MULTI-CRITERIA DECISION MAKING FOR OPERATING ATM SYSTEM

A DISSERTATION

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IN

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CANDIDATE'S DECLARATION

We, (Reetika Singh and Shivani Kalyan), Roll no., 2K20/MSCMAT/24 and 2K20/MSCMAT/39 respectively are students of M.Sc. (Mathematics), hereby declare that the project Dissertation titled "Multi-Criteria Decision Making For Operating ATM System" which is submitted by us to the Department of Applied Mathematics, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled “Multi-Criteria Decision Making For Operating ATM System” which is submitted by Reetika Singh and Shivani Kalyan, Roll No. 2K20/MSCMAT/24 and 2K20/MSCMAT/39 respectively to the Department of Applied Mathematics, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

The development of appropriate decision-making methods is an important part of Operations Research. Multi Criteria Decision Making (MCDM) is one of the most popular categories of such methods. It deals with the testing of many conflicting criteria by providing solid decisions on the most complex domains. MCDM has seen an amazing amount of use in the last few decades. In this paper, we will learn how to study multi-criteria decision-making for operating ATM systems. We will then discuss the origin, composition, and classification of the various terms of MCDM followed by the literature review, working, and features of the ATM system. This paper introduces the Turing machine concept, examines the working of ATM in the domain of Theory of Computation which is defined by three key concepts: languages, grammar, and automata. Following the transition model of multiple selection criteria at each stage of ATM System, we'll present the formal model. After that, we will give the computation of all possible decisions that are made by the ATM processor with the help of a table showcasing the transition behavior of each state. Finally, we will thoroughly explain multiple criteria in each operating phase of the ATM system.

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It was extremely gratifying to have the opportunity to receive guidance and assistance throughout the process of the dissertation, and we were extremely fortunate to be able to acknowledge this at the conclusion of our study.

Dr. L.N. Das deserves our heartfelt thanks for giving us the chance to carry out this research on "Multi-Criteria Decision Making for Operating ATM Systems." All that we have accomplished is due to his specific supervision and timely support. We did a lot of research and learned a lot because of him.

Additionally, we would like to thank him for his encouragement and guidance throughout this research process.

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LIST OF SYMBOLS, ABBREVATIONS

$(S, C, \Sigma, s, b, \delta, F)$ represents seven tuple relationship where:

S is the set of valid states that represents the domain of the working of ATM System,

$S = \{s_0, s_1, s_2, \dots, s_{13}\}$ here the states are:

s_0 −System

s_1 −Main Menu

s_2 −Validity of ATM Card

s_3 −Check PIN

s_4 − Sorry! Can't read the card

s_5 − Enter Amount

s_6 −Card Blocked

s_7 −Insufficient Balance

s_8 −Transaction Declined

s_9 −Insufficient Funds

s_{10} −Invalid Transaction

s_{11} −Check Denomination

s_{12} −Money Withdrawn

s_{13} −Eject Card

C is the set of multiple criteria at each state considered by the ATM to make decision before proceeding to the next state, where $C = \{c_1, c_2, \dots, c_8\}$

c_1 −Hologram

c_2 −Magnetic Stripe

c_{21} − CVV matches with AVS or not

c_{22} − ATM card is expired or not.

c_{23} − ATM card is Blocked/Reported or not

c_3 − Placement of the ATM Card

c_4 − When number of unsuccessful trials are greater than 3

c_5 − Account Balance is greater than the amount to be withdrawn or not

c_6 − Limit Per Transaction is crossed or not

c_7 – Cash availability at ATM

c_8 – Minimum ATM Withdrawal Limit is crossed or not

- $\sum$ is the set of events that the ATM may accept and process, $\Sigma = \{0,1\}$
- s is the start state of the ATM, $s = s_1$ (Main Menu)
- b is the blank symbol; this happens when we insert a card but do not perform any action.
- F is the set of ending set, $F = \{s_{13}\}$ (Eject card)
- δ is the transition function of the ATM that determines the next state of Turing Machine, s_{i+1}, on the basis of the current state s_i and a specific incoming event $\{0,1\}$, i.e.,

$$s_{i+1} = \delta(s_i, \{0,1\}), \text{ where, } \delta = f: (S, C) \times \sum \rightarrow S \; .$$

CHAPTER 1

INTRODUCTION

Multiple-criteria decision-making (MCDM) deals with cases of conflicting goals among decision-makers. Before explaining in more detail this way, it is important to understand what we mean by the terms used in the MCDM. Therefore, the criteria in decision-making define the degree of the judgment of the course of action as more desirable than the other. Considering the different options that conflict on a large scale becomes a problem of Multiple-Criteria Decision Making.

Multi criteria decision making is generally characterized by the presence of complex, contradictory information that reflects different perspectives and changes over time. The MCDA's approach aims to assist decision-makers by organizing information in a certain way, by considering possible conditions, and by reducing the likelihood of remorse after the decision. It leads to a feeling of satisfaction and confidence about deciding which way is best. The best can be obtained by analyzing the different range of terms, conditional weights, and choosing the most appropriate ones. By making weight and related trade between terms clear in a systematic way, the MCDM results in clear and consistent decisions.

In this sense, Multi-Criteria Decision Analysis describes a set of legal mechanisms that explicitly take into account multiple conditions in the process of guiding individuals or groups to make critical decisions. It also saw an amazing amount of use in the last few decades. Its role in the various areas of application has increased significantly, especially as new methods develop and as older methods develop.

There are some myths about the MCDA, one of which is that it will provide a "correct" answer, provide “objective” analysis that will relieve decision-makers of the burden of making difficult decisions, and ease the pain of decision-making.

Despite the model used, we must understand that there is no such thing as a "correct answer." Because the concept of optimality does not relate to a multiple-criteria framework, MCDA cannot be excused from within the development approach commonly adopted by ordinary performance research or management science. By using the MCDA, compliance can be clarified and regulated by mixing objective measurement and value judgment. As such, this is not an invalid submission; the MCDA merely attempts to be more transparent in its subjective judgments and to be explicit in its needs. While this is not always an easy process - for instance, trading is difficult but it cannot be avoided entirely. Through the MCDA, decision-makers will be able to identify these situations and assist in thinking of creative ways to overcome the need for complex trade, perhaps by promoting the development of new options. It can also maintain a level of equality by allowing inaccurate judgments but it cannot eliminate the whole need for harsh judgments.

Overall, the MCDM aims to reduce the incidence and impact of bias from decision-makers relying on their ‘gut feeling’, as well as the team’s decision-making failure, which inevitably hampers decision-making. We believe the purpose of MCDA should be to evaluate the main benefits, to help decision-makers learn about the problem they are facing, including priorities, organizations, values, and goals, and to evaluate these in context. The problem of guiding them in identifying the preferred course of action.

1.1 LITERATURE SURVEY

The first official example of the MCDM approach is seen in Benjamin Franklin's "moral or intellectual algebra" from 1772 [1] in which he discussed how to determine important issues on a simple paper. Write down the positive arguments for the decision on one side and write down the arguments against it on another side. Next, eliminate all issues on each side of the paper that are related and equally significant. In the absence of all disputes on one side, the side with the remaining arguments must be supported. Franklin used this method when making critical decisions [2].

In the mid-1960s, Bernard Roy and his colleagues formed ELECTRE, a family of Europe's Multi-Criteria Decision-Making Techniques [2]. They aim to create a targeted network of preferences. By putting these methods into practice, you create superior decisions or decisions that are the best. Then the EURO Working Group "Multiple Criteria Decision Aiding" was founded by Roy in 1975 [2].

Ralph Keeney and Howard Raiffa published their final book, “Decisions with Multiple Objectives: Preferences and Value Trade-offs” in 1976 [3]. This book was instrumental in establishing the refined methods for choosing between more than just two alternatives, and it involves many decision-makers who give birth to a multi-qualification theory as a discipline that has become a common indicator and text for many generations of decision-making research and the MCDM [1].

Surprised by the multicriteria crisis, Stanley Zionts met Jyrki Wallenius at the European Institute for Advanced Studies in Management in Brussels in 1973 [2]. Collectively, they have worked on methods and systems to support problem-solving decisions for many interactive multiple objective mathematical programming systems. In 1979, the Zionists helped develop the MCDM summary with his management article: "MCDM - If not Roman numerals, then what?" [2].

Daniel Kahneman and the late Amos Tversky made significant contributions to the ethics of behavioral decision theory, and Kahneman went on to win the Nobel Prize in Economics in 2002 for his contributions in this field [2]. It is widely believed that if Tversky had lived, he would have shared the Nobel Prize with Kahneman [2].

John Evans provided a way to compute all efficient extreme points that became the highly recommended topic for developing a multiple criteria simplex.

1.2 CLASSIFICATION FOR SOLVING MCDM PROBLEM

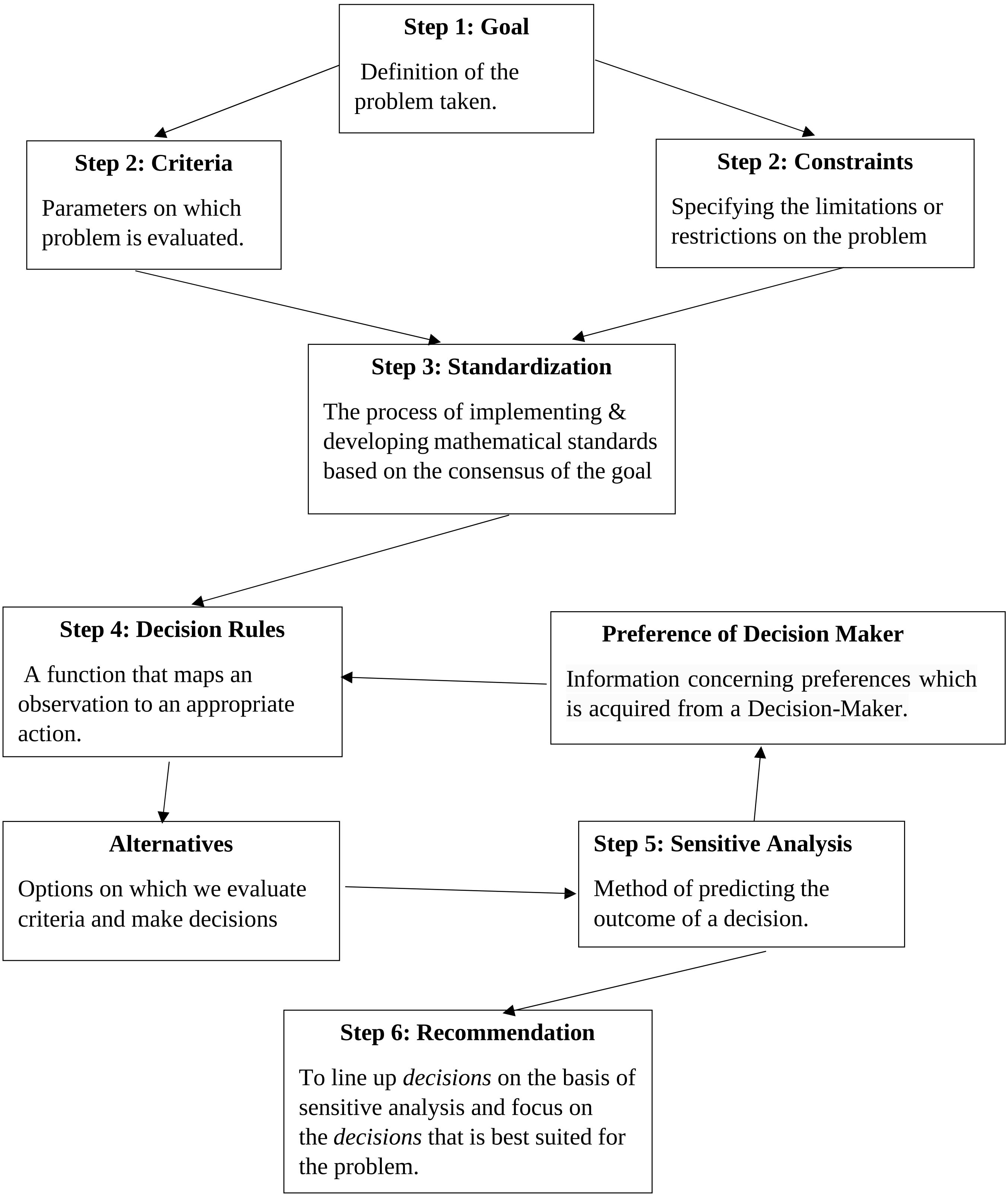

Figure 1: *Approach for solving MCDM Problem*

Multi-Criteria Decision Making is classified into the following categories:

1.2.1 Multi Objective Decision Making (MODM)

This stems from the idea that Multi Objective Decision-Making is concerned with problems in which we have a continuous decision space. For example, mathematical programming problems with multiple objective functions. The first reference to this problem, also known as the "vector-maximum" problem, was given by Kuhn and Tucker, 1951. [4]

1.2.2 Multi Attribute Decision Making (MADM)

Multi-Attribute Decision Making concentrates on those decision problems in which we have discrete decision spaces. In these problems, the set of alternatives has been predetermined. [5] Despite the fact that its methods are wide-ranging, many of them share certain characteristics. Following is the table describing the key differences between these categories:

	MODM	MADM
1.	When there are several objectives to make a decision. These objectives are the constraints.	When there are several alternatives that are carried out based on various attributes of the object to make a decision.
2.	Here, objectives considered are function: $f_1, f_2, f_3, \ldots$	Here, we consider alternatives: $A_1, A_2, A_3, \ldots A_n$
3.	The objectives or goals are explicitly defined as: Ex- While buying some products, we need to maximize the quality as well as we need to maximize the savings.	The objectives are implicitly defined i.e., we don't directly say we need to maximize the profit. Ex- If we are selecting the candidates out of 50 applicants for our company.
4.	Attributes are defined implicitly. For example:- Maximize $f(x)$ Subject to $g(x) \leq 0$	Attributes are defined explicitly Ex:- To evaluate an applicant for a job, we need to evaluate his/her • Resume • Experience • Knowledge
5.	Alternatives are infinite in number. That is, we can have a very large number of feasible solutions.	Alternatives are finite in number. For example, while selecting a candidate we are not taking millions of alternatives, but a small(finite) number of alternatives.
6.	Alternatives are implicit	Alternatives are explicit
7.	Modelling paradigm is Process-oriented	Modelling paradigm is Outcome-oriented

Table 1: *Difference between MODM and MADM*

CHAPTER 2

ATM OPERATING SYSTEM

Automated Teller Machine, also known as ATMs, is a Money Transmission Equipment that is one of the best developments in the banking sector. Using an ATM, customers can perform a number of quick self-help functions, including withdrawals, deposits, and transfers.

There were a number of groups around the world in the 1960s, working independently to devise a way to withdraw money from the bank by committing no crime. In 1960, an American named Luther George Simjian founded the Bankograph, which allowed customers to place cash and checks on it [6]. The first ATM was established in June 1967 on the road in Enfield, London at the Barclays bank branch [6]. The British founder John Shepherd-Barron is said to have been founded. Customers have been able to withdraw up to the GBP10 limit within a set period of time.

ATMs have eliminated the need to visit a bank branch for simple banking transactions, such as depositing cash or withdrawing cash. Gone are the days when customers primarily used bank branches during business hours.

ATMs fall into two categories:

1. Basic ATMs allow customers to withdraw cash and receive account balance information.
2. Another one is the more sophisticated deposit processing machine, which provides credit card payment services and reports account details

2.1 BASIC PARTS OF ATM

Card reader: Every ATM has a card slot. An ATM card's magnetic stripe captures account information via the device's card reader when the card is swiped or pressed against the reader.

The host processor uses this information in order to deliver the transaction to the cardholder's bank.

Key Pad: A Keypad is given in all ATMs where you can insert numbers to enter the PIN or the amount to be withdrawn. The keypad also allows the card holder to tell the bank what type of work will be required such as withdrawals, balance checks, etc. These keypads can either be physical buttons at an ATM or virtual keypad on the touch screen.

Speaker: There is a speaker in most of the ATMs where the auditory instructions of accessing the machine & doing transactions are given.

Display screen: In addition to being a guide to the operator at every stage of the transaction, the display screen shows information to the cardholder. Leased-line ATMs usually use a monochrome or CRT color (cathode ray tube) display while Dial-up ATMs usually use a monochrome or color LCD. [7]

Receipt printer: It records all the details of the transaction like a type of transaction, amounts withdrawn, date and time, and the remaining balance of your account in the receipt. On request, the printer prints out a worksheet receipt for the cardholder.

Cash dispenser: It is called the heart of an ATM. From this, you can collect cash after withdrawing a certain amount. The entire lower part of ATMs is a cash-containing filter. The cash dispenser calculates each bill and provides the required amount. Money is stored securely in the Automated Teller Machine by bank officials. All of these actions are performed by sensors of high accuracy. The ATM maintains a complete record of all transactions with the aid of the RTC.

2.2 HOW DOES ATM WORK?

First Step: You need to swipe your ATM card. A card reader is installed inside the machine. The card reader reads the magnetic stripe of the card and stores the amount recorded on it (which shouldn't be scratched).

Second Step: A message is displayed on the screen i.e., "ENTER PIN". First, the bank assigns each account holder a PIN, which is then changed by that account holder. As soon as the user enters the PIN, the machine encodes the PIN and it is sent to the host processor, which then connects it to the Bank terminal. In order to verify the accuracy of the PIN, the processor compares it to the recorded information.

Third Step: ATM sends the request i.e., "Request Amount". Input from the ATM is sent to the host processor, which then forwards it to the networks for approval, such as Visa, Master Card, etc.

Fourth Step: As soon as the network requests the withdrawal, the bank checks to see if that amount is available on the customer's account.

Fifth Step: By saying YES, the bank makes an electronic transfer to the account of the host processor. The host will forward the authorization code to the bank.

Sixth Step: Bills in the cash cartridges under or at the back of the computer screen are calculated by the electronic eye and pushed out of the cash slot.

2.3 FEATURES OF ATM

1. **The versatility of ATM**: ATM is not bound to only dispense cash but also you can get certain facilities such as:
    - depositing the cash
    - transfer funds between connected bank accounts
    - payments of bills
    - find account balance
    - prints a list of recent activities

- generating mini statements.

and many more.

2. **User-friendly:** It is designed in such a way that anyone can use it. Even illiterate individuals and especially-abled people. With the introduction of biometric identification scanners and speakers, it becomes easier for the users.
3. **Less Language barrier:** Country like India where many languages are spoken. ATM needs to be Multilingual to operate properly. You can use the ATM of your comfort language. You can also perform a range of features in your foreign language as well.

CHAPTER 3

THEORY OF COMPUTATION

In the course of our research, we will explore the Working of ATM in the domain of Theory of Computation which is defined in three fundamental ideas i.e., languages, grammars, and automata. First, we will discuss the definition of these parameters in formal languages and then illustrate the process of the Turing machine.

3.1 LANGUAGE

According to the definition provided in the dictionary, language involves the use of symbols and ambiguous rules in order to convey ideas, facts, or concepts. The above definition allows us to grasp the concept of language intuitively, however, it isn't enough to define the meaning of the language used in formal languages. Language in a formal language is a subdivision of set Σ that's defined for a finite and non-empty set of symbols known as the alphabet. Here set is denoted by this Σ. From each symbol, we form strings, which are a finite sequence of symbols from the alphabet.

3.2 GRAMMAR

Since we know that our daily language is vague and inaccurate, and informal definitions in English are often inadequate. So, we learn a common and powerful concept namely, Grammar. In the English language, well-formed sentences are indicated by grammar. The same idea is expressed in formal languages.

In natural languages, Grammar indicates a finite set of syntactical rules for establishing meaningful conversations. The mathematical model of grammar was provided by **Noam Chomsky** in 1956 who is very good at writing computer languages. Grammar plays a key role in defining ways to learn natural languages mathematically [8].

Definition: A grammar G is defined as a quadruple G=(V, T, S, P) where,

V is a finite set of objects called variables,

T is a finite set of objects called terminal symbols,

S belongs to V, is a special symbol called the start variable, P is a finite set of productions [9]. By defining the production rules, grammar is defined as a process of transforming one string into another, and by doing so, the language associated with that grammar is defined.

Here we also assume that the sets V and T are nonempty and disjoint. So, by applying the production rules in a different order, grammar can generate a variety of strings. All of these terminal strings are collectively referred to as grammar's language that is the language defined by the grammar.

Definition: Let $G = \{V, T, S, P\}$ be a grammar, then the set

$L(G) = \{w \in T \, : \, S \Rightarrow w\}$

is the language generated by the grammar G [9] .

Here if $w \in L(G)$ then the sequence $S \Longrightarrow w_1 \Longrightarrow w_2 \Longrightarrow w_3 \Longrightarrow . \, . \, . \, . \, . \Longrightarrow w_n \Longrightarrow w$ is derived from the sentence w, the strings S, w_1, w_2, w_3. . . . w_n which contain variables as well as terminals, are called sentential forms of derivation [9].

3.3 AUTOMATA

An automaton is an abstract digital computer model. It has an input reader. A series of characters i.e., strings are assumed to be the input written on an input file, which is read by the automaton but not changed by it.

Following is a schematic representation of a general automaton:

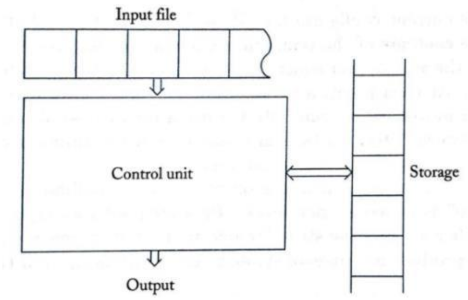

Figure 2: *A schematic representation of a general automaton*

In this, each **input file** is divided into cells and each input file can hold one symbol [10]. The input mechanism reads the input file one symbol at a time, left to right. It is also possible to sense the end of an input string via the end-of-file condition in the input mechanism. The automaton produces the **output** of some form which may have a temporary **storage** device, consisting of an unlimited number of cells, each capable of holding a single symbol from an alphabet that is not necessarily the same one as the input alphabet [10]. Automatons have the ability to read and change the content of storage cells.

Last but not least, the automaton has a **control unit** that can be in one of a few limited internal states and can change its state in a defined manner.

It is assumed that the automaton operates in a time frame that is distinct. A control unit is in a particular state at any given time, and the input method scans a certain symbol on the input file. The next state or transition function establishes the **internal state** of the control unit at the next time step.

This **transition function** provides the following state depending on the current state, the current input symbol, and the information currently in the temporary storage [10]. The output may be generated or the temporary storage may be updated during the transition from one period to another. The term **configuration** is used whenever we refer to a specific state of a control unit, input file, and temporary storage [10]. Furthermore, the act of moving an automaton from one configuration to another is called a **move**.

3.4 FINITE AUTOMATA

Finite Automata, or finite state machines, are the simplest abstract machines that can recognize patterns. They have five elements or tuples. The input symbol determines the tool's state and rules for moving from one state to another. In essence, it functions as an abstract digital machine model. The figure below describes some of the key components of general automation.

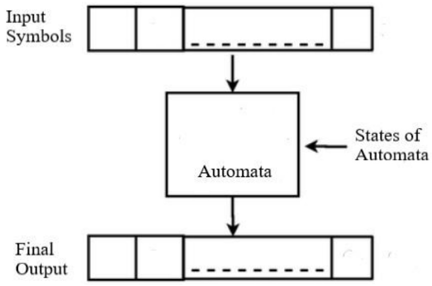

Figure 3: *Key Components of Finite Automata*

There are 2 types of automata:

1. Deterministic automata
2. Non-deterministic automata.

3.4.1 Deterministic Finite Automata (DFA)

As the name suggests, deterministic automata determine their movements separately by the current configuration. Knowing the internal state, inputs, and contents of temporary storage will provide us with an exact prediction of how the future automaton will behave.

Acceptors are automatons that only respond with a "yes" or "no" when asked. When presented with an input string, an accepter either accepts or rejects the string.

There is a more general automaton known as a **transducer** that can produce strings of symbols as output.

By deterministic, we mean that when the input symbols are read, the automaton changes its current state to another state or may remain in the same state.

Definition: A deterministic finite automaton (or DFA) is defined by a quintuple that consists of 5 tuples $\{S, \delta, s, F, \Sigma\}$ where

S: a set of all states,

Σ: a set of input symbols which machine takes as input,

s: Initial state of a machine,

F: a set of the final state,

δ: Transition Function, defined as $\delta: S \times \sum \rightarrow S$ [11].

The DFA machine stays in only one state at a time for particular character input. Every state has its transition function. Null (or ∈) moves are also forbidden in DFA, i.e., DFA cannot change state without input.

3.4.2 Non-Deterministic Finite Automata

On the other hand, a non-deterministic automaton may have a wide range of possible moves at any given point, so we can only anticipate a handful of possibilities.

A Non-Deterministic Finite Automata is a state machine that consists of states and transitions capable of either accepting or rejecting a finite string.

Symbols in a Non-Deterministic Finite Automata can undergo a number of transitions from the same state. It is similar to Deterministic Finite Automata, except for the following additional features:

1. It is allowed to perform a null (or ε) move, which is to say it can proceed forward without reading symbols.
2. A particular input can be transmitted to any number of states.

An NFA consists of a quintuple(or 5-tuple) such that,

$M = (S, \Sigma, \delta, s, F)$, where

S is a finite set of all states,

Σ is a finite set of all symbols of the alphabet,

$\delta: S \times (\{\Sigma \cup \varepsilon\}) \rightarrow 2^S$ is the transition function from state to state,

$s \in S$ is the start state, in which the start state must be in the set S,

$F \subseteq S$is the set of accept states, in which the accept states must be in the set S. [12]

Here, the order of the elements does matter.

The standard Turing machine shows deterministic behavior as one can either go in the left direction or the right direction for a particular input whereas, in the case of a non-deterministic Turing machine, one can go in both directions.

3.5 TURING MACHINE

A Turing machine is an imaginary machine that reads an infinite tape through which it interacts with the outside world. A tape is divided into cells with symbols (one symbol at a time) or blank spaces, and as the reading progresses, the output is recorded on that tape as well. A 'head' is placed on a specific cell of the tape that moves left (L) or right (R) one cell at a time as it performs reads and writes. We may say, therefore, that the computation in the Turing machine is done with the help of a transition function, which directs the machine how to react to the symbols on the tape.

The Turing machine was first proposed by Alan Turing in 1936 [13]. Unlike physical machines, Turing machines are mathematical machine objects. Turing proposed that it is not necessary to discuss how the machine actually does its work. It is enough to believe that it can accomplish the actions as specified and to believe that those actions can be uniquely described.

Alternatively, Turing machines can be called "general-purpose computers" having infinite tapes.

It consists of

the control unit helps to read the current tape symbol,

writes a symbol on the tape,

moves one place to the left or right,

switches to the following state,

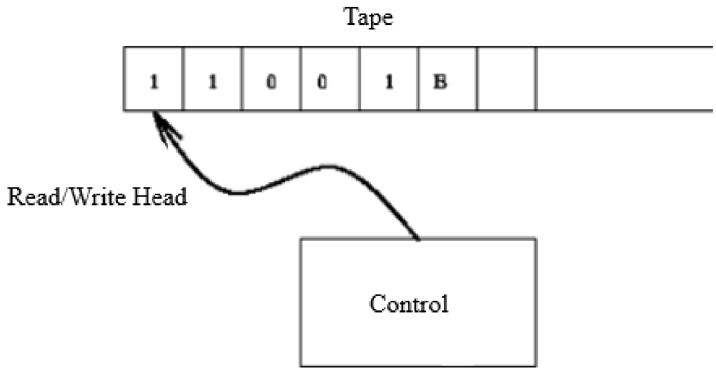

Figure 4: Turing Machine

where each transition of the machine is a 4-tuple which can be represented as,

($State_{current}$, Symbol, $State_{next}$, Action)

which is read as, 'if the machine is in the current state i.e., $State_{current,}$ and the cell being scanned contains Symbol then, move into next state i.e., $State_{next}$ taking Action' [14].

A Turing machine can therefore mark a symbol on the tape in the current cell or move the head cell left or right while performing an action. However, if it reaches a point where it cannot make a particular/unique transition, it is said to halt.

Moreover, one could consider a Turing machine as a finite-state machine that resides in a horizontal form, stretched across an infinitely long tape containing symbols from a finite alphabet Σ. Based on the symbol it's currently reading, and its current state, the Turing machine writes a new symbol '0' or '1' in that location, moves left or right or stays in place, and enters a new state [13]. The numbers '0' and '1' denote blanks and symbols, respectively.

The transition function on the machine gives instructions on how to perform various tasks, such as overwriting a symbol, moving left or right, entering a new state, optionally stopping, and outputting an answer given the current state and symbol that the machine is reading.

Definition

Turing machines are composed of seven-tuples $(S, s_0, \Gamma, \mathrm{b}, \Sigma, \mathrm{F}, \sigma)$, where

$S =$ a finite set of states with one of them $s_0 \in S$ being a designated starting state which is defined as a state the machine starts its operation in,

$\Gamma =$ a finite set of symbols with one of them $b \in \Gamma$ being a designated starting state,

$\Sigma \subset \Gamma$ is a subset of input symbols,

$P \subset S$ is a subset of accepting states which finalizes the computation that is when the machine reaches F, the computation final state,

$\sigma: S \times \Gamma \rightarrow S \times \Gamma \times \{L, R\}$ is a partial transition function [14].

In the event that the machine reaches a state and input that are not defined for σ, the machine will halt. Here, in this transition function, $s_0 \in S$ represents the start state, $s_{accept} \in S$ represents the accept state, and $s_{reject} \in S$ represents the reject state, where $s_{accept} \neq s_{reject}$.

The transition function σ is referred to as the heart of Turing machines because it describes how the machine moves between different configurations.

Since transition function σ tells us how the machine gets on from one configuration to another, it is also known as the heart of a Turing machine. In Turing machines, one's current state, tape content, and head location describe its configuration.

The machine at state $s \in S$, reads the current symbol $\gamma \in \Gamma$ on the tape loading to

$$\sigma(s, \gamma) = (s^1, \gamma^1, d)$$

where,

s^1 is the next state,

γ^1 is the output symbol written by the head on the tape,

$d \in \{L, R\}$ is the movement of the head (left or right) on the infinite tape [13].

CHAPTER 4

MULTIPLE SELECTION CRITERIA AT EACH WORKING STAGE OF ATM

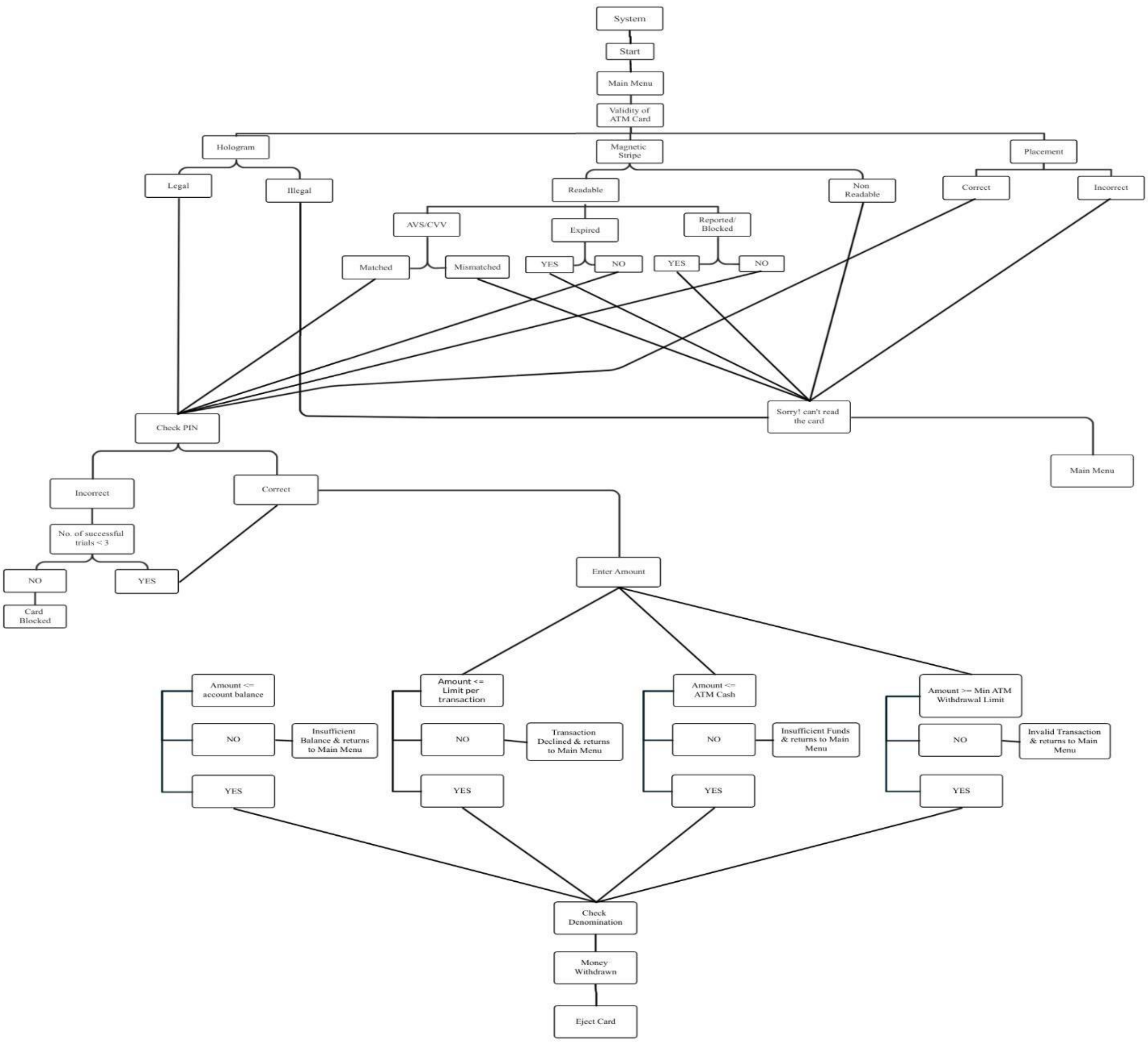

Figure 5: *Transition model of Multiple selection Criteria at each stage of ATM*

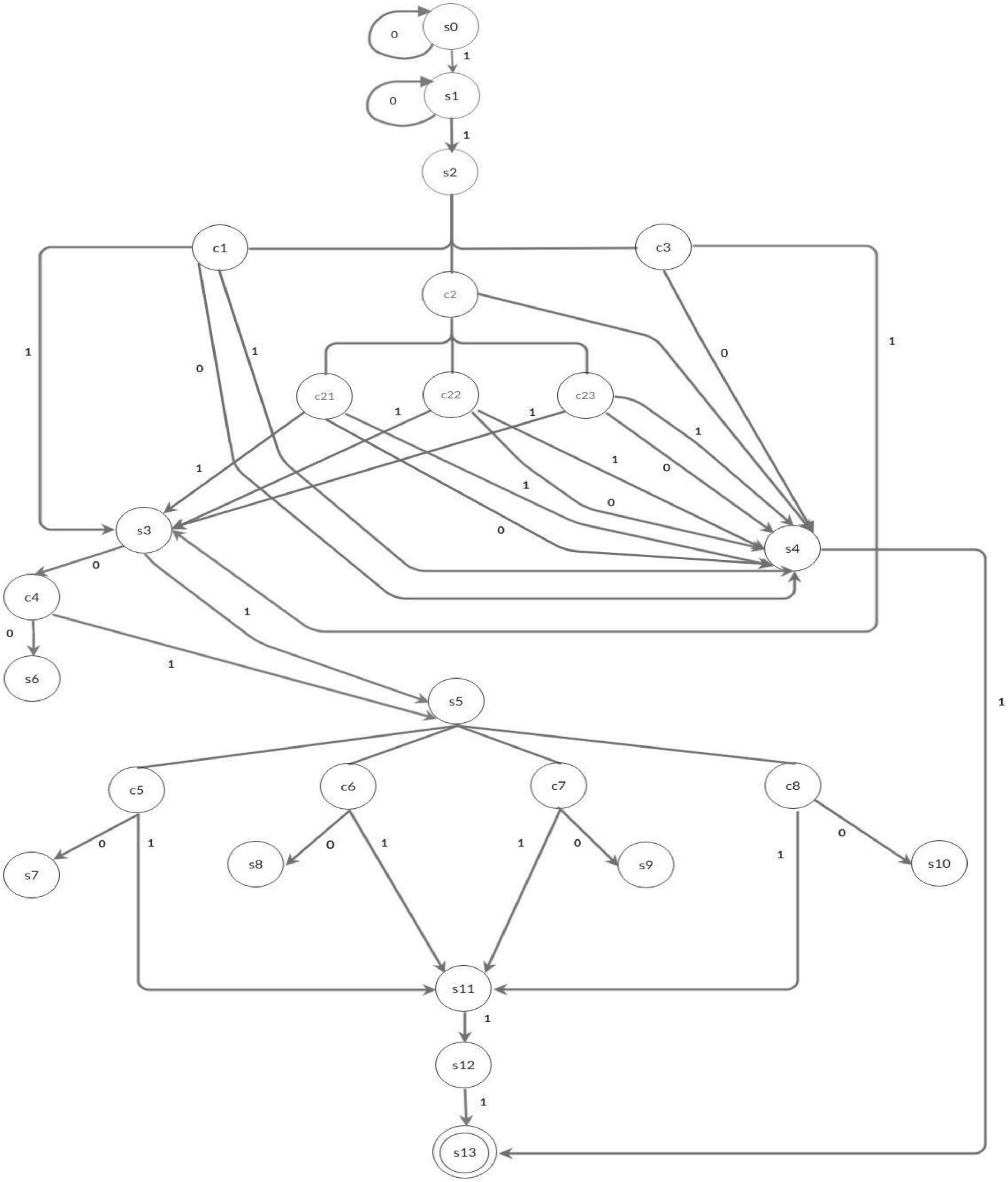

Figure 6: *Abstract Transition model of Multiple selection Criteria at each stage of ATM*

4.1 THE NOTATION/ TERMINOLOGIES FOR DETERMINATION OF TRANSITION TABLE AND GRAPH

The formal model of Operating ATM System using MCDM is defined as a non-deterministic Turing Machine DATAMST.

DATAMST || $(S, C, \Sigma, s, b, \delta, F)$ represents seven tuple relationship where:

- S is the set of valid states that represents the domain of the working of ATM System,

$S = \{s_0, s_1, s_2, \dots, s_{13}\}$ here the states are:

s_0 −System

s_1 −Main Menu

s_2 −Validity of ATM Card

s_3 −Check PIN

s_4 − Sorry! Can't read the card

s_5 − Enter Amount

s_6 −Card Blocked

s_7 −Insufficient Balance

s_8 −Transaction Declined

s_9 −Insufficient Funds

s_{10} −Invalid Transaction

s_{11} −Check Denomination

s_{12} −Money Withdrawn

s_{13} −Eject Card

- C is the set of multiple criteria at each state considered by the ATM to make decision before proceeding to the next state, where $C = \{c_1, c_2, \dots, c_8\}$

c_1 −Hologram

c_2 −Magnetic Stripe

c_{21} − CVV matches with AVS or not

c_{22} − ATM card is expired or not.

c_{23} − ATM card is Blocked/Reported or not

c_3 − Placement of the ATM Card

c_4 − When number of unsuccessful trials are greater than 3

c_5 − Account Balance is greater than the amount to be withdrawn or not

c_6 – Limit Per Transaction is crossed or not

c_7 – Cash availability at ATM

c_8 – Minimum ATM Withdrawal Limit is crossed or not

- $\sum$ is the set of events that the ATM may accept and process, $\Sigma = \{0,1\}$
- s is the start state of the ATM, $s = s_1$ (Main Menu)
- b is the blank symbol; this happens when we insert a card but do not perform any action.
- F is the set of ending set, $F = \{s_{13}\}$ (Eject card)
- δ is the transition function of the ATM that determines the next state of Turing Machine, s_{i+1}, on the basis of the current state s_i and a specific incoming event {0,1}, i.e.,

$$s_{i+1} = \delta(s_i, \{0,1\}), \text{ where, } \delta = f: (S, C) \times \sum \rightarrow S .$$

4.2 TRANSITION BEHAVIOR OF EACH STATE

States	Σ	Next State
(s_0)	b	$\{s_0\}$
(s_0)	0	$\{s_0\}$
(s_0)	1	$\{s_1\}$
(s_1)	0	$\{s_1\}$
(s_1)	1	$\{s_2\}$
(s_2, c_1)	0	$\{s_4\}$
(s_2, c_1)	1	$\{s_4, s_3\}$
(s_2, c_2)	0	$\{s_4\}$
(s_2, c_2)	1	$\{s_4, s_3\}$
(s_2, c_3)	0	$\{s_4\}$
(s_2, c_3)	1	$\{s_4, s_3\}$
(s_3)	1	$\{s_5\}$
(s_3, c_4)	0	$\{s_5\}$
(s_3, c_4)	1	$\{s_6\}$
(s_4)	1	$\{s_1\}$
(s_5, c_5)	0	$\{s_7\}$
(s_5, c_5)	1	$\{s_{11}\}$
(s_5, c_6)	0	$\{s_8\}$
(s_5, c_6)	1	$\{s_{11}\}$
(s_5, c_7)	0	$\{s_9\}$
(s_5, c_7)	1	$\{s_{11}\}$
(s_5, c_8)	0	$\{s_{10}\}$

(s_5, c_8)	1	$\{s_{11}\}$
(s_{11})	1	$\{s_{12}\}$
(s_{12})	1	$\{s_{13}\}$

Table 2: *Transition Behavior of each state*

Using all of the possible decisions based on the following criteria, the following table (2) illustrates the transition behavior of State s_2:

c_1	c_2	c_3	F
0	0	0	$\{s_4, s_{13}\}$
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	$\{s_3\}$

Table 3: Transition Behavior of State s_2

Here we can observe from the above transition table that the transition behavior of state s_2 is determined by three criteria that are c_1, c_2, and c_3. Therefore, the total number of possible decisions made from this criterion will be $2^3 = 8$. This signifies that ATM can face eight possible scenarios on the state s_2, out of which only one decision will lead to that next state s_3 i.e., (1,1,1) case and rest will lead to the states $\{s_4, s_{13}\}$.

Similarly, we can define the transition behavior for the state s_3 and s_5. We can observe from Figure 6 that the transition behavior of state s_3 is determined from a single criterion c_4 and state s_5 is determined by 4 criteria. Therefore, ATMs can face $2^1 = 2$, $2^4 = 16$ scenarios on state s_3 and s_5 respectively.

4.3 EXPLANATION OF MULTIPLE SELECTION CRITERIA AT EACH STAGE OF THE ATM SYSTEM

In this section, we have described the multiple selection criteria evaluated by ATMs during cash withdrawal at each working stage. This is a Multi-Attribute Decision Making problem as it deals with multiple attributes and has a single objective that is to withdraw money.

State 1: Main Menu

This is the first stage of ATM where it shows the main ATM functions. When a user withdraws money from an ATM, they select the withdrawal option from the menu and insert their respective ATM card.

State 2: Validity of ATM Card

When the user places the ATM Card inside the machine, ATM first checks the validity of the card by considering the following criteria:

Criteria 1-Hologram:

Payments can be processed more securely when using debit/ATM cards holograms. If someone pays you with a card, it is crucial that you look at the hologram to confirm it is real. It indicates a valid card and is a valid identification. In the absence of a hologram, an issue may exist with the card or the card may be forged by the person using it.

A card reader is installed in ATMs to perform this function. The ATM is designed with a hologram code reading system that utilizes reconstruction light from a light source to illuminate the recorded areas of the hologram which contain codified data recorded as image data, and a code reading sensor is positioned at the reconstruction position within the reconstruction image created by the reconstruction light. The code reading sensor is provided with a control means to obtain codified data from the hologram reconstruction image.

Multiple layers of images are stacked on top of each other to create hologram on the ATM card. This adds to the illusion of motion when the card is moved even slightly. Due to the way the image is displayed on the ATM card, it appears raised above the plastic, giving it a sense of depth.

The security hologram, invented by MasterCard International in the early 1980s, now appears not just on ATMs, credit cards, and passports, but also on electronic gadgets and bank notes.

The fact that holograms are multi-imaged prevents counterfeiting because the images of a hologram cannot be captured with an optical scanner or copied with a photocopier. Moreover, holograms are generally embedded with images that can be instantly verified to ensure immediate security.

In this way, ATMs verify whether the card inserted by the user is legal or not. In the case of a legal card, it will move forward with the process, otherwise it rejects the card and directs the user to the main menu.

Criteria 2-Magnetic Stripe:

Magnetic stripes are an imperative criterion for checking the validity of an ATM card. This stripe appears at the back of an ATM card. A magnetized pattern can be recorded on this stripe to store digital data. Magnetic stripes have three tracks, each measuring 110 inches wide.

In accordance with ISO/IEC standard 7811, the bank follows these guidelines:

- There are 79 read-only characters on track one with 210 bits per inch (bpi).
- Track two is 75 bits per inch and can hold 40 four-bit plus parity bit characters.
- There are 107 four-bit plus parity bit characters on track three at 210 bps.

The ATM card only utilizes the first two tracks. The third track consists of the country code, units of currency, PIN protected by cryptography and the authorized amount. However, its use is not standardized among banks.

There are two formats of track one information, A, which is reserved for the card issuer, and B, which includes the start sentinel of 1 character with format code="B", primary account number: varies up to 19 characters, separator: it's of 1 character, country code: it’s of 3 characters, name: varies from 2 to 26 characters, separator: it’s of single character, the expiration date or separator may differ from a character to 4 characters, discretionary data: it has 79 characters in total which is enough to fill out the maximum record length, end sentinel: it’s of 1 character, and Longitudinal Redundancy Check (LRC): it's a computed check character with a single character.

Track two follows a format developed by the banking industry, with start sentinel: It's 1 character, primary account number: it's up to 19 characters, separator: it's 1 character, country code: it has 2 characters, expiration date or separator: It's up to 4 characters, discretionary data: it's 40 characters in total, which is sufficient to fulfil the maximum record length, and LRC: it's 1 character.

At an ATM, the validity of an ATM card is determined by electronic data capture (EDC). By inserting the ATM card through the card reader, the EDC software calls an acquirer by dialing a number stored in a modem. Acquirers are the computers that process ATM authentication requests and provide a transaction guarantee from the bank to the ATM.

As soon as the acquirer receives the card authentication request, it checks the transaction for validity and reads the record on the magnetic stripe. This record contains the valid card number, expiration date, ATM card limit, and usage.

It is probably either one of the following that is preventing the ATM from reading the card:

-The magnetic stripe is dirty or scratched.

-Magstripes can be erased due to exposure to magnets and a store's electronic article surveillance tag demagnetizer.

Mismatch in AVS and CVV (c_{21}):

An AVS or CVV error can also result in a transaction being declined. Card Verification Value (CVV) is a three-digit number on the back of your ATM card that acts as a security code. Banks develop the Address Verification System (AVS) to detect suspicious transactions.

There is a possibility of suspicious transactions when too many PINs are being fed at once at an ATM or observing spending patterns that differ from your usual habits. Many banks now have a whole upgraded system of security in place which can play the role of being way too safe and blocking your card.

Consequently, when you insert your ATM card at an ATM and these two security systems are mismatched with the data stored at the bank, your transaction will not be processed.

Expiry Date of ATM Card(c_{22}):

There is an expiration date on every ATM card. There is an expiration date on the back of the card, written as XX/XX (month and year). A card can be used until the last day of the month in which it expires. For example: a card ending in 11/25 is valid until November 30, 2025. In such a case, your account will remain active, but not your card.

Before proceeding with any transaction, the ATM checks if the ATM card has passed its expiration date. Your old card will likely be declined if you try to use it after its expiration date, or the ATM will swallow it.

Blocked/ Reported ATM Card (c_{23}):

ATM also check whether the user is using a blocked or reported card. Using such a card for the transaction will prevent the ATM from returning it and processing the transaction.

Criteria 3-Placement:

When we swipe our ATM card into the card reader, a green light above the card reader will blink to indicate that the card has been properly inserted and our access has been granted. A red light will blink and the access will be rejected if the card is not positioned correctly.

Inserting an ATM card, the right way requires the magnetic stripe to be at the bottom and the chip of the card must be facing up at the front.

You may be asked to return your card after your transaction has been completed by some ATMs, while others will simply ask for it back after reading the information stored on your card.

In most cases, the ATM will proceed with its process if the card is placed correctly, otherwise it will prompt you to place it correctly.

State 3: Check PIN

If all the conditions of validity of the ATM card are met then the processor will check whether the PIN is correct or incorrect.

So how do ATMs check your PIN?

It basically needs 3 things –

-An Algorithm that encompasses a complex formula embedded in the ATM machine software.

-A 16-digit number that encrypts your ATM card data.

-And the hash key, which is your PIN that is not stored anywhere.

The bank gives you an account by combining these 3 items into an exponential logical operation and then making a junk of useless code that's stored on the server via the internet. A junk code is created from the algorithm which is performed again with the PIN and card number that you input into the software when you need money. This junk code is pulled from the bank's server and compared with the new one that has been generated, and if they match, you receive your money.

Interestingly enough, your PIN does not go anywhere beyond the ATM. Your card number, however, does go to the bank server to confirm that you have an account and to prepare for the operation. Unless the bank is provided with the PIN code, they have nothing more than this blob of encrypted information pertaining to our passwords.

After an operation, only junk code is compared. With only a one-bit output, the algorithm says 1 if the PIN was correct to indicate that the request amount was discharged, says 0 to indicate that the password was incorrect.

An ATM card is simply a piece of plastic with a 16-digit number on the black magnetic strip. It can be cloned by anyone in less than 2 minutes using the right hardware. When you lose your card, any person can use it to make purchases, which is a big loophole because the bank doesn't use authentication. Nevertheless, a lost card cannot be used on an ATM without the pin. Using a brute force method, it would take billions of years to crack a key of this size. This is due to

(the speed at which the computer cracks the code in flops) x 2^(the number of bits of encryption, usually 256).

Simply put, the bank has no idea what anyone's PIN is and they therefore ask you to reset it rather than remind or show the original PIN to you if you forget it. You are the only one who knows your own PIN as well as the people with whom you shared it.

Correct PIN:

If the entered PIN is correct then ATM will proceed to the next step.

Incorrect PIN:

An ATM card PIN is a crucial piece of information when withdrawing cash from an ATM. At the ATM machine it is ok to put in the wrong PIN number twice, but when you do it thrice it becomes an issue.

In accordance with RBI guidelines, only three attempts should be made to enter an ATM card PIN when withdrawing cash from an ATM. Once you exceed three attempts, your card will be blocked automatically. In addition, the RBI advises customers not to write their PIN number on their cards, not to share their PINnumber with anyone, and not to let anyone see their PIN while carrying out transactions. The RBI also recommends not keeping an easy PIN that combines elements like birth date, age, etc. While this may make it hard for most card holders to remember their password, it is a preventative measure to protect against fraud.

Hence, you can be blocked if you have entered your ATM card PIN incorrectly thrice at an ATM.

State 5: Enter Amount

When the user enters the amount, prior to proceeding to the next step, ATM checks the following criteria:

Criteria 5-Account Balance:

When amount to be withdrawn ≤ Account balance:

This will successfully lead to the next step, and the machine will process the amount.

Amount to be withdrawn > Account balance:

If the amount to be withdrawn from the ATM exceeds what is in your account, then the ATM can withdraw money or it will decline the transaction, depending on the arrangement with your bank.

Case 1: When you cannot complete the transaction

A link is established between the ATM and the bank's data base that displays your account balance. Due to insufficient funds in the account, the ATM will not process withdrawals that exceed the balance in your account.

There are jurisdictions where withdrawing excessive amounts of money requires you to sign an agreement. In some cases, the bank takes a snap decision while the transaction is ongoing.

Case 2: When you can complete the transaction

Banks may allow you to withdraw more than your account balance, but that will be enough to place your account in negative territory, depending on the terms of your **overdraft arrangement** (if any).

To determine whether the withdrawal exceeded the available funds, or whether it exceeded the total funds, is crucial. Banks will reject transactions, even when there seems to be funds in a bank account, because account holders can only access or withdraw funds that they have in available funds. Here's how banks differentiate between these two types of funds:

An **available fund** is the amount a depositor can access at the time of withdrawal

A **total fund** includes both available funds and funds that are not yet processed such as uncleared checks or unpaid purchases/ transactions.

There is a possibility of withdrawing funds beyond the account balance, but the withdrawals come with repercussions, bank terms, and fees. A withdrawal that exceeds the available funds is regarded as an overdraft and are subject to penalties. In this case, overdraft penalties will be paid from new deposits, while the remaining balance will be available to account holders. It is important for account holders to understand how to protect themselves from overdrafts through **overdraft protection**.

The term overdraft protection refers to a service or program offered by financial institutions i.e., account holders can opt in, which allows bank account holders to withdraw more than their account balance and be charged an overdraft fee. In the event that you don't opt for some type of overdraft protection and withdraw funds over the amount in your account, the transaction will "fail" that is, the recipient of the check will not receive the funds.

Criteria 6-Limit Per Transaction:

'Limit Per Transaction' refers to the maximum accumulated daily limit permitted by the Bank and communicated to the cardholder by the Bank from time to time. This limit relates to each type of transaction to which the cardholder may have access.

The machine checks whether the amount entered by the user is less than the limit per transaction or is it greater.

Amount to be withdrawn ≤ Limit per Transaction

This will successfully lead to the next step, and the machine will process the amount.

Amount to be withdrawn > Limit per Transaction

The amount will not be processed in this case, as there is a daily spending limit, and if the amount is exceeded, the card will be declined.

For example: You can withdraw more money from an ATM using your savings account, but you cannot withdraw more than six times per month. This is a federal law, so it applies to all savings accounts at all banks. It is vital to know your debit card and bank financial transaction limits thoroughly.

The main reasons a bank restricts withdrawals are cash availability limits and security concerns:

Cash Availability Limits: When you deposit a pay check into your checking account, the bank doesn't simply store it in a vault until you request it. Rather, banks use the money to lend to people and businesses, bundling it with other people's deposits.

It would be impossible for the bank to know which ATM to keep stocked with cash in order to meet your needs. This is even if it kept your cash on hand. Would you rather use the ATM at your local bank branch or the one at the corner store? Having withdrawal limits prevents customers from draining ATMs or causing the bank to run out of cash.

Security Concerns: In addition, banks limit ATM withdrawals out of concern for identity theft and unauthorized withdrawals. Often, it is difficult to get your money back if your rarely used credit card is stolen and you do not notice for a long time. By limiting withdrawals, a criminal is less likely to empty your account quickly.

Criteria 7-ATM Cash:

The ATM evaluates this criterion as well before processing any transaction. It is the currency delivered to and maintained in each ATM before it is dispensed to the cardholder making a withdrawal transaction, to a person under an Electronic Check Authorization Transaction, or to a person under a Credit Card Cash Transaction.

Before processing any transaction, ATM checks if the entered amount by the user is less than the ATM Cash or not.

Amount to be withdrawn ≤ Cash available in ATM

This will successfully lead to the next step, and the machine will process the amount.

Amount to be withdrawn > Cash available in ATM

This usually happens when an ATM runs out of cash. In such a scenario, an ATM can react in three ways:

(i) You are notified that your selection cannot be completed by the ATM

(ii) ATMs dispense less money than you entered. This occurs when the tray does not have all the available currency combinations.

(iii) The amount is deducted from the account, but the ATM is unable to disburse the cash.

Criteria 8-Minimum ATM Withdrawal Limit:

Minimum ATM withdrawal limits are the amounts of cash that customers can withdraw from an ATM at a minimum. When processing transactions, ATMs evaluate this criterion. The machine determines if the amount entered by the user is greater than the Minimum ATM Withdrawal limit.

Amount to be withdrawn ≥ ATM withdrawal limit

This will successfully lead to the next step, and the machine will process the amount.

Amount to be withdrawn < ATM withdrawal limit

Attempting to withdraw less than the minimum withdrawal limit will result in a "technical error" or "invalid transaction".

When all the four criteria, viz. Once criteria c_5, c_6, c_7 and c_8 are satisfied together, the ATM will proceed to the next state. Here, the ATM will check the denomination of available cash from the cash tray.

State 11: Check Denomination:

As we know, an ATM is an electromechanical device with a switch that knows how much and what denominations of cash are available. Upon entering your PIN and verifying that you have sufficient funds in your account, a switch instructs the ATM to withdraw the requested amount.

Isn't it curious how ATMs are able to decide what denomination and how many of each to give out?

Switches usually disburse the last note available in the ATM in the lowest denomination available at the time of withdrawal. For example, when withdrawing Rs 900 from an ATM, it will offer one Rs500 note and four Rs100 notes if the ATM has both Rs500 and Rs100 denominations. As an alternative to Rs500 and Rs100, it has Rs200 and Rs100, so the ATM will disburse four notes of Rs.200 and one note of Rs100.

Within the ATM, currency notes are stacked inside 'cassettes.' Each cassette contains notes of one denomination. Some older ATMs may only have two cassettes, while most ATMs in the country have four. A cassette must be calibrated according to the length, the width, and the thickness of the notes it is supposed to hold in order for the ATM to recognize what denominations are available and on which cassettes. At the ATM factory or on the ATM site, trained technicians perform this process.

Staff from the bank or the bank's authorized agencies load currency notes into the cassettes in the ATM on a regular basis. The banks must issue clean and crisp notes that are compatible with ATMs and ensure the notes are authentic. In security vans with armed escorts, cash is transported from the currency vaults of banks to ATMs.

ATMs are reloaded with cash depending on a vast array of factors, including the number of transactions made in the past, the value of withdrawals, the beginning of the month (salary period), festivals, long weekends, and the distance from the cash vault.

During an ATM withdrawal, you may hear a great deal of noise coming from within the machine. An ATM generates this noise when its dispenser arm pulls out the number of notes it needs from its cassette. From the cassette, notes are picked up one at a time and placed on dispenser belts, which then move and lead the notes up to the ATM outlet. Although ATMs dispense cash in an accurate manner, there may be occasions where there is an error and all notes cannot be disbursed to you.

And then ATM proceeds to the next state while dispensing the entered amount. Upon successful completion of a transaction, the user is prompted to eject the card.

CHAPTER 5

ISSUES FACE BY ATM

It is possible for your card to be compromised by scammers when your ATM does not dispense cash, despite a sufficient balance. What you can do is, get quick details of the ATM, time, and amount you were trying to withdraw. Visit your bank to notify the problem. They will immediately block your debit card and issue you a new one.

What's more frustrating is receiving an SMS telling you the amount has been deducted from your account when the ATM declines your transaction. It is especially concerning if the amount is large.

Generally, this is due to two factors:

Technical Error: The ATM may be malfunctioning. This is due to poor internet connections, power outages, and too many transactions processing at once, among other factors. You can either wait a while and try again, or visit another ATM terminal. Otherwise, you can contact your bank about the problem. A bank's machines are normally checked periodically as part of normal procedure. All complaints received are resolved promptly. Therefore, your money should be credited to your account automatically in some time, and you will be notified of the same by the bank

Fraud: Check the slot before inserting your card to avoid fraud. There have been cases where a skimmer was inserted into the slot and read all the information on the magnetic strip. Stolen information can be used to clone your card, allowing money to be withdrawn from your account.

CHAPTER 6

CONCLUSION

Our paper presents multiple criteria that the ATM considers at each state before deciding whether to proceed to the next. The basis of this research was largely shaped by the concept of Multi-Criteria Decision Making. It's a very vast and complex topic that helps to test many contradictory criteria and provide solid decisions in the most complex situations.

The concept of MCDM was first introduced, then its origin and literature review were discussed. Having explained the approach to solve the MCDM problem through a flow chart, we have identified the differences between Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM), and have concluded that the problem considered is a Multi Attribute Decision Making (MADM) because for operating ATM system multiple attributes are considered, and here we have considered one objective that is to withdraw money.

Automated Teller Machine (ATM), is a Money Transmission Equipment that is one of the best developments in the banking sector. We have briefly explained the working of ATM operating system followed by the discussion of the ATM's basic parts and the features involved. This paper also shows the concept of the Turing machine, examines the working of ATM in the domain of Theory of Computation which is defined by three key concepts: languages, grammar, and automata. We represented the transition model of multiple selection criteria at each stage of ATM System followed by the formal model of same that is defined as a non-deterministic Turing Machine. This is a seven-tuple relationship i.e., $(S, C, \Sigma, s, b, \delta, F)$ where, the transition function of the ATM is defined as:

$$s_{i+1} = \delta(s_i, \{0,1\}), \text{ where,}$$

$$\delta = f: (S, C) \times \sum \rightarrow S \,.$$

Our model gives us a way to compute all the possible decisions that the ATM processor can make at each state with the help of the table showing transition behavior of each state. Following this, we explained the whole process indetail as shown in the transition model of Multiple selection Criteria at each stage of ATM working.

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