the inability of many Micro Finance Institutions in Ghana to recover loans from their clients which is leading to their eventual collapse. It has been presumed that proper evaluations are not done by the Micro Finance Institutions thereby advancing loans to wrongful applicants. The main objective of this research was therefore to provide a Fuzzy approach to credit scoring in order to reduce the loan default among the Micro-Finance Institutions so as to ensure their continuous existence. The research used three Fuzzy Input variables with their triangular membership function, an Output variable and twenty-seven fuzzy rules in the development of an evaluation model.

**Keywords: Credit Scoring, Fuzzy Logic, Micro Finance**

**Fuzzification, Defuzzification**

## 1. INTRODUCTION

Ghana witnessed a growth of the Micro Finance Industry (MFI) from 2002 to 2007 [1]. Unlike the traditional banks, the MFIs are established to support Small and Medium Term Enterprise (SMES) and individual loans to meet certain personal demands. [2] defined MFI's operations as small financial transactions with low income households and micro enterprises (both urban and rural), using non-standard methodologies such as character -based lending, group guarantees, and short-term repeat loans.

The serious competition among the various MFI to offer loans to prospective clients inhibits them to do proper scrutiny of loan application thereby putting them at a great risk. [1] cited (Bruet, 2004) that the credit granting technologies used by MFI's make them face a number of risks (including financial, operational and strategic risks) in the pursuit of their objectives and are therefore required to develop and implement credit risk policies and strategies. Credit risk assessment is therefore the single most important function that

Micro Finances have to take so serious if they have to remain in business.

## 2. PROBLEM STATEMENT

Many Micro Finances in Ghana have become insolvent due to their inability to recover loans granted to their clients. It is presumed that, proper evaluation of the loan applications are not done by the MFI thereby granting loans to wrongful applicants. Most often the credit officer employs self-judgment in the appraisal of applications which leads to inconsistencies and biases resulting in wrongful decisions.

In literature, various properties have been used to predict the likely-hood of client repaying a loan, if granted. These properties are scored based on the importance of the properties. However, the socio-economic of Ghana requires a selection of different variables to help in predicting the likelihood of repayment.

## 3. RELATED WORK

Fuzzy logic has had successful application in many fields since Zadeh presented the theory in 1965[3]. These applications can be found in medicine, artificial intelligence, decision theory, operations research and host of other applications. Fuzzy theory deals with imprecision and vagueness and represent information from Zero (0) to One (1). It can effectively describe imprecise knowledge of human subjective judgment by linguistic term. Fuzzy logic has also been applied in credit scoring where a lender finds the credit score of a borrower to determine his/her credit worthiness.

[4] Presented classification of bank customers for granting banking facility using fuzzy expert system based on rules extracted from the banking data. [5] Presented a new approach to determining credit ratings and its application to Vietnam's listed firms. [6] Presented credit assessment of bank customers by a fuzzy expert system based on rules extracted from association rules.

## 4. METHODOLOGY

### 4.1 Data Collection

The research was done using Kwikplus Micro Finance as a case study. Kwikplus is a vibrant Micro Finance and it is situated at Nhhiaeso a surburb of Kumasi in the Ashanti Region. Data collected was carried out through interview and observations of the operations the Firm.

### 4.2 Research Process

It was assumed that, given the uncertainty of human behaviour, it is very important to study the behavioural pattern of the clients with respect to their ability to repay the loan, if granted. As a result, three input variables were identified to aid in predicting the clients' behaviour. These variables namely *Duration* (the length of time or period that the client has been with the firm), *Minimum_Balance* (the amount of money the client leaves with the MFI within a specified period of time), and *Daily-Deposit* (the amount of money a client saves with the MFI on a regular basis). These variables eventually became the input variables for the input-membership function where each was scaled and given a percentage value of 45, 35, and 20 percent respectively. The variables were each assigned a linguistic label Risky, Less-Risky or Advisable depending on the fuzzy value threshold. Consequently, an output variable (Advice) was identified to serve as an output membership function which was also given a threshold value.

Further, twenty seven possible Fuzzy rules were constructed using the fuzzy **Min- function.** These rules are the various possible combinations of the input variables with their fuzzy values. These rules eventually served as the basis for evaluation of loan applications. Further the Centroid Defuzzification method was chosen to find the crisp output which provides the decision to the loan officer. The centroid can is repented mathematically as.

$$CoG(y') = \frac{\sum \mu_y(x_i)x_i}{\sum \mu_y(x_i)}$$

where $\mu_y(x_i)=$ Membership value in the membership function and $x_i=$ center of membership function.

### 4.3 Software Tool

Matlab 7.0.1 is a powerful scientific tool used for various works including the modeling of fuzzy system. It was used to simulate the model. The various input membership function (Duration, Minimum-Balance, Daily-Deposit) and the output function (Advice) were captured. The various rules were also captured in the system too.

## 5. IMPLEMENTATION

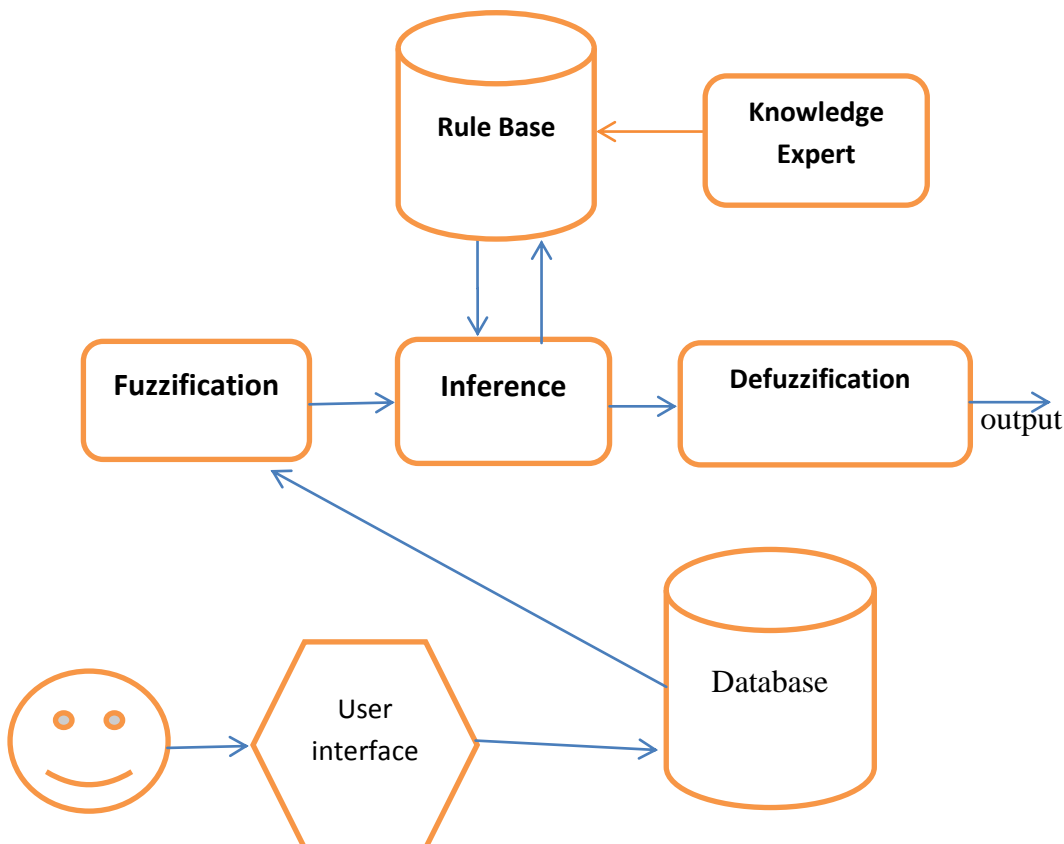Figure 1 describes the architecture of the model.



**Fig 1: Architecture of the Proposed Model**

## 5.1 User Interface

The user interface is the first stage where the user interacts with the system. It helps the user communicate with system effectively. This is done through the use of the keyboard to enter information into the system.

## 5.2 Database

The Database contains information about the clients and the operational data of the Micro Finance. Basic information of the client like name, date of enrollment, savings amount, etc. would be kept in the database.

The database is normalized and efficiently support queries and ad hoc queries posed to the system. The fuzzifier picks

individual detail date of registration, "**Daily_Doposit"** and the "**Minimum_Balance"** from the Databases. These are converted as fuzzy values and kept within the system.

## 5.3 Fuzzification

The Fuzzification process is expected to convert the crisp input (from the database) values into a fuzzy set. Three input variables were used. The input variables are each given a percentage scale to represent. An input membership functions are constructed indicating the threshold of all the three input variables which helped in building the rules for the system. Tables 1, 2, and 3 show the input membership function and their linguistic terms. Figure 2 describes the duration of input membership function with threshold for Risky, Less Risky, and Advisable.

**TABLE 1. INPUT MEMBERSHIPS - Duration**

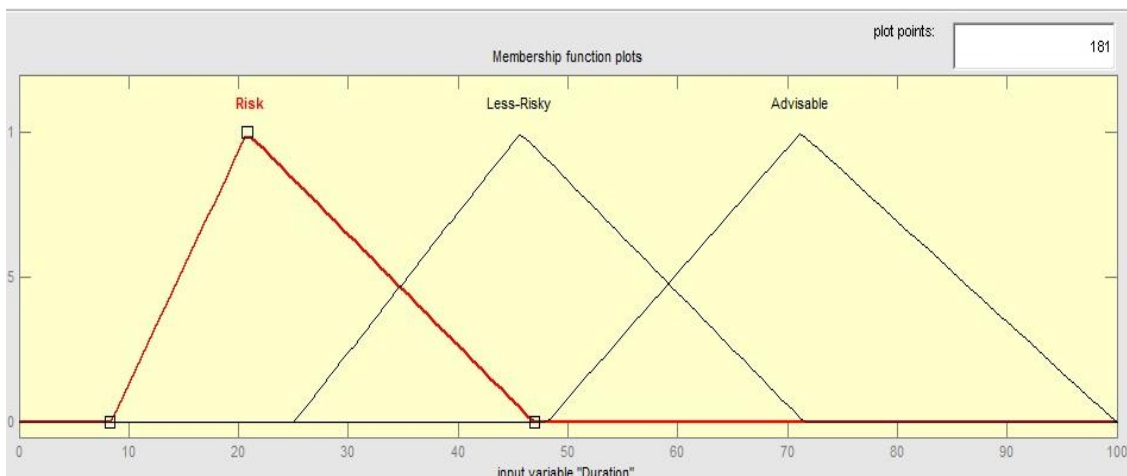| Range of Values (Months) | Fuzzy values (0 -1) | Converted Ranges of values (%) | Linguistic Term |
|---|---|---|---|
| 1 – 4 | 0.08 – 0.33 | 8.33 – 33.33 | Risky |
| 3 – 8 | 0.25 – 0.67 | 25 – 66.67 | Less-Risky |
| 7 – 12 | 0.583 – 1 | 58.33 – 100 | Advisable |



**Fig 2: INPUT MEMBERSHIP- Duration**

**TABLE 2. INPUT MEMBERSHIPS - Minimum_Balance**

| Range of Values GH¢ (Ghana Cedis) | Fuzzy values (0 -1) | Converted Ranges of values (%) | Linguistic Term |
|---|---|---|---|
| 1 – 50 | 0.01 – 0.50 | 1 – 50 | Risky |
| 40 – 70 | 0.40 – 0.70 | 40 – 70 | Less-Risky |
| 60 – 100 | 0.60 – 1.00 | 60 – 100 | Advisable |

**TABLE 3. INPUT MEMBERSHIPS – Daily-Deposit**

| Range of Values GH¢ (Ghana Cedis) | Fuzzy values (0 -1) | Converted Ranges of values (%) | Linguistic Term |
|---|---|---|---|
| 1 – 3 | 0.10 – 0.33 | 10 – 30 | Risky |
| 2 – 6 | 0.20 – 0.60 | 20 – 60 | Less-Risky |
| 4 – 10 | 0.40 – 1.00 | 40 – 100 | Advisable |

## 5.4 Rule base (knowledge base)

The rule base contains the various rules constructed in consultation with a knowledge expert. These rules form the actual working rules for the fuzzy controller. Based on the input and output membership functions, twenty seven (27) rules were generated. Using the Mamdani Inference System with the Min-Operator (see appendix II for the rules)

## 5.5 Defuzzification

The Defuzzification process outputs the aggregated function as crisp values using the centroid method. The centroid finds the Centre of gravity of the aggregated values.

**TABLE 4. OUTPUT MEMBERSHIPS-Advice**

| OUTPUT VARIABLE | RANGE OF VALUES | Linguistic Term |
|---|---|---|
| Advice | 0 – 25 | Risky |
| | 25.1-60 | Less Risky |
| | 60.1-100 | Not-Risky |

Table 4 describes the output membership function. The output membership function contains only one variable namely Advice and its range of fuzzy values and defined linguistic term.

## 6. EXPERIMENTATION

The model was implemented with fifteen (15) simulated clients. Result can be found in appendix I. Sample graphical representation are shown as figures 3, 4, and 5.



**Fig 3: Simulated Results-Advisable**

Fig 3 is an example of the simulated results-Advisable. The input Duration score is 76.5, Min-Balance 78.9, Daily-Deposit 64.5 which gave an output Advice of 72. Based on the Output function of table 4.2, the applicant is deemed qualified for the loan as the score is within the **Advisable** threshold.
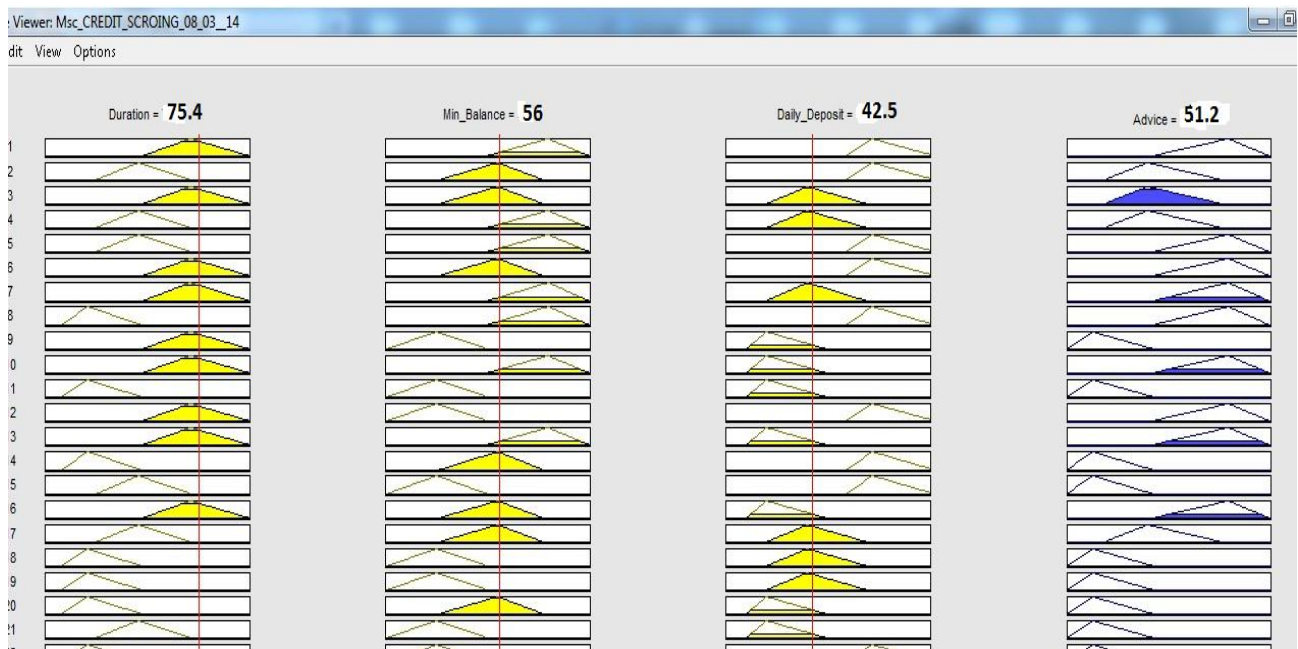
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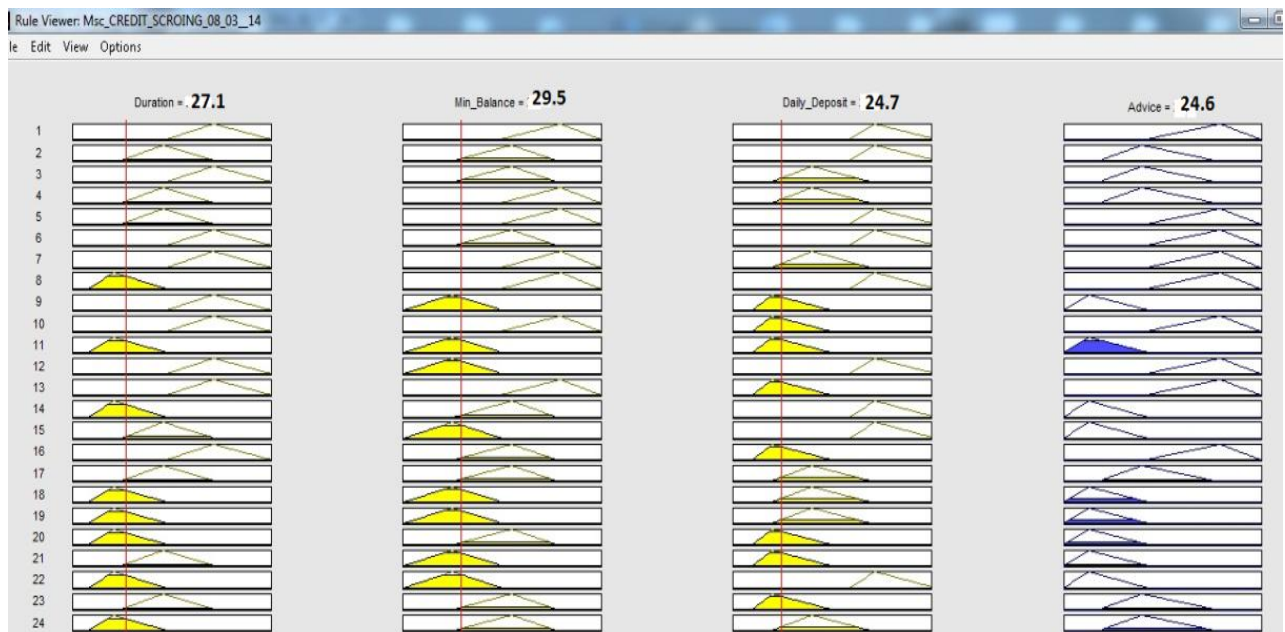**Fig 4: Simulated Results – Less Risky**



**Fig 5: Simulated Results- Risky**

## 7. COMPARTIVE ANALYSIS OF EXISITING AND NEW SYSTEM

This section compares the existing system with the new system.

**Table 5: Comparative Analysis of Existing and New System**

| PROCESS OF LOAN APPLICATION AND EVALUATION FOR MICRO FINANCES IN GHANA | FUZZY LOGIC APPROACH TO CREDIT SCORING FOR MICRO FINANCES IN GHANA |
|---|---|
| Step 1: Receive Loan Application from client<br>Step 2: Connect to Credit Reference Bureau for Verification (via the internet)<br>    If applicant owes another M.F.I or has defaulted before deny him/her the loan,<br>Else<br>Step 3: Does applicant own a shop or a business?<br>    If no, deny him/her the loan<br>Else<br>Step 4: Can Applicant provide a cash lien for two months<br>    If no, deny him/her the loan<br>Else<br>Step 5: Can applicant provide collateral<br>    If no, deny him/her the loan<br>Else<br>    Approve loan (3 times the cash lien) | Step 1. Identify fuzzy input variables.<br>Step 2. Put score on each variable<br>Step 3. Fuzzify the inputs and store in Database<br>Step 4. Define the fuzzy rules<br>Step 5. Use the fuzzy system to evaluate the loan application |

### 7.1 Disadvantages of the existing approach

The existing system is a five step approach (see Table 5) to determine the suitability or otherwise of an application without putting a score on each of the variable. At each level, if the application does not meet the criteria, the application is rejected. It also exposes the danger that Micro Finances can fall into. It can be reasoned that the variables chosen for the evaluation may not give the true reflection or behaviour of a client that would give a basis to predict his or her likelihood of defaulting from loan contracted.

**Cash Lien:** An applicant may register and save with the MFI with the sole intention to assess loan. Having met the criteria and given the loan, the client may default in payment.

**Credit Reference Bureau:** The non-availability of credible Data, like proper house numbering, street address systems in Ghana puts a limitation in the work of the credit Reference Bureau. The use of the variables like Date of Birth, Name or provided ID card information (except for the recent Biometric passport) cannot reveal the true Identity of a person. The researchers' personal experience have shown that people have maintained more than one form of ID card with different information. It is in view of this problem that the current Government of Ghana tasked all Metropolitan Assemblies to conduct house numbering and street address systems in order to easily locate properties from time to time.

**Collateral**: It is the money or property used as a guarantee, which a client will repay loan after taken a loan. Collateral is not easily convertible to cash. In case, of default by a client the MFI goes through legal difficulties to dispose of the collateral especially in the case of properties which are the

abode of the client. This would therefore take much of the MFI's time and resource to retrieve the defaulted money.

### 7.2 Benefits of the new system

The new system assigns a score (weight) on each variable, as illustrated in Table 5. Subsequently rules are defined to help in the evaluation which helps in determining Risky, Less Risky and Advisable applicants.

## 8. CONCLUSION

This research was necessitated by the inherent problem faced by Micro Finance institutions in advancing loans its clients. The primary objective of the research was to develop a credit scoring model to counteract the challenges faced by Micro Finances in Ghana using fuzzy logic

### 8.1. Summary of Findings

The research found that, Fuzzy Logic is effective in modelling applications where human judgement is involved and can be used in evaluating loan applications. However, the choice of variables, especially thresholds can make the model less-useful if economic conditions change in the future unless the variables are adjusted. For example, the stipulation of one hundred Ghana Cedis (¢100) for a "*Minimum-Balance*" is based on the current economic situation in Ghana owing to the fact MFI clients are believed to be low income earners. Also the savings is pegged at two (¢2) and ten Ghana (¢10) for minimum and maximum "*Daily_Deposit*" respectively are also based on the current economic conditions.

## 8.2. Recommendation

Micro Finance should vigorously invest in their Information Technology Infrastructure. The Association of Micro Finance Industry should as matter of urgency come together to support the effort of the Credit Reference Bureau of Ghana by submitting borrower's information at the right time to ensure that borrowers do not go defrauding other banks. Prospective clients of MFI should be duly registered as it pertains in the bigger banks and the information should include finger biometric registration at the point of registering.

The model developed should be made available to the association of MFI in Ghana for use to evaluate loan applications. Human efforts should be limited as this leads to subjective judgment which would lead to wrongful decisions

## 9. FUTURE WORKS

Credit scoring has received tremendous work within the research community with most of the tools being statistical. Fuzzy logic has however proven to be a better alternative. A further research should look at the *"credit unions"*, the *"Susu"* lending system and all the non-banking institutions in Ghana

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**APPENDIX I**

**SIMULATED EVALUATION RESULT**

| Account No | Duration | Min-Balance | Deposit | Advice | Decision |
|---|---|---|---|---|---|
| XYZ001 | 21.1 | 29.5 | 24.7 | 24.6 | RISKY |
| XYZ002 | 48.8 | 78.9 | 24.7 | 45.8 | LESS-ADVISABLE |
| XYZ003 | 48.8 | 79.9 | 64.5 | 65.1 | ADVISABLE |
| XYZ004 | 76.5 | 78.2 | 64.5 | 72.1 | ADVISABLE |
| XYZ005 | 75.4 | 56 | 42.5 | 72 | ADVISABLE |
| XYZ006 | 95 | 42 | 45 | 50.7 | LESS-ADVISABLE |
| XYZ007 | 50 | 78 | 79 | 73.1 | ADVISABLE |
| XYZ008 | 25 | 59 | 63 | 49.2 | LESS-ADVISABLE |
| XYZ009 | 87.2 | 40.1 | 61.2 | 61.6 | ADVISABLE |
| XYZ010 | 89 | 12 | 70 | 72 | ADVISABLE |
| XYZ011 | 75.4 | 56 | 42.5 | 51.2 | LESS-ADVISABLE |
| XYZ012 | 45 | 44.5 | 60.9 | 41.4 | LESS-ADVISABLE |
| XYZ013 | 37 | 38.1 | 31.6 | 35.2 | LESS-ADVISABLE |
| XYZ014 | 0 | 0 | 0 | 50 | ERROR |
| XYZ015 | 100 | 100 | 100 | 50 | ERROR |

**APPENDIX II**

**INFERENCE RULES**

| If | Duration (45%) | Minimum_Balance (35%) | Daily_Deposit (20%) | Advice |
|---|---|---|---|---|
| 1 | Not-Risky | Not-Risky | Not-Risky | Advisable |
| 2 | Less-Risky | Less-Risky | Not-Risky | Less-Advisable |
| 3 | Not-Risky | Less-Risky | Less-Risky | Less-Advisable |
| 4 | Less-Risky | Not-Risky | Less-Risky | Less-Advisable |
| 5 | Less-Risky | Not-Risky | Not-Risky | Advisable |
| 6 | Not-Risky | Less-Risky | Not-Risky | Advisable |
| 7 | Not-Risky | Not-Risky | Less-Risky | Advisable |
| 8 | Risky | Not-Risky | Not-Risky | Advisable |
| 9 | Not-Risky | Risky | Risky | Not-Advisable |
| 10 | Not-Risky | Not-Risky | Risky | Advisable |
| 11 | Risky | Risky | Risky | Not-Advisable |
| 12 | Not-Risky | Risky | Not-Risky | Advisable |
| 13 | Not-Risky | Not-Risky | Risky | Advisable |
| 14 | Risky | Less-Risky | Not-Risky | Not-Advisable |
| 15 | Less-Risky | Risky | Not-Risky | Less-Advisable |
| 16 | Not-Risky | Less-Risky | Risky | Advisable |
| 17 | Less-Risky | Less-Risky | Less-Risky | Less-Advisable |
| 18 | Risky | Risky | Less-Risky | Not-Advisable |
| 19 | Risky | Not-Risky | Less-Risky | Less-Advisable |
| 20 | Risky | Less-Risky | Risky | Not-Advisable |
| 21 | Less-Risky | Risky | Risky | Not-Advisable |
| 22 | Risky | Risky | Not-Risky | Risky |
| 23 | Less-Risky | Less-Risky | Risky | Less-Advisable |
| 24 | Risky | Less-Risky | Less-Risky | Less-Advisable |
| 25 | Less-Risky | Not-Risky | Risky | Less-Advisable |
| 26 | Not-Risky | Risky | Less-Risky | Advisable |
| 27 | Less-Risky | Risky | Less-Risky | Less-Advisable |