A FIS RISK ANALYSIS APPROACH AS A TOOL TO PRIORITIZE RISKS

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Salini Mettu, candidate for the degree of Master of Applied Science in Industrial Systems Engineering**,** has presented a thesis titled, A FIS Risk Analysis Approach as a Tool to Prioritize Risks***,*** in an oral examination held on October 14, 2016. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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ABSTRACT

In this work, a Fuzzy Inference System (FIS) as a risk analysis tool was developed to prioritize risks. The developed FIS risk analysis tool was applied to assess the risks in a drug dispensing process in a pharmacy, and also in a chemical process industry. The tool uses Bow-tie analysis and fuzzy concepts to analyze and prioritize a risk by computing its score. The risks, risk factors, and impacts were identified based on reported events and expert's knowledge. Bow-tie analysis was used to determine the factors that cause the occurrence of a risk and the impacts of a risk. Fuzzy estimates for the risk factors and impacts were obtained from the expert. The developed Mamdani FIS was used to compute the risk score. Based on the risk score, the risks were prioritised. Proper mitigation plans are suggested to control the risk events based on their risk score. For comparison, Failure Mode Effects Analysis (FMEA) was applied on the drug dispensing process and on chemical process industry. The results from the application of FMEA method agrees with the results obtained from the application of the proposed FIS risk analysis tool in both cases. The advantages of the developed FIS risk analysis tool over FMEA are: FIS risk analysis tool considers risk factors and impacts of a risk event to calculate its risk score whereas FMEA does not consider them. In some cases FMEA assigns same Risk Priority

Number (RPN) to different risks irrespective of the severity, occurrence and detect ability scores. But FIS risk analysis tool gives a unique score to the risk event based on the expert's knowledge. Recent studies show a method, lean fuzzy bow-tie analysis method on a chemical industry. In order to verify the developed FIS risk analysis tool, its results were compared against lean fuzzy bow-tie analysis method results on chemical industry and the results were similar. The advantage of FIS risk analysis tool over lean fuzzy bow-tie analysis is that the developed tool reduces the computational effort and assigns a unique score to the risk event rather than assigning a range (example: high, medium, low) to the risk.

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LIST OF ABBREVATIONS AND SYMBOLS

Abbreviation or Symbol	Description
ANN	Artificial Neural Network
D	Ease of detection
FIS	Fuzzy Inference System
FL	Fuzzy Logic
FMEA	Failure Modes and Effects Analysis
IMP	Impact
IS	Impact Score
MF	Membership Function
OS	Occurrence Score
O	Rate of occurrence
RCA	Root Cause Analysis
RE	Risk Event
RF	Risk Factor
RPN	Risk Priority Number
S	Severity

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CHAPTER 1 - INTRODUCTION

1.1. Research Background

Patient safety is an important health issue and is a priority for health care improvement throughout the world. Patient safety can be defined as "the prevention of harm to patients, from either errors of commission or omission" (Teinila et al.,2008). The United States, United Kingdom and other countries have several research programmes which deals with the issues related to patient safety. The greatest challenge in this area is to organize these research efforts to benefit patients (Battles and Lilford, 2003).

Kohn (2000) defined medical errors as "the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim". Medical errors occur frequently. In Canada, medical reporting is not compulsory, so comprehensive accurate data on medical errors does not exist (David, 2001), therefore, US statistics are presented. The number of deaths in US in 1999 is shown in the Figure 1.1. The deaths due to medical errors exceed those due to car accidents, breast cancer and AIDS (Kohn, 2000). In 2010, a research in the Journal of Patient Safety says that the number might be much higher between 210,000 and 440,000. The third leading cause of deaths in US is medical errors (Allen, 2013).

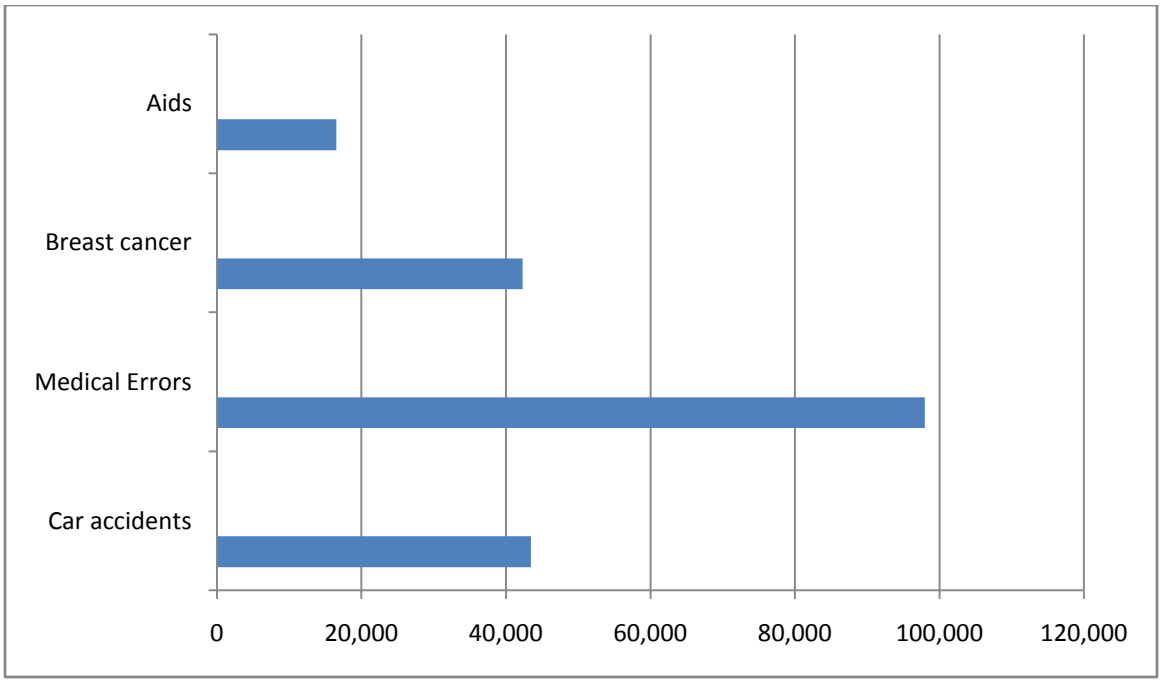


Figure 1.1 Number of deaths per year in 1999, US (Kohn, 2000).

1.2. Medication Errors

"A medication error is defined as any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer" (Shah, 2009). One type of medical errors which causes adverse drug events is medication errors. They cause harm to patients as well as costly to the healthcare system. Extrapolation from the US information shows that an estimated 2% of hospitalized patients encounter a preventable adverse drug event and an expected700 deaths for every year result from

medication errors (Nair et al., 2010). To improve patient safety effectively, the occurrences of medication errors need to be reduced. "Medication errors occur during drug prescribing, drug dispensing and drug administration stages in the medication use process" (Shah, 2009). Drug prescribing is the process of giving authorization to a patient to use a medicine by a medical practitioner (such as doctors, dentists). Drug dispensing is the process of dispensing a drug as prescribed in the prescription. Typically, drug dispensing is done by pharmacists in a pharmacy. Drug administration is the path by which a drug enters into the body. Mostly drug administration is done by the nurses in many settings.

1.3. Risk Analysis

Occupational health and safety management program dedicates a substantial effort to risk analysis. This includes being conscious of risks, recognising who might be at risk, deciding if existing control measures are satisfactory or if additional measures should be implemented, and protecting against injuries or illness. When executed at the designing or planning stage, prioritizing risks and the necessary control measures are essential to set up the plan. In health care industry, risks to patients are common. In order to reduce the risk exposure to patients, organizations must have suitable risk analysis tools to analyse and monitor risks (Canada Center for Occupational

Health and safety, 2016). Many methods, such as: Root Cause Analysis, Failure Mode Effect Analysis, Bow-tie analysis and others exist to perform risk analysis(Jie et al., 2012). The research reported herein focuses on risk analysis of medication errors as the risk or risk event occurring in a pharmacy. The highest frequency of medication errors occurs during the drug dispensing process which is the thesis research focus (Certina, 2010).

1.4. Intelligent System Techniques

Today, intelligent system techniques from the soft computing field have proven to be very effective in solving many real world problems. Some of the available and widely used intelligent techniques include: Artificial Neural Networks - (ANNs), Fuzzy Logic - (FL) and Genetic Algorithms - (GAs) (Jang et al., 1997). Applications range from characterization, identification, modification and control. Many decision making methodologies are based on Fuzzy Logic. “Fuzzy Inference Systems - (FIS) have the ability to handle real world problems that are based on user knowledge and experience and can also deal with uncertain, incomplete and vague data” (Aqlan and Ali, 2014). The purpose of selecting intelligent techniques is to create a convenient user interface and reduce the work done by the user.

1.5. Drug Dispensing Process

"Dispensing refers to the process of preparing and giving medicine to the patient as prescribed. It involves the correct interpretation of the prescription and accurate preparation and labelling of medicine to the appropriate patient for use" (Ensuring good dispensing practices, 2012). The various settings involved in the drug dispensing process are clinic, public, hospital, private, and community pharmacy setting. Drug dispensing process is carried out by people who have a lot of training and respective knowledge. Even a small mistake in the drug dispensing process has a great impact on the patient care. The main steps involved in the drug dispensing process include:

- Patient presents prescription to be filled.
- Pharmacist obtains information from patient.
- Pharmacist processes prescription in computer and prepares medication label.
- Technician selects medication from shelf.
- Medication is packaged based on the prepared label.
- Patient's counseling by pharmacist.
- Patient pays for prescription and leaves pharmacy.

Generally, Drug dispensing process thought to be a simple process which is infallible. Unfortunately, several things can interfere with the process resulting in errors. Several activities occur simultaneously interrupting the drug dispensing process causing distractions and errors. Some of the activities based on interviewing a pharmacist are as follows:

- Five to six patients waiting for prescriptions.
- The pharmacist has two lines active on the phone.
- Sometimes the pharmacist gets an emergency prescription to fill for the nursing home.
- Data entry and medical history check are required for a new patient's prescription at pharmacy
- Three technicians ask queries about drugs and prescriptions.
- Several other tasks include patient's counseling regarding the drug usage, prescribed medication packaging and completing the billing transaction

Typically, several distractions and interruptions occur during the drug dispensing process at pharmacy. Hence the possibility of occurrence of errors in such a fast paced environment is very high.

1.6. Chemical Process Industry

Chemical industry is an important part of today's economy. In the past few decades, the diversity of the products manufactured in the chemical industry has increased rapidly. Due to this, the possibility of occurrence of risks in the chemical industry has also increased (Aqlan and Ali, 2014). Hence risk analysis has become a very important aspect in chemical industry to prevent the occurrence of accidents. The chemical industry considered in this work is a paint manufacturing industry. It manufactures all types of adhesives, printing inks, decorative paints and industrial paints. The risk events, risk factors and impacts are identified based on the expert's knowledge. The application of the proposed tool in chemical industry is discussed in CHAPTER 6.

1.7. Objectives

The work reported herein is an extension of Aqlan and Ali (2014)’s work in the chemical industry. A FIS risk analysis tool was developed by replacing fuzzy set theory with fuzzy inference systems and this tool was applied in the drug dispensing process at a pharmacy and also in chemical process industry. The objective of this thesis was to

- Identify the risk events, risk factors and impacts

- Develop a Fuzzy Inference System risk analysis tool to prioritize the risk events by considering both risk factors and impacts
- Failure Mode Effects Analysis (FMEA) method was applied on the drug dispensing process and on chemical industry and the results were compared with the FIS risk analysis tool results
- Apply the FIS risk analysis tool in chemical process industry and the results were compared with the "lean fuzzy Bow-tie analysis method" (Aqlan and Ali, 2014).

1.8. Advantages of FIS Risk Analysis Tool Over FMEA and Lean Fuzzy Bow-tie Analysis

FMEA does not consider the risk factors and impacts of a risk event in calculating the risk score of a risk event; whereas FIS risk analysis tool considers both risk factors and impacts and hence gives an accurate risk score. In some situations, FMEA assigns same Risk Priority Number to different risks irrespective of the occurrence, severity and detect ability scores. But the developed FIS risk analysis tool assigns a unique score to the risk event based on expert's knowledge. The advantage of FIS risk analysis tool over lean fuzzy bow-tie analysis is that the developed tool reduces the computational effort and assigns a unique score to the risk event rather than

assigning a range (example: high, medium, low) to the risk. It is further explained in CHAPER 6.

1.9. Application of the Thesis

In Canada, each province has its own way for tracking and reporting medication errors. According to the National Association of Pharmacy Regulatory Authorities, as of January 1, 2016, “the total number of community pharmacies in Canada are 9,750” (National statistics, 2016). “Nearly 38,000 pharmacists dispense more than half a billion prescriptions in Canada annually” (Megan, 2015). Error reporting by pharmacists is not a compulsory process in Canada. “However Nova Scotia has implemented a mandatory tracking tools” (Rachel, 2016) for the pharmacists to report errors as well as near misses. In 2008, a compulsory reporting system, "SafetyNetRX" (SafetyNetRx, 2015) was introduced in Nova Scotia (Howorun, 2016). The first phase of the project took place for eight months and thirteen pharmacies were participated. Eight hundred and thirteen errors were reported during the first stage. “Once the program became mandatory for all pharmacies in Nova Scotia, 75,000 medication errors were reported over three years period” (Howorun, 2016). "COMPASS (Community Pharmacists Advancing Safety in Saskatchewan)" (Howorun, 20116) a

model of SafteyNetRX has been introduced in Saskatchewan (Howorun, 2016). It has three phases. The duration of phase one is from September 2013 to August 2014 and only ten pharmacies were involved in the program. 575 errors were reported during the Phase 1 (Howorun, 2016). In 2015, phase 2 was launched and 86 pharmacies were participated and 4313 incidents were recorded(Ng, 2015). Phase 3 was started in February 2016 and 120 pharmacies were participated. The medication errors reported until now are 5719 (Howorun, 2016). The Saskatchewan College of Pharmacy Professionals plans to involve all pharmacies in Saskatchewan in this program (Jeannetta, 2015). Soon all the pharmacies report the medication errors, their causes and impacts. This would result in a great amount of data available to be analysed. A more comprehensive analysis of risk and the effect on patient health could be modeled with the tool developed herein.

The combination of Fuzzy Inference systems and Bow-tie analysis assigns a different risk score to each risk event. This makes easier for a chemical industry to choose the mitigation strategies. The risk analysis tool developed in this research is very useful as it provides an outlook of errors happening in the industry.

CHAPTER 2 - LITERATURE REVIEW

This chapter focuses on the literature related to the concepts used in the research reported in here.

"Medical errors represent a serious public health problem and pose a threat to patient safety" (Pietra et al., 2005). A few risk analysis methods are reported in the literature for analysing medical errors in the field of patient safety. One of those methods is RCA. "Root Cause Analysis (RCA) is a structured analytic methodology used primarily to examine the underlying contributors to an adverse event or condition" (Pietra et al., 2005). Kristina and Julie (2006) focused on "assessing the errors using the Canadian Root Cause Analysis (RCA) Framework. Root Cause Analysis framework was developed by the Canadian Patient Safety Institute, Saskatchewan Health, and the Institute for Safe Medication Practices (ISMP) Canada to provide a standardized approach to the retrospective analysis of critical incidents and near-miss events in health care" (Kristina and Julie, 2006).They applied RCA on an incident which was reported by a patient regarding wrong drug dispensing. Julia (2016) discussed about RCA advantages and limitations and stated that "RCA has a limitation, known as the blinder effect". RCA is focused only at a particular part of the process that result to a risk event

instead of considering the whole process. Also, RCA is applied after the occurrence of a risk event. It does not help in preventing the risk of event occurrence.

Failure Mode Effects and Analysis (FMEA) is utilizing a Risk Priority Number (RPN) ranking system to assess and recognize the high level of risks, and to organize the control actions. Julie et al. (2015) designed a framework mitigating the risks using Failure Mode Effects and Analysis (FMEA) to improve patient safety. They performed FMEA for only one stage in the drug dispensing process. Reiley (2002) applied FMEA at a children's hospital during an analysis of causes of medication errors. According to Geneve (2016), there are some limitations with FMEA in extracting a good estimate of ratings to the failure and sometimes different risk events have the same Risk Priority Number (RPN) which makes difficult for the user to prioritize the risks. Also, FMEA does not take the risk factors and their impacts into consideration in calculation of RPN. Barbara et al. (2015) proposed a new risk assessment method named "HFdFMEA (Human Factor dependent FMEA) based on dependency of used parameters and observation of human factors to improve patient safety". The drawback in this method is that there is a lot of computation

involved in calculating the human factors based on risk priority number for the identified risks.

Bow-tie analysis is a combination of fault tree analysis and event tree analysis. It considers both risk factors and impacts of the accident scene. It can be used to evaluate all types of risks (Aqlan and Ali, 2014). A "semi - quantitative risk assessment methodology based on bow-tie analysis" to analyse the risk in an industry that builds ships was proposed by Jacinto and Shiva (2010) . Mokhtari et al. (2011) used "incident and accident analysis" in a pharmaceutical production plant. Wierenga (2013) applied "Bow-tie model in medication safety risk analysis with consecutive experience in two hospitals". Aqlan and Ali (2014) combined lean principles and Bow-tie analysis with fuzzy set theory to analyse risks in chemical process industry.

Recent works concentrated on enhancing the "Bow-tie analysis by decreasing the uncertainty in data using fuzzy sets, Bayesian approach and other methods" (Aqlan and Ali, 2014). There is no literature related to risks prioritization using Bow-tie analysis combined with Fuzzy Inference Systems to improve patient safety. Hence this research is focused in that particular area. This approach is further elaborated upon in the next chapter.

CHAPTER 3 - METHODOLOGY

Details of the proposed methodology of FIS risk analysis applied to medication errors is explained in this chapter.

3.1. Risk Analysis Method

Patient safety can be improved by analysing and assessing the risks and identifying the causes. “Medication errors arise throughout the stages of prescribing, dispensing and administration of the medication use process” (Shah, 2009). The frequency of errors in the dispensing stage is relatively higher than the other stages in the medication use process. (Certina, 2010). Hence this work considers only the drug dispensing process where the risks have been analyzed and prioritized. Any risk event is occurred by various risk factors and leads to a variety of consequences. “Risk is defined as the probability of occurrence of a risk event multiplied by the impact of that risk event. It has three components, namely, risk factors, the risk or risk event, and its impacts” (Aqlan and Ali, 2014). The knowledge of risk management approaches that are used in other high risk industries is applied to medication dispensing process in order to develop a risk analysis tool in the field of patient safety.

3.1.1. Bow-tie Analysis

One of the risk analysis instruments which is widely used in high risk industries is Bow-tie analysis. The fundamental principles involve event tree analysis and fault tree analysis (Wierenga et al., 2009). “Fault tree analysis - is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine series of lower - level events” (Aqlan and Ali, 2014). “Event tree analysis - is a forward, bottom up, logical modelling technique for both success and failure that explores responses through a single initiating event and a path for assessing probabilities of the outcomes and overall system analysis are developed” (Wikipedia, 2016).

The components of Bow-tie analysis diagram are risk factors, risk events, impacts and risk reducers. The causes that initiate a risk event to happen in the system are risk factors. Risk impact is the consequence of a risk event on the system. Each risk event is occurred due to multiple risk factors and has a set of impacts. There are two types of risk reducers: preventive barriers and protective barriers. "Preventive barriers are used to reduce the probability of occurrence of a risk and protective barriers are used to minimise the impact of a risk event on the system" (Aqlan and Ali, 2014).

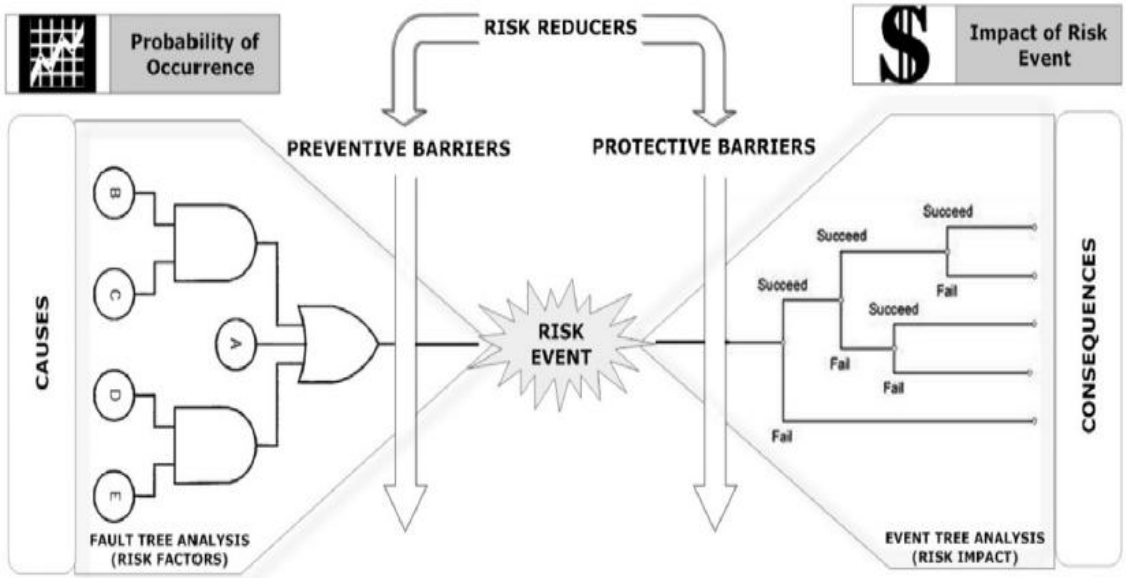


Figure 3. 1 Diagrammatic representation of the Bow-tie analysis (Aqlan and Ali, 2014)

Bow-tie analysis is a combination of fault tree analysis and event tree analysis as shown in the Figure 3.1. The left side of the diagram shows fault tree analysis. A,B,C,D,& E represents risk factors and they are linked with either OR or AND relation to cause a risk event. The center of the diagram has preventive and protective barriers for a risk event. The right side of the diagram shows event tree analysis. It shows all the impacts of a risk event.

3.1.2. Rational for Using Bow-tie Analysis

At present, pharmacists use a root cause analysis approach to identify the main causes of errors or problems in the drug dispensing process (Ismp, 2012). In root-cause analysis, statistical correlation between risk factors and

risk Impacts is not possible. Also root cause analysis is applied only after an occurrence of risk. In contrast, Bow-tie analysis can be used before the occurrence of an event. It also gives the correlation between risk factors and the event impact. Hence by implementing proper mitigation plans, the occurrence of risk events can be controlled.

3.2. Intelligent Techniques

Intelligent system techniques are software programs that model humans to emulate human analysis and judgement. Their applications play a very important role in various research fields, as they have proven to be very useful and effective in different types of projects (Marketing and Artificial Intelligence, 2016). Among the various intelligent system techniques, Fuzzy logic, artificial neural networks and Genetic algorithms are widely used in a variety of problems (Jang et al., 1997).

3.2.1. Rational For Using Fuzzy Logic Approach in Risk Modelling

The research reported herein uses fuzzy logic concepts. There is a lot of uncertainty involved in estimating the values of risks. One of the best ways to deal with uncertainty is the use of fuzzy logic. One of the commonly

used method to perform quantitative risk analysis is Monte Carlo analysis. It involves determining the impact of the identified risks by running simulations to identify the range of possible outcomes for a number of scenarios. A random sampling is performed by using uncertain risk variable inputs to generate the range of outcomes with a confidence measure for each outcome. Whereas, by using fuzzy logic, inputs from different category like risk likelihood and risk impact can be compared to compute the risk score for an identified risk. However this cannot be performed with Monte Carlo method. To appreciate the fuzzy modeling techniques as used in this work, the diagrams and notations associated with fuzzy concepts as used in "Neuro - Fuzzy and Soft Computing" (Jang et al., 1997) are summarised below.

3.3. Fuzzy Logic

Zadeh (1965) suggested the concept of fuzzy logic. This multi valued logic is introduced to cope with vague data. Godil et al. (2011) described fuzzy logic "as an extension to the conventional Aristotelian and Boolean logic since it deals with “degrees of truth” rather than absolute values of “0 and 1” or “true/false” ". In fuzzy logic, everything is a matter of degree. Mainly it is used to transfer the individual knowledge and language into variables that can take qualifiers or numerical values. According to fuzzy

logic theory, real world problems are complex and their behaviour is not linear. It is widely used in various other fields like engineering, computer science, manufacturing etc...(Godil et al., 2011).

3.4. Fuzzy Sets

According to Zadeh (1965) "fuzzy set is a class of objects with a continuum of grades of membership and can be mathematically expressed as : If X is a collection of objects denoted generically by x, then a fuzzy set A in X is defined as a set of ordered pairs:

$A = \{(x, \mu_A(x)) / x \in X\}$,

where $\mu_A(x)$ is called the membership function (MF) for the fuzzy set A. The MF maps each element of X to a membership grade (or membership value) between 0 and 1". In a classical set, the membership function value is strictly zero or one and has crisp boundaries. Whereas in fuzzy set, the value can be between zero to one and has fuzzy boundaries (Zadeh, 1965).

3.4.1. Linguistic Variables

"As the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance become almost

mutually exclusive characteristics" (Jang et al 1997). Due to this belief, Zadeh (1967) suggested the concept of linguistic variables. The concept of linguistic variable is explained by using the following example.

Example :

X(temperature) = {less high, high, more high}

Y (room feels) = {less warm, warm, more warm}

In this example, "temperature" and "room feels" are linguistic variables and the linguistic values are "less high", "high", "more high", "less warm", "warm", "more warm". Each linguistic value is defined by a fuzzy set. These fuzzy sets are defined by the characterized membership functions.

3.4.2. Membership Function Formulation

"A fuzzy set is completely characterized by its Membership Function (MF)" (Zadeh, 1965). They can be defined either in one dimension or in two dimension depending upon the type of problem. Different types of MFs of one dimension are as follows (Jang et al., 1997):

- Triangular MFs
- Trapezoidal MFs
- Gaussian MFs

- Generalized bell MFs
- Sigmoid MFs
- Left-right MFs

Gaussian MF is used in this research. It is shown in Figure 3.2. The MF's were designed in such a way that the overlapping is maximum among the MF's. It has the advantage of computational efficiency because of its smoothness and has been widely used. (Mathworks, 2016).

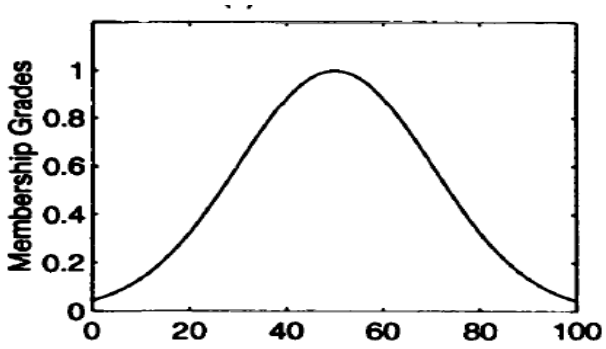


Figure 3.2 Representation of Gaussian MF (Jang et al., 1997).

3.5. Fuzzy Rules

The main element in fuzzy logic to express the pieces of human knowledge is fuzzy rule. Fuzzy rules are similar to “IF….THEN” rules. The format of a fuzzy rule is as follows:

"IF x is A THEN y is B" (Jang et al., 1997)

where A and B are linguistic values defined by fuzzy sets (Jang et al.,1997). The antecedent is “x is A” and the consequence is “y is B”. These rules are defined based on the available expert knowledge or historical data or literature available in a particular research area. If a system is designed with more number of fuzzy rules from various resources, then the uncertainties in that system can be reduced (Jang et al., 1997).

3.6. Fuzzy Reasoning

"Fuzzy reasoning is the process of deriving conclusions from the defined fuzzy rules. The basic rule of inference in traditional two-valued logic is modus ponens, according to which we can infer the truth of a proposition B from the truth of A and the implication A ---> B can be inferred" (Jang et al., 1997). For example, if A is expressed as "room temperature is high" and B with "room feels hot", then if it is true that " room temperature is high ", it is also true that " room feels hot ".

Premise 1 (fact) - x is A (temperature is high)

Premise 2 (rule) - IF x is A THEN y is B (IF room temperature is high then room feels hot)

Consequence (conclusion) - y is B (room feels hot)

But, in an individual thinking, modus ponens is applied in an approximate way. In human reasoning, the above example is implied as follows:

Premise 1 (fact): room temperature is more/less high

Premise 2 (rule): IF room temperature is high, THEN room feels hot

Consequence (conclusion): the room feels more/ less hot

Where more high or less high are close to being high, and more hot or less hot are close to being hot. All of these linguistic values are defined by fuzzy sets. This type of reasoning is known as fuzzy reasoning.

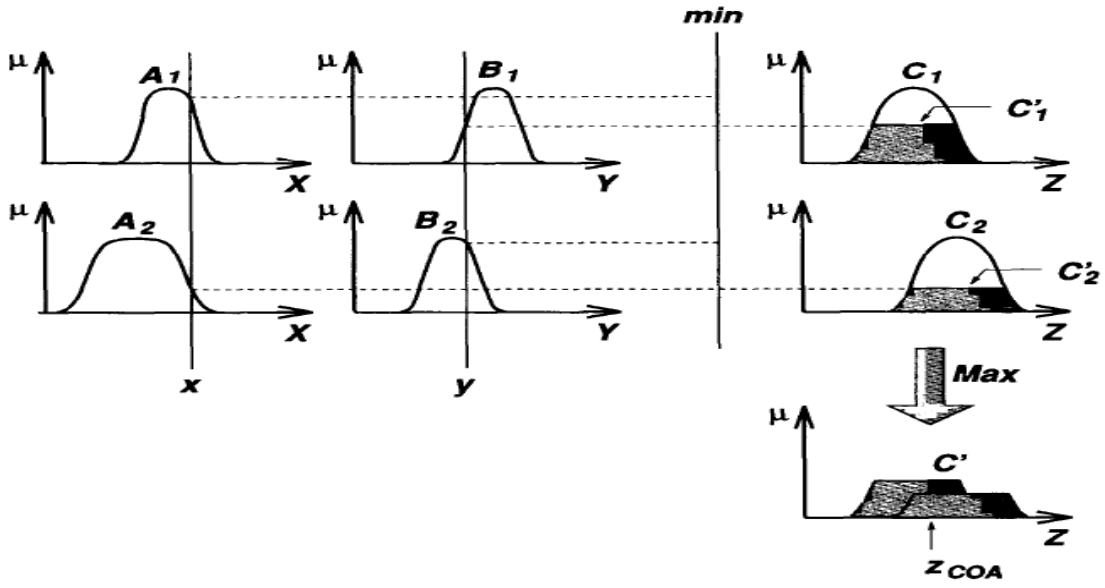


Figure 3. 3 Fuzzy reasoning mechanism in Mamdani fuzzy inference system using min-max composition (Jang et al., 1997).

In Figure 3. 3,

- x is input 1 and is defined by A_1 and A_2 as membership functions
- y is input 2 and is defined by B_1 and B_2 as membership functions
- z is the output and defined by C_1 and C_2 as membership functions

3.7. Fuzzy Inference System (FIS)

Fuzzy inference system uses the concepts of fuzzy sets, fuzzy IF - THEN rules and fuzzy reasoning altogether. The basic components of a FIS are rule base, data base and reasoning mechanism (Jang et al., 1997)

Rule base - It has a set of well defined fuzzy IF-THEN rules which are defined base on expert knowledge

Data base - It defines the different membership functions that are used in the fuzzy IF-THEN rules

Reasoning mechanism - Based on the defined fuzzy IF...THEN rules, reasoning mechanism performs the inference procedure and derive a conclusion. FIS takes either fuzzy inputs or crisp inputs. The FIS output can be either crisp or fuzzy depending upon the type of FIS. Different types of FIS models are used in solving variety of problems. They are:

- Mamdani model

- Sugeno model
- Ttsukamoto model

In this research, Mamdani FIS is used. It takes both crisp inputs and fuzzy inputs but gives only fuzzy sets as output. Hence defuzzification is required to obtain a crisp value that best represents the output fuzzy set (Jang et al., 1997). There are five methods for defuzzifying a fuzzy output. They are as follows:

- Smallest of max
- Largest of max
- Centroid of area
- Mean of max
- Bisector of area

All the defuzzification methods are showed in the Figure 3.4. In terms of magnitude, the smallest of max is the minimum of the maximizing Z. The largest of max is the maximum of the maximizing Z. The centroid of area gives the center value of the area under the curve. The mean of maximum is the average of the maximizing Z at which the membership function reach maximum. This Research work uses the centroid of area defuzzification method to transform fuzzy output set to a crisp value. This method gives the

center of area under the curve. It is the most commonly used defuzzification method as it effectively calculates the best value between multiple output linguistic terms. It is also fast and does not require high computational effort (Jang et al., 1997). The main limitation of fuzzy logic is the selection of T norm and T co-norms for a fuzzy relation. Anyone can design their own model to perform the operation. The problem is not able to find the efficient and appropriate one among them.

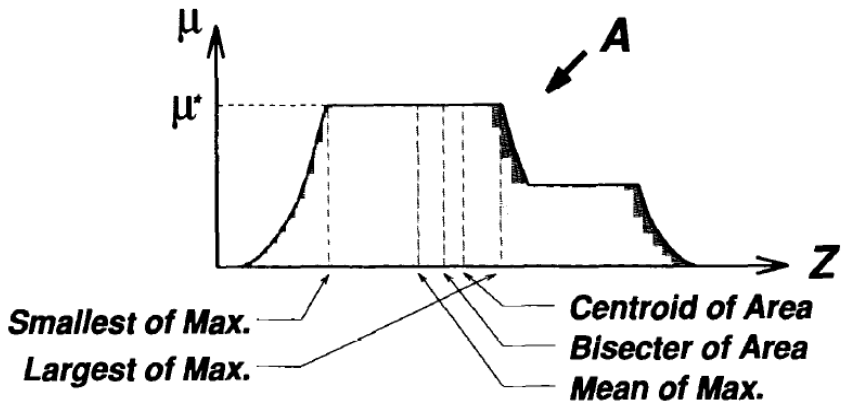


Figure 3. 4 Graphical representation of all defuzzification methods (Jang et al., 1997)

3.8. Methodology Framework

The objective of this research is to design a tool, which can be used in any pharmacy as a risk analysis tool. The steps involved in designing the FIS risk analysis tool are as follows:

- Identification of risk events (RE), risk factors (RF) contributing the risk events and risk impacts (IMP)
- Calculation of probability of occurrence score and impact score for each of the identified risk event
- Risk score calculation using Mamdani Fuzzy inference system (FIS)
- Prioritization and monitoring risks

3.8.1. Identification

In this step, major risk events that can occur in the industry are identified. Identification of risk events can be done in many ways; such as, based on the history of risk events that happened in the industry previously or by conducting interviews to capture the expertise of employees working in the industry or from the available literature resources. After identifying the risk events, major risk factors that contribute to the risk event and the impacts of the corresponding risk events are collected. Each risk event can have one or more risk factors and also one or more impacts. Bow-tie analysis is performed. Bow-tie diagrams are used to show the links between the risk factors, risk event and impacts (Aqlan and Ali, 2014).

3.8.2. Risk Score Calculation

After identifying risks, it is important to control and monitor the identified risks for improving the industry. Risk score of a risk event is the combination of probability of occurrence score and the impact score. Calculating the risk score helps in prioritizing the risks and appropriate mitigation plans can be implemented. This work considers both risk factors and the impacts of a risk event to calculate a risk score when using Mamdani FIS. By using the software MATLAB 2010a (Mathworks, 2016), Mamdani FIS is applied in different scenarios. Each FIS, as shown in the Figures 3. 5, 3. 6 and 3. 7 has different rules that are based on the their function.

Risk score calculation steps follow:

Step 1: The probability of occurrence score of a risk event is calculated by using the probability of occurrence of the risk factors as inputs to the Mamdani FIS. The probability of occurrence score of risk factors are obtained from the expert. FIS gives the output based on the fuzzy IF...THEN rules that are defined based on the expert knowledge. Suppose a Risk event, RE 1 is caused due to two risk factors, RF 1 and RF 2, then the design to compute probability of occurrence score is as shown:

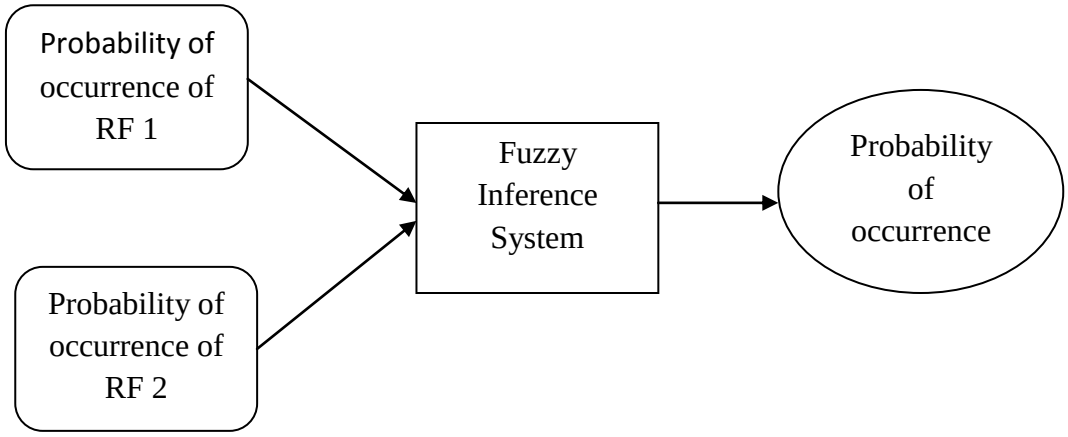


Figure 3. 5 Probability of occurrence score calculation of a risk event considering probability of occurrence of corresponding risk factors - Left side : inputs, Right side : output

Step 2: The Impact score of a risk event is calculated using intensity level of each impact as inputs to the FIS. The intensity level of each impact for the corresponding risk event is obtained from the expert. The output is computed based on the defined fuzzy IF....THEN rules. Suppose the Risk Event, RE 1 has two Impacts, IMP 1 and IMP 2, then the Impact score of a RE 1 is computed as below:

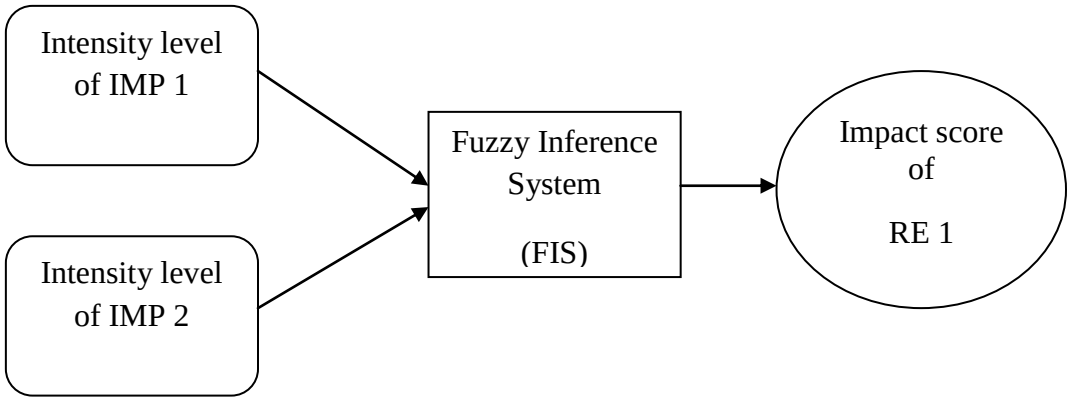


Figure 3.6 Impact score calculation of a risk event considering Intensity levels of the corresponding risk event impacts- Left side : inputs, Right side : output

Step 3: Finally, the risk score is calculated by using the probability of occurrence score and the impact score as inputs to Mamdani FIS.

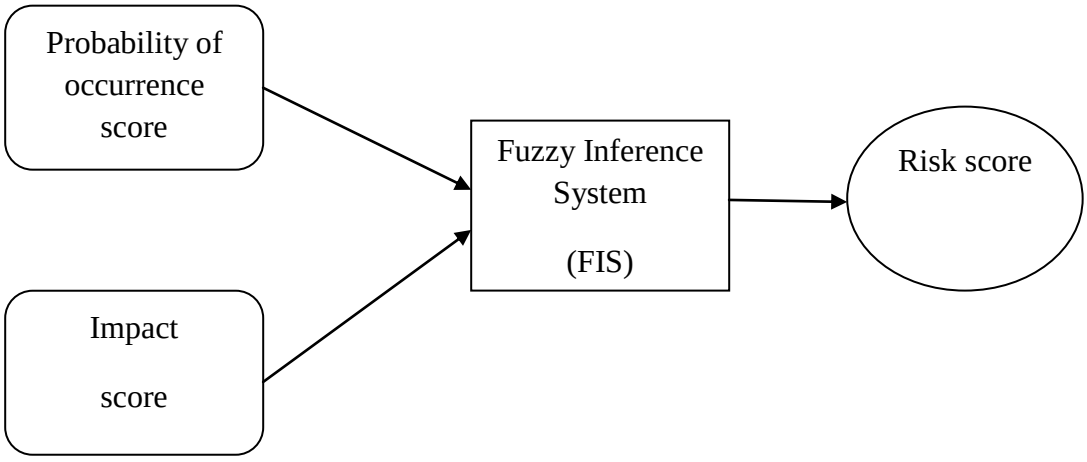


Figure 3. 7 Risk score calculation of a risk event considering both Probability of occurrence score and Impact score- Left side : inputs, Right side : output

3.8.3. Prioritization and Monitoring the Risks

In drug dispensing process, there are many risks, risk factors and impacts. Hence there are many blocks as explained above for calculating probability of occurrence score, Impact score and Risk score. All these blocks are integrated into a single framework, which is explained in the following section. Based on the computed risk score, the risks are prioritized. Risk events with high risk scores are identified and proper mitigation strategies are applied to prevent the risk events from happening in the industry.

3.9. Building a FIS Model in the MATLAB Toolbox

The Mamdani FIS models were created in the fuzzy toolbox in the MATLAB 2010a (Mathworks, 1984) interface. Since the toolbox does not require code programming, it makes the process interactive at all times. The user merely needs to define parameters by interacting and manipulating the tools. The toolbox has two types of tools: the editing tools and view-only tools (Mathworks, 1984). The components that are included in the editing tools are as follows:

FIS editor: In this editor, the user defines the inputs, outputs of the system and their names. The type of defuzzification method used is defined in the

FIS editor. There is no limit in the number of inputs and outputs in this toolbox . However, their limit may be restricted by the available computer memory. The yellow boxes in the Figure 3. 8 indicate inputs and the blue box on the right indicates output. In this editor appropriate T norm, T conorm and defuzzification methods were selected based on the considered problem.

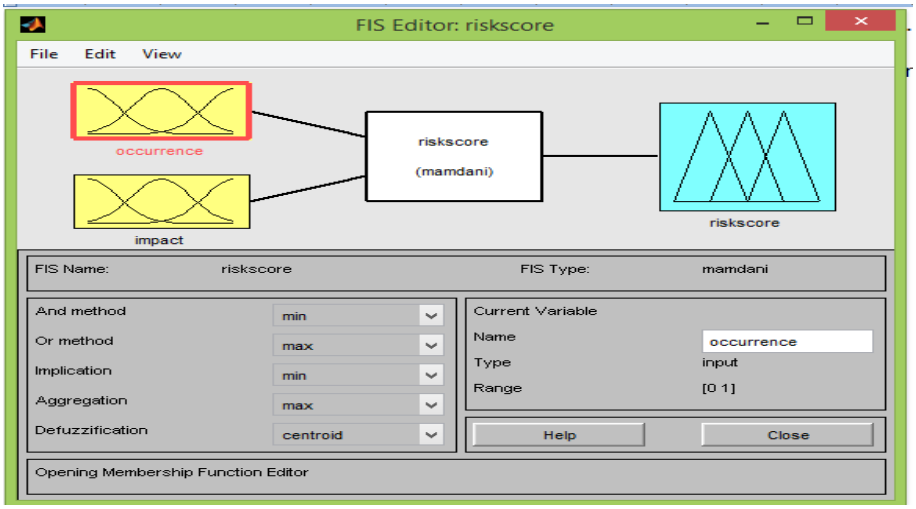


Figure 3. 8 FIS editor (MATLAB 2010a)

MF editor: In the membership function editor, the user defines the shapes and ranges of all the membership functions associated with each variable. The shape and range of the membership functions are decided based on the type of problem and also based on expert's knowledge . A screen capture of the membership function editor is shown in Figure 3. 9

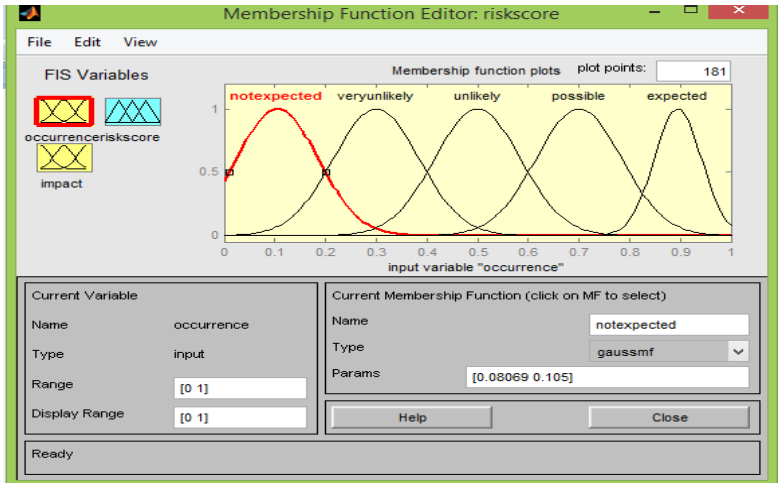


Figure 3. 9 Membership Function editor(MATLAB 2010a)

Rule editor: The user defines the antecedent and consequent of the fuzzy rules in the editor. The behaviour of the system is defined by this tool. The following figure is a screen capture of the rule editor.

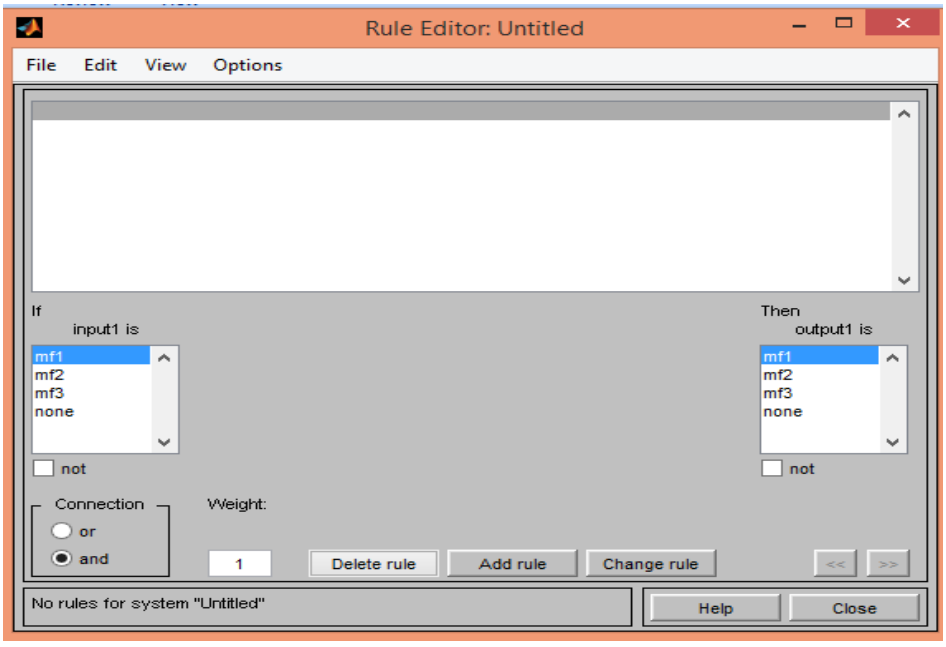


Figure 3. 10 Rule editor(MATLAB 2010a)

There are only two types of view-only tools; the rule viewer and the surface viewer.

Rule viewer: The fuzzy inference diagram can be viewed in the rule viewer and displays the current or active rules which MF's influence the output.

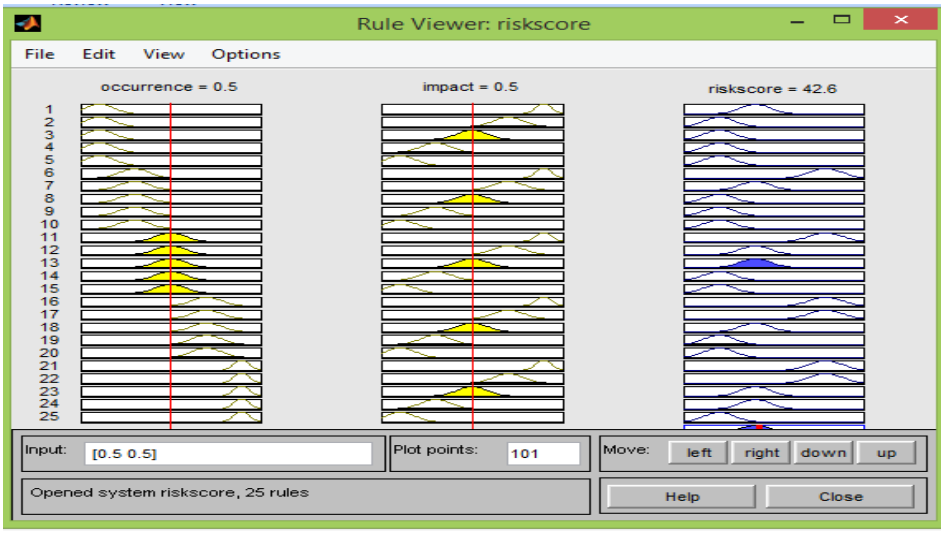


Figure 3. 11 Rule viewer(MATLAB 2010a)

Surface viewer: It is used to view the results of the various combinations of inputs and outputs. It generates and plots the output for the system. The following figure displays the surface viewer. For example, the Figure 3. 12 shows that risk score increases as occurrence score and Impact score increase.

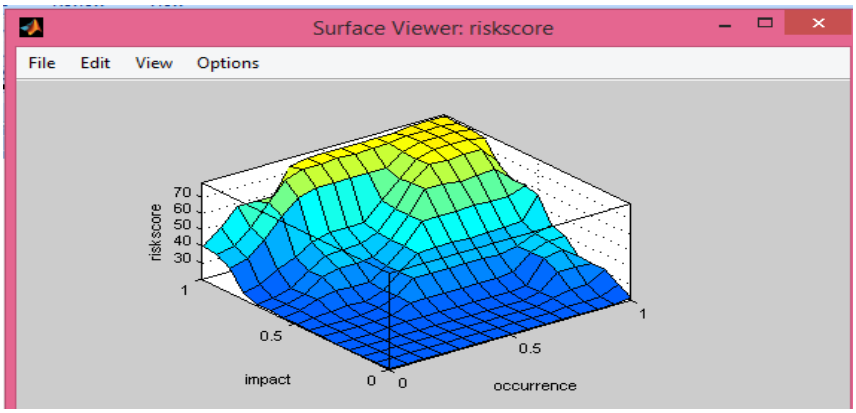


Figure 3. 12 Surface Viewer (MATLAB 2010a)

To show the reader different inputs and outputs for each of the proposed FIS models, several figures are provided in the Chapter 4. Also, the surface plots resulting from different combinations for each FIS method are shown in Appendix B.

CHAPTER 4 - APPLICATION ON PHARMACY DRUG DISPENSING PROCESS

This chapter discusses the application of proposed FIS risk analysis tool on the drug dispensing process at pharmacy.

4.1. Application in Pharmacy

The proposed FIS risk analysis tool was applied to a drug dispensing process at a pharmacy (Pharmasave, keremeos, BC) to improve patient safety. A pharmacist named Sravani, working at this pharmacy was interviewed about major risk events, risk factors and their impacts at this store. She answered to the questions based on her experience. The inputs i.e., probability of occurrence of each risk factor and the intensity level of each risk impact were provided by her. The rules in the fuzzy inference systems are defined based on her expertise. This is just an example used to demonstrate the capability of the developed system. The main independent risk events identified in a drug dispensing process in a community pharmacy are

- **RE1**-Transcription error
- **RE2**-Patient misidentification
- **RE3**-Labeling error
- **RE4**-Interruptions in pharmacy
- **RE5**-Dispensing wrong drug
- **RE6**-Pharmacist distraction

4.1.1. Risk Factors and Impacts of Risk Events in Pharmacy

Risk event is represented as RE. Risk factor and impact are denoted by *rf* and *imp* respectively.

Transcription error RE1: Transcription error is one type of data entry error. It is the misinterpretation of the patient prescription by the pharmacist and entering wrong data into the computer system. Main causes or risk factors for the transcription error are

- rf_{11} – *Ambiguous prescription* - Prescription with illegible handwriting by the health care provider
- rf_{12} –*Incorrect order entry* - Entering wrong drug name or wrong dosage or in wrong patient profile in the computer system

The impact of Transcription error is

- imp_{11} $-$ *Wrong medication to the patient* - Delivering wrong medication to the patient. It can affect patient health in many ways.

Patient Misidentification RE2

The main cause or risk factor for patient misidentification is

- rf_{21} $-$*Patients with similar names* - Patients having either first or last names similar.

The impacts of the patient misidentification risk event are

- imp_{21} $-$*Incorrect prescription released to the patient*
- imp_{22} $-$ *Side effects to the patient*

Labeling Error RE3

The risk factors for labeling error are

- rf_{31} $-$*Clutter on table*
- rf_{32} $-$*Untrained staff*

The impact of the labelling error is

- imp_{31} $-$*Delivery of wrong drug to the patient*

Interruptions in Pharmacy - RE - 4

The risk factors for interruptions in pharmacy are

- rf_{41} $-$*Phone calls*
- rf_{42} $-$*Under staffing*

The impacts due to interruptions in pharmacy are as follows

- imp_{41} $-$*Delay in medication dispensing*
- imp_{42} $-$*Pharmacist inefficiency*

Wrong Drug Dispensing - RE - 5

The risk factors for Wrong drug dispensing are

- rf_{51} $-$*Look alike or sound alike drugs*
- rf_{52} $-$*Skip Patients counseling*
- rf_{53} $-$*Unorganized work flow*

The impacts due to wrong drug dispensing are

- imp_{51} $-$*Patient side effects*
- imp_{52} $-$*Patient Mortality*

Pharmacist Distraction - RE - 6

The risk factors for pharmacist distraction are

- rf_{61} $-$*Meal breaks issue*
- rf_{62} $-$*Improper room conditions*

The impacts due to Pharmacist distraction in a pharmacy are

- imp_{61} $-$*Improper duties delivery*
- imp_{62} $-$*Prescription error*

The overall framework to calculate risk score in pharmacy drug dispensing process using Mamdani FIS and bow-tie analysis is shown in Figure 4. 1.

4.2. Mamdani Fuzzy Inference Models

In order to simulate various fuzzy inference systems that are described in the proposed methodology, MATLAB is used. The fuzzy models that are used in the proposed methodology are Mamdani fuzzy inference models. The reason for using Mamdani fuzzy inference model is that it "allows considering and defining data from the user's perspective in order to properly identify the processes with non-measurable parameters. Moreover, it also assumes the real user's control situation, which uses fuzzy

judgements" (Jang et al., 1994). The membership functions and defuzzification method that are used to model the Mamdani fuzzy inference system were explained in section 3.6.

4.3. Data Collection

The inputs that are obtained from an expert, the pharmacist, were probability of occurrence of risk factors and level of intensity of impacts for corresponding risk events. These inputs are tabulated in the Table 4. 1 & 4. 2. The proposed methodology was applied to the pharmacy setting by using the tabulated inputs.

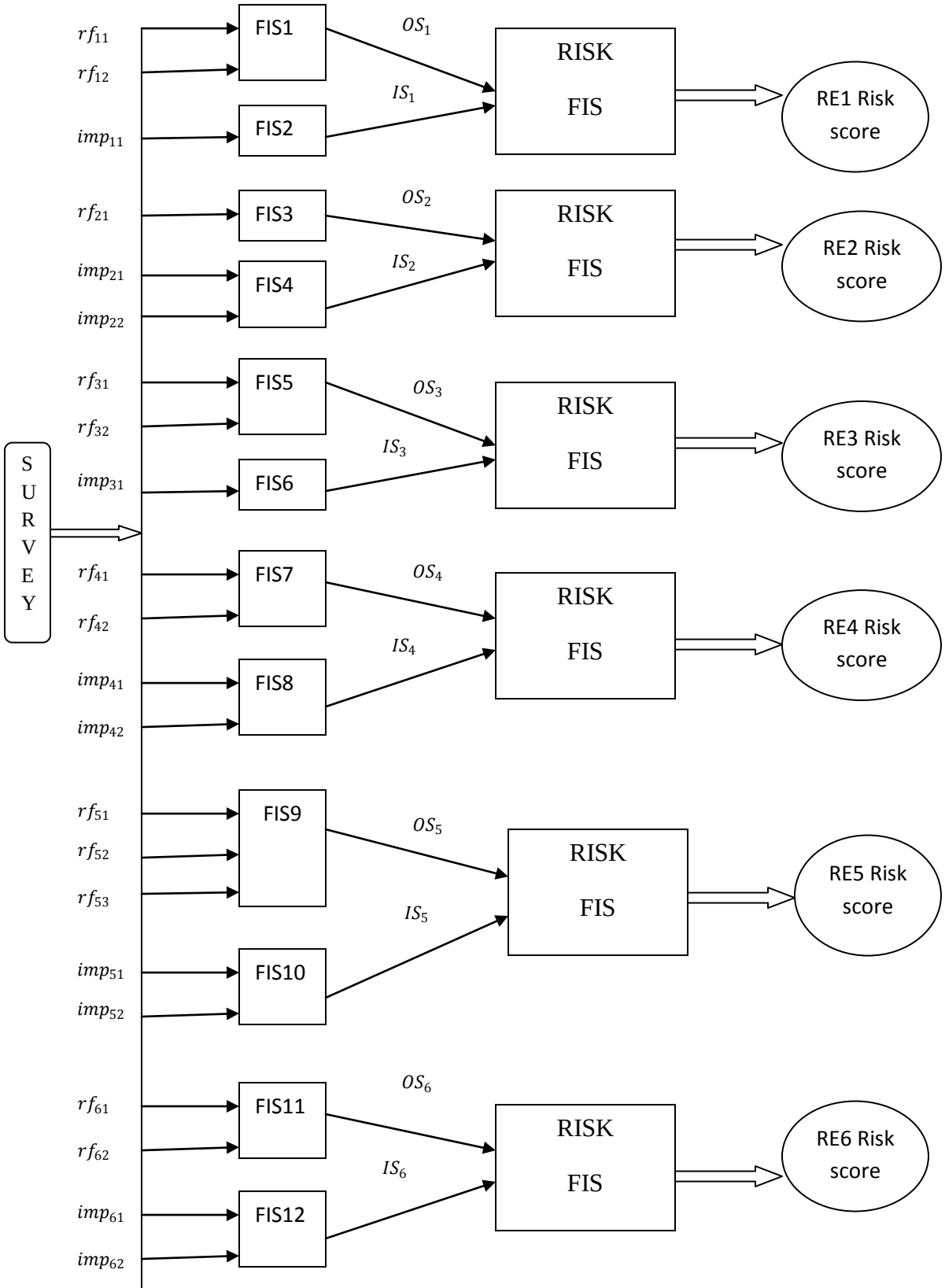


Figure 4. 1 Overall framework to calculate risk score using Mamdani FIS and Bow -tie analysis in drug dispensing process

Table 4. 1 Tabulation of Probability of occurrence of risk factors

S.no	Risk events	Risk factors	Probability of occurrence
1	**Transcription error**	*Ambiguous Prescription*	0.4
		Incorrect entry	0. 3
2	**Patient misidentification**	*Patient with similar names*	0.2
3	**Labelling error**	*Clutter on table*	0.9
		Untrained staff	0.7
4	**Interruptions**	*Phone calls*	0.7
		understaffing	0.8
5	**Wrong drug dispensing**	*Look alike/ sound alike drugs*	0.7
		Skip patient's counselling	0.4
		Unorganized work flow	0.5
6	**Pharmacist Distraction**	*Meal breaks issue*	0.5
		Improper room conditions	0.4

Table 4. 2 Tabulation of Impacts intensity level inputs

S.no	Risk events	Impacts	Impact intensity
1	**Transcription error**	*Wrong medication to the patient*	0.6
2	**Patient misidentification**	*Incorrect prescription released to patient*	0.5
		Side effects to patient	0.8
3	**Labelling error**	*Delivery of wrong drug*	0.4
4	**Interruptions**	*Delay in medication dispensing*	0.6
		Pharmacist inefficiency	0.5
5	**Wrong drug dispensing**	*Patient side effects*	0.9
		Patient mortality	0.7
6	**Pharmacist distraction**	*Delivery of Improper duties*	0.5
		Prescription error	0.4

The following chapter presents the results obtained on simulating the proposed framework in a pharmacy drug dispensing process.

CHAPTER 5 - RESULTS AND ANALYSIS

This chapter presents the results obtained from the implementation and application of the FIS risk analysis tool as introduced in the previous chapters.

The fuzzy modeling for drug dispensing process in a pharmacy results to thirteen different Mamdani fuzzy inference models. FIS 1 and FIS 2 were used for calculating probability of occurrence score and impact score for risk event 1 (RE 1), respectively. FIS 3 and FIS 4 were used for calculating probability of occurrence score and impact score for risk event 2 (RE 2), respectively. FIS 5 and FIS 6 were used for calculating probability of occurrence score and impact score for risk event 3 (RE 3), respectively. FIS 7 and FIS 8 were used for calculating probability of occurrence score and impact score for risk event 4 (RE 4), respectively. FIS 9 and FIS 10 were used for calculating probability of occurrence score and impact score for risk event 5 (RE 5), respectively. FIS 11 and FIS 12 were used for calculating probability of occurrence score and impact score for risk event 6 (RE 6), respectively. Additionally FIS 13 was used to calculate the risk score for all of these identified risk events.

5.1. Fuzzy Inference Models

To implement the proposed Mamdani FIS models, the MATLAB, 2010a software package and its FUZZY Logic Toolbox were selected as a platform. The details on the implementation and operation of the proposed Mamdani FIS models in the fuzzy Logic Toolbox were provided in the Section 3.8. All the member ship functions used in this research were Gaussian MF's and their range is decided based on the expert's inputs. The linguistic variables used in FIS 1, FIS 3, FIS 5, FIS 7, FIS 9, FIS 11 follow in Table 5. 1.

Table 5. 1 Linguistic variables and fuzzy numbers for FIS 1, FIS 3, FIS 5, FIS 7, FIS 9, FIS 11

Linguistic Variables	**fuzzy numbers**
Expected	(0.7,0.9,1.0)
Possible	(0.5,0.7,0.9)
Unlikely	(0.3,0.5,0.7)
Very unlikely	(0.1,0.3,0.5)
Not expected	(0.0,0.1,0.3)

The linguistic variables used in FIS 2, FIS 4, FIS 6, FIS 8, FIS 10, FIS 12 are tabulated in Table 5. 2.The linguistic variables used in the FIS 13 are shown in Table 5. 3.

Table 5. 2 Linguistic variables and their corresponding fuzzy numbers for FIS 2, FIS 4, FIS 6, FIS 8, FIS 10, FIS 12

Linguistic Variables	**fuzzy numbers**
High	(0.7,0.9,0.1)
Medium	(0.5,0.7,0.9)
Low	(0.3,0.5,0.7)
Very low	(0.1,0.3,0.5)
None	(0,0.1,0.3)

Table 5. 3 Linguistic variables and their corresponding fuzzy numbers for FIS 13

Linguistic Variables for Risk score	**fuzzy numbers**
High	(50, 80, 100)
Medium	(20,40,60)
Low	(0, 20, 40)

5. 2. FIS models for Transcription Error

FIS 1, FIS 2 and FIS 13 were used in the calculation of transcription error risk score. FIS 13 is explained at the end of this chapter. FIS 1 has ambiguous prescription and incorrect entry into the systems as inputs and probability of occurrence of transcription error as output as shown in Figure 5. 1. Hence it has 2 inputs, one output and it has 25 fuzzy rules. FIS 2 as shown in Figure 5. 2 has wrong medication to the patient as input and transcription error impact as output. As such, it has one input, one output and 5 fuzzy rules. As the system take the if-then rules to execute an action, surface plots resulting from different input combinations are obtained and

are shown in the Appendix B. IF...THEN rules are provided in the Appendix - A.

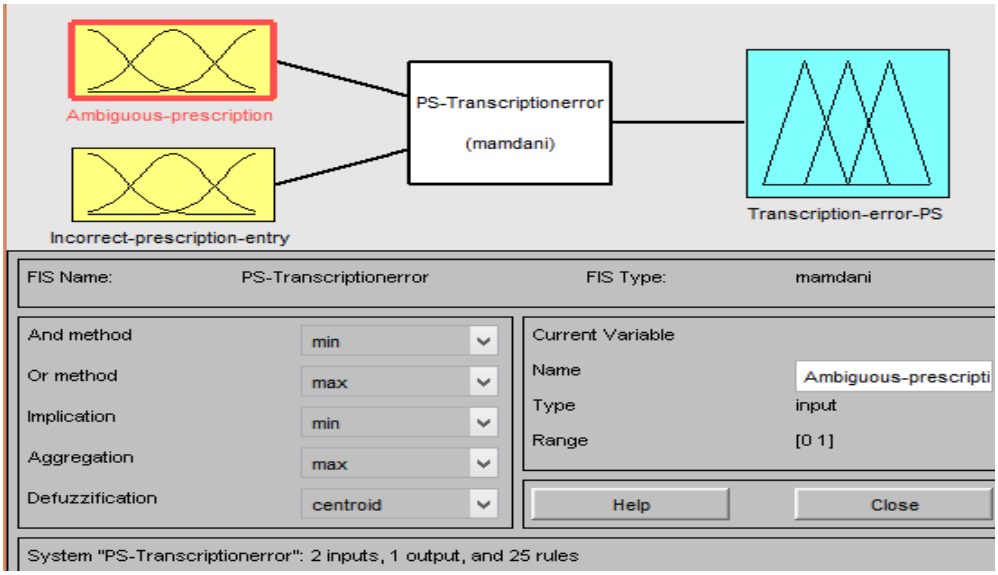


Figure 5. 1 Mamdani FIS for calculation of probability of occurrence of transcription error

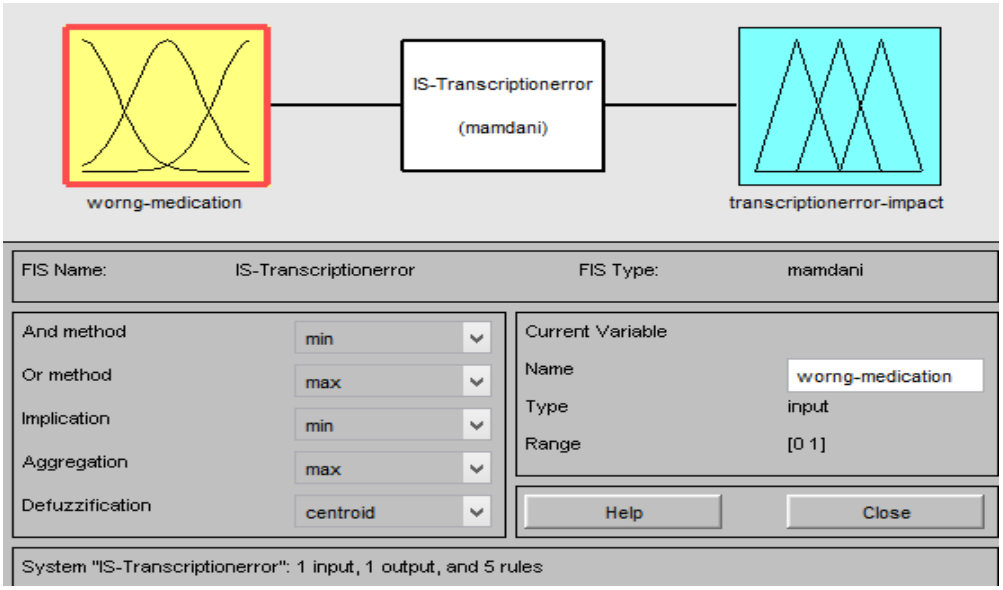


Figure 5. 2 Mamdani FIS for calculation of impact score of transcription error

5.3. FIS models for Patient Misidentification Error

FIS 3 and FIS 4 were used to compute the probability of occurrence score and Impact score of patient misidentification error, respectively. FIS 3 has patient with similar names as input and probability of occurrence score as output. Hence this Mamdani model as shown in Figure 5. 3 has 5 fuzzy rules. FIS 4 has incorrect prescription released to the patient and side effects to patient as inputs and Impact of patient misidentification error as output. Hence the Mamdani model described in Figure 5. 4 has 2 inputs, 1 output and 25 fuzzy rules.

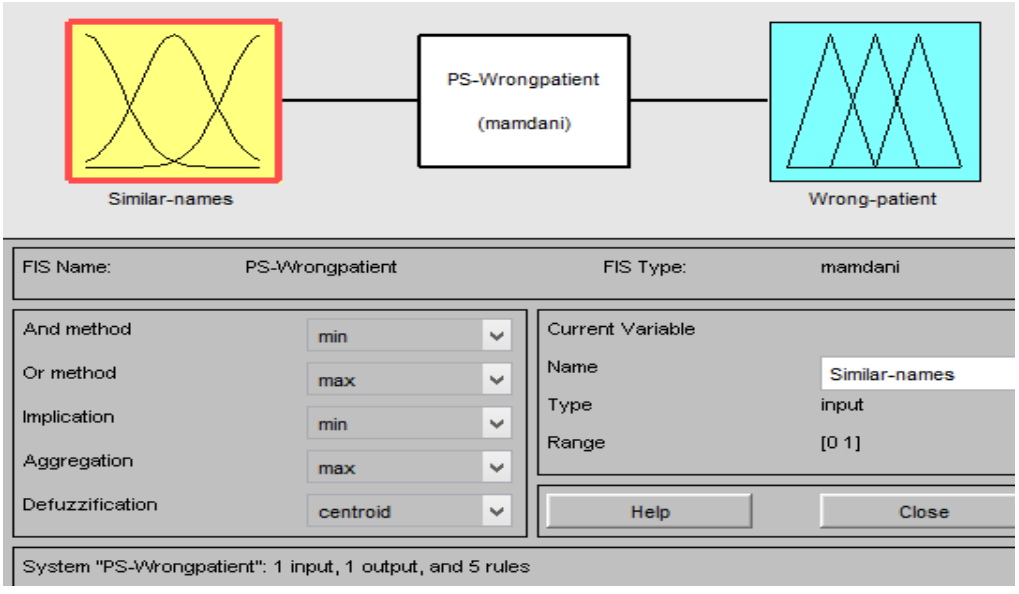


Figure 5. 3 Mamdani FIS for calculation of probability of occurrence of Patient misidentification error

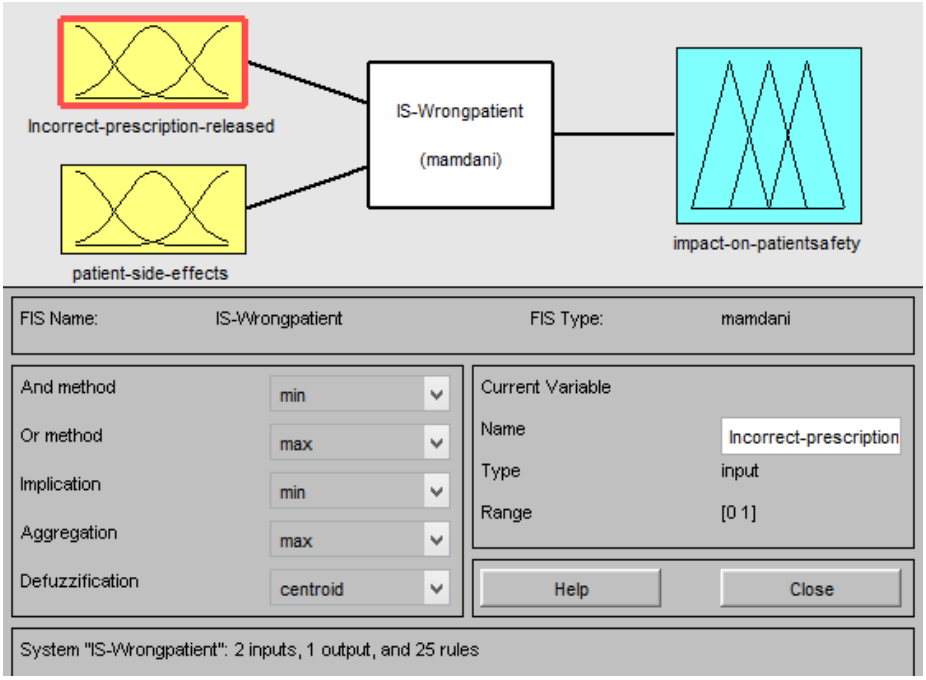


Figure 5. 4 Mamdani FIS for calculation of impact score of Patient misidentification error

5.4. FIS models for Labelling Error

FIS 5 and FIS 6 were used to compute the probability of occurrence score and impact score of labelling error, respectively. FIS 5 has clutter on table and untrained staff as inputs and probability of occurrence score as output. Hence this Mamdani model as shown in Figure 5. 5 has 2 inputs, 1 output and 25 fuzzy rules. FIS 6 has delivery of wrong drug as input and Impact of labelling error as output. Hence the Mamdani model described in Figure 5. 6 has 1 input, 1 output and 5 fuzzy rules.

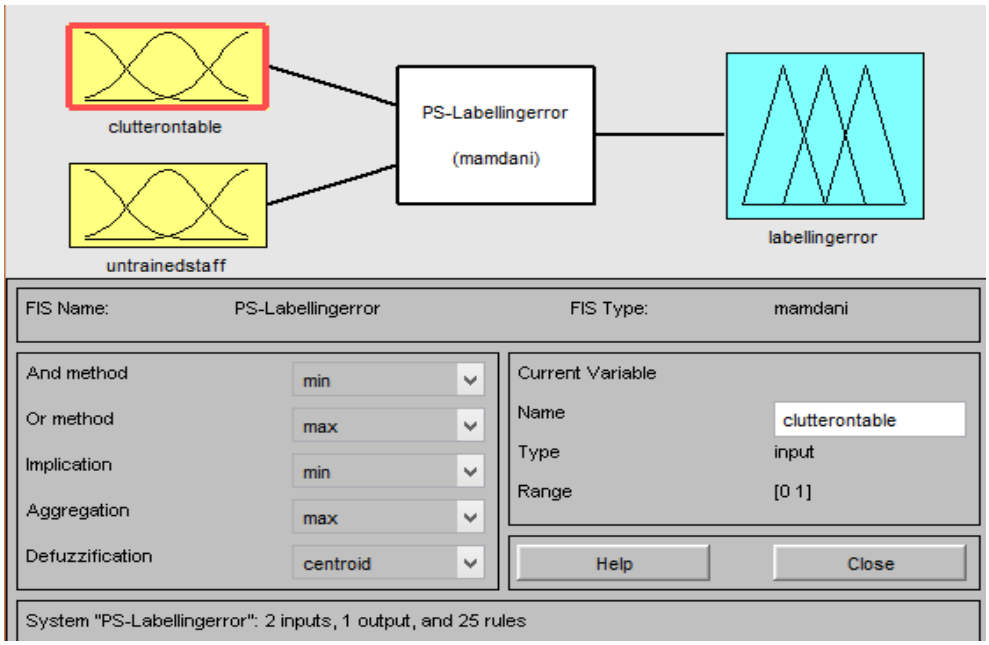


Figure 5. 5 Mamdani FIS for calculation of probability of occurrence of labelling error

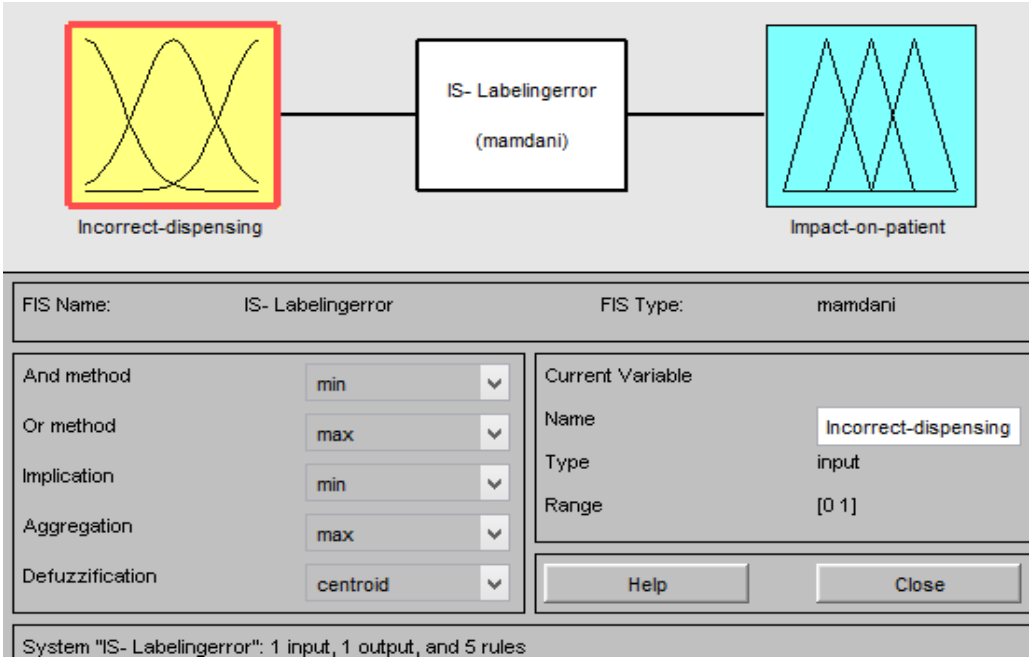


Figure 5. 6 Mamdani FIS for calculation of impact score of labelling error

5.5. FIS models for Error Due to Interruptions

FIS 7 and FIS 8 were used to compute the probability of occurrence score and impact score of error due to interruptions, respectively. FIS 7 has phone calls and under staffing as inputs and probability of occurrence score as output. Hence this Mamdani model as shown in Figure 5. 7 has 2 inputs, 1 output and 25 fuzzy rules. FIS 8 has delay in medication dispensing and pharmacist inefficiency as inputs and Impact of interruptions as output. Hence the Mamdani model described in Figure 5. 8 has 2 inputs, 1 output and 25 fuzzy rules.

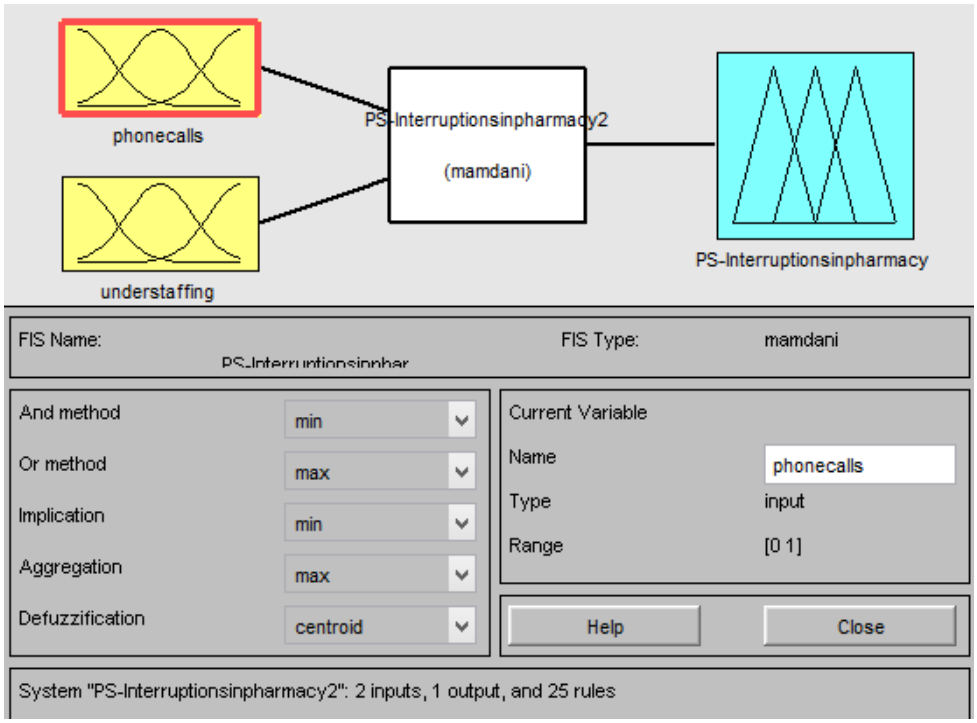


Figure 5. 7 Mamdani FIS for calculation of probability of occurrence of error due to interruptions

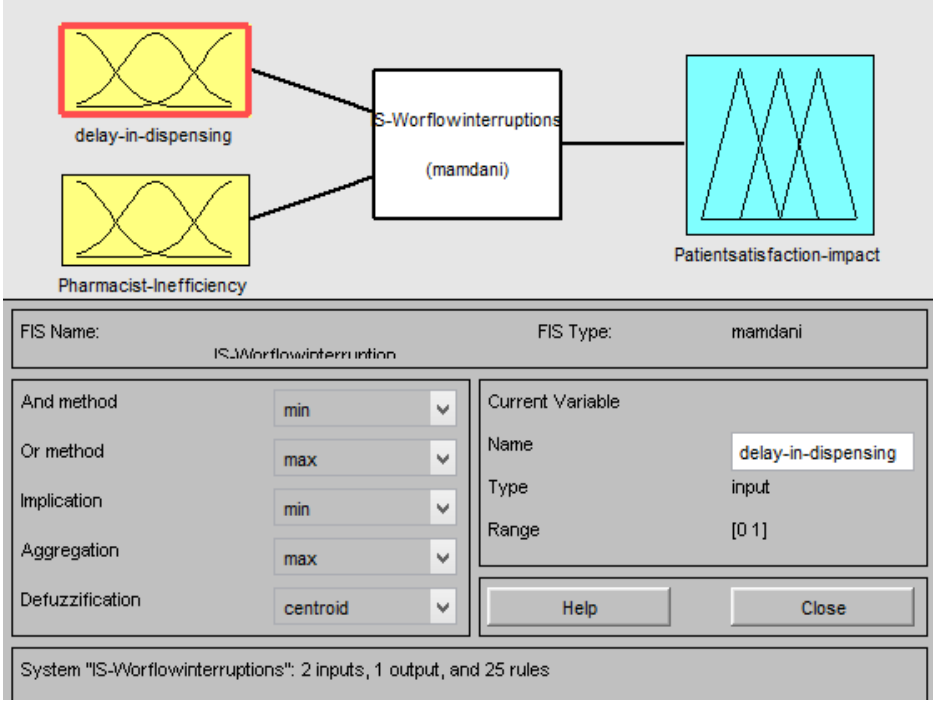


Figure 5. 8 Mamdani FIS for calculation of impact score of error due to interruptions

5.6. FIS models for Wrong Drug Dispensing Error

FIS 9 and FIS 10 are used to compute the probability of occurrence score and impact score of wrong drug dispensing error, respectively. FIS 9 has Look alike/ sound alike drugs, skip patient's counselling and Unorganized work flow as inputs and Probability of occurrence score as output. Hence this Mamdani model as shown in Figure 5. 9 has 3 inputs, 1 output and 125 fuzzy rules. FIS 10 has Patient side effects and mortality as inputs and Impact of wrong drug dispensing error as output. Hence the Mamdani model described in Figure 5. 10 has 2 inputs, 1 output and 25 fuzzy rules.

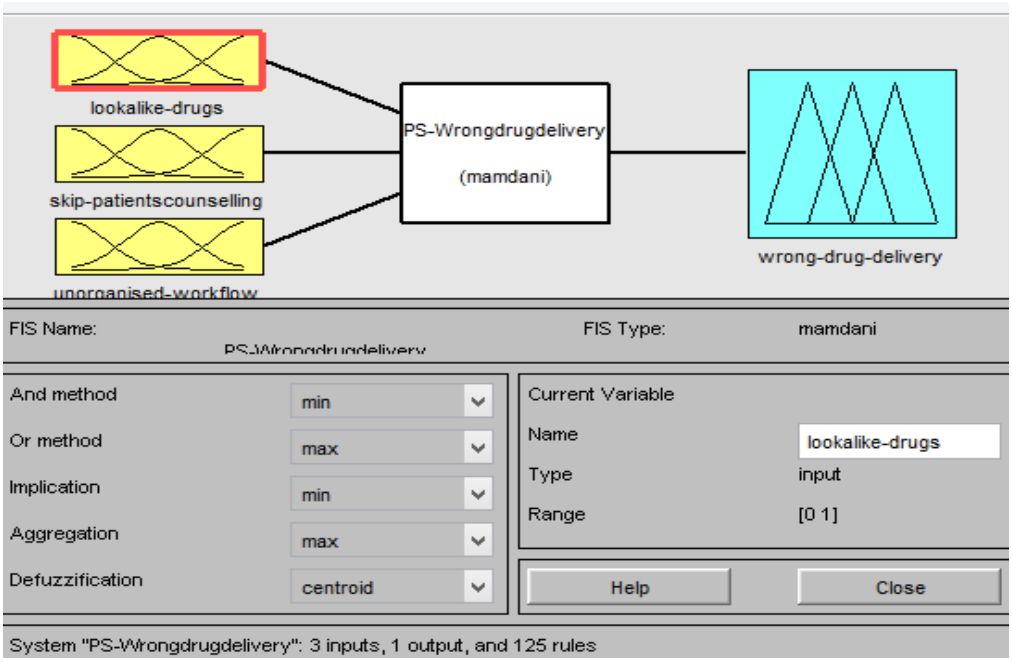


Figure 5. 9 Mamdani FIS for calculation of probability of occurrence of wrong drug dispensing error

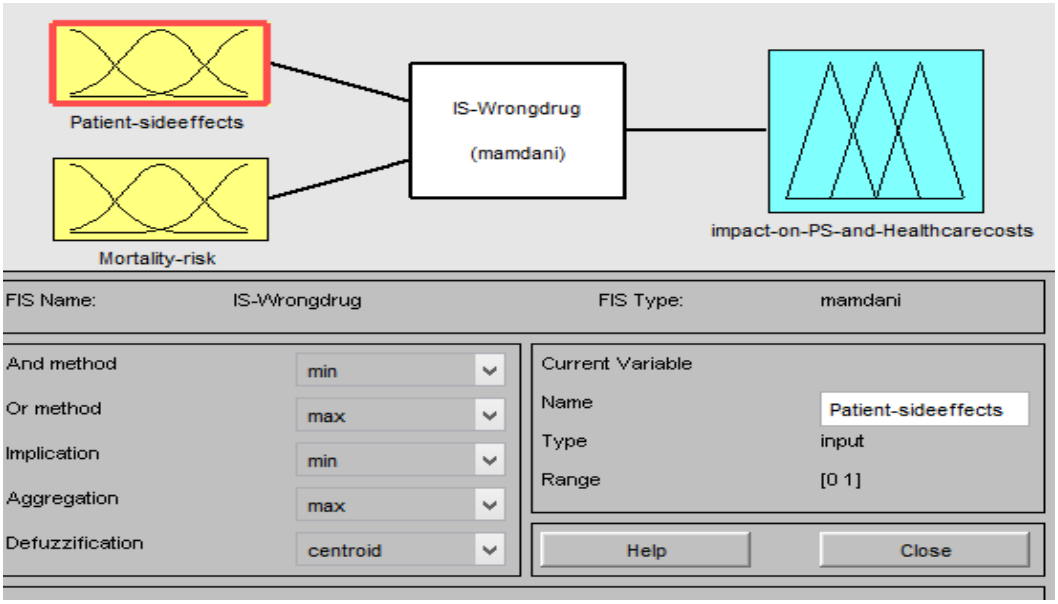


Figure 5. 10 Mamdani FIS for calculation of impact score of wrong drug dispensing error

5.7. FIS Models for Error Due to Pharmacist Distraction

FIS 11 and FIS 12 were used to compute the probability of occurrence score and Impact score of error due to pharmacist distraction, respectively. FIS 11 has meal breaks issue and improper room conditions as inputs and Probability of occurrence score as output. Hence this Mamdani model as shown in Figure 5. 11 has 2 inputs, 1 output and 25 fuzzy rules. FIS 12 has delivery of improper duties and prescription error as inputs and Impact of error due to pharmacist distraction as output. Hence the Mamdani model described in Figure 5. 12 has 2 inputs, 1 output and 25 fuzzy rules.

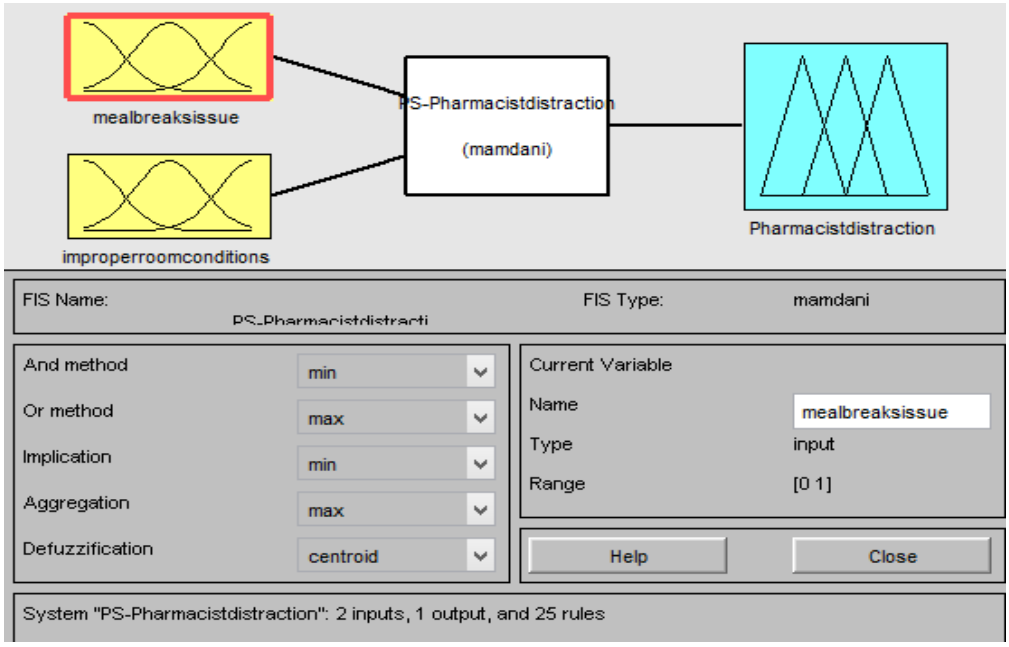


Figure 5. 11 Mamdani FIS for calculation of probability of occurrence of error due to pharmacist distraction

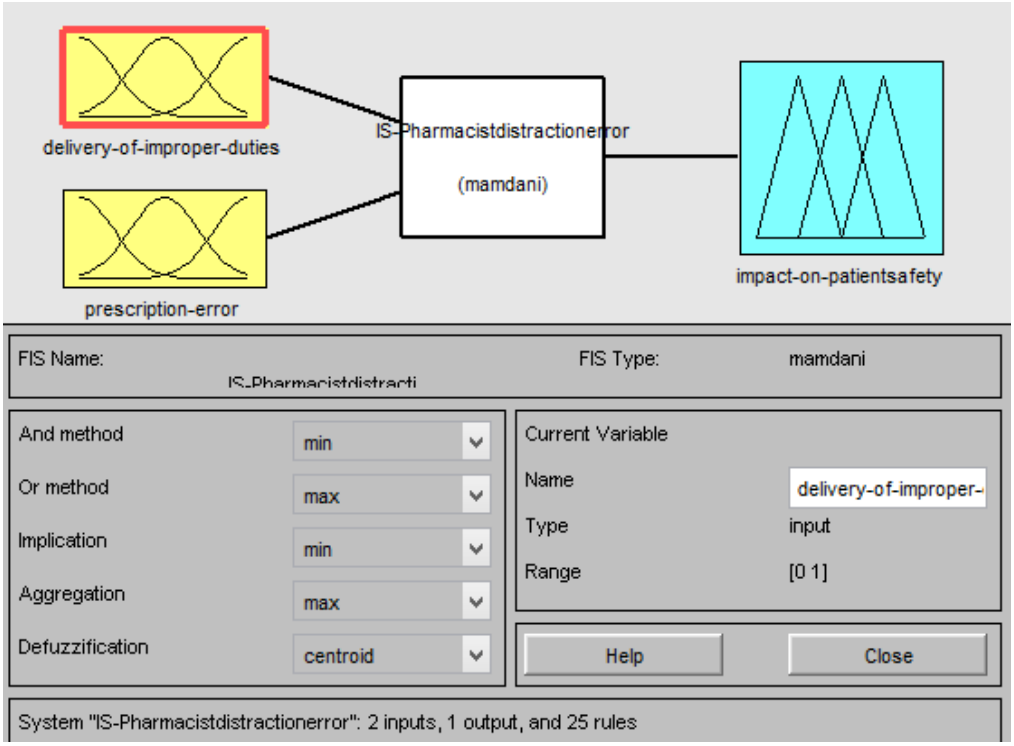


Figure 5. 12 Mamdani FIS for calculation of impact score of error due to pharmacist distraction

5.8. FIS Model for Risk Score Calculation

After the implementation of all the Mamdani models as described previously, each risk event has probability of occurrence score and impact score. At this point, FIS 13 shown in the Figure 5. 13 was used to calculate the risk score for each risk event. FIS 13 has probability of occurrence score and impact score as inputs and risk score as output. Hence it has 2 inputs, one output and 25 fuzzy rules.

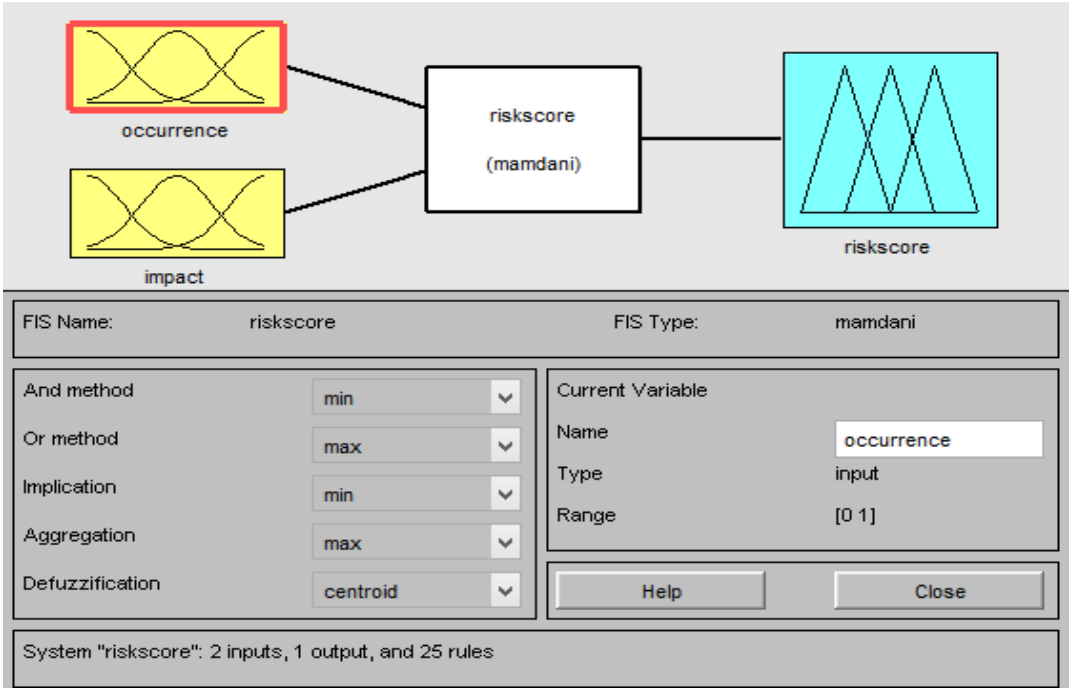


Figure 5. 13 Mamdani FIS for calculation of risk score for each risk event

The probability of occurrence score, impact score and risk score for all the six risk events are tabulated in Table 5. 4.

From the Table 5. 4, it is clearly seen that risk event 5 and risk event 4 has high risk scores. Therefore, proper mitigation plans need to be implemented to improve the patient safety. The risk score tabulated in the Table 5. 4 is completely based on the inputs obtained from the pharmacist. The occurrence of errors may not be consistent in any organisation. It changes from day to day. Similarly in a pharmacy the occurrence of errors in drug dispensing process are not constant. Therefore, this FIS risk analysis

tool can be used in a pharmacy on a regular basis to check the risk scores for each risk event and implement appropriate mitigation plans.

Table 5. 4 Probability of occurrence score, impact score and risk score for all the risk events

S.no	**Risk events**	**Probability of occurrence score**	**Impact score**	**Risk score**	**Risk rank**
1	Transcription Error	0.511	0.603	44.2	4
2	Patient Misidentification	0.226	0.655	32.8	6
3	Labelling error	0.58	0.412	34.2	5
4	Interruptions	0.647	0.533	49.1	2
5	Wrong drug delivery	0.528	0.754	56.1	1
6	Pharmacist distraction	0.603	0.536	48.7	3

5.9. Comparison of FIS Risk Analysis Tool Results on Pharmacy Drug Dispensing Process with FMEA Results

Failure Mode Effects Analysis (FMEA) is one of the risk analysis methods which is widely used in non - health care industries (Reiley, 2000). In FMEA risks are treated as failure modes. For each of the identified failure mode, three measures are done. They are "rate of occurrence", "severity" and "ease of detection". (Reiley, 2000). Each failure mode is assigned with a Risk Priority Number (RPN). Based on the RPN, the criticality of the failure modes were identified. Risk priority number is calculated as follows:

" RPN = rate of occurrence (O) x severity (S) x ease of detection (D)" (Reiley, 2000)

Table 5. 5 "Rating the occurrence of failure mode effects" (Greenall et al., 2012)

Frequency	Score
Yearly	1
Monthly	2
Weekly	3
Daily	4
Hourly	5

Table 5. 6 "Rating the severity of failure mode effects" (Greenall et al., 2012)

Severity	***Score***	***Description***
No effect	1	Effect is not noticeable
Slight effect	2	Less effects to the patient
Moderate effect	3	Minor performance loss
Major effect	4	High performance loss
Severe effect	5	Higher permanent loss

The inputs for occurrence, severity, and detection to calculate the RPN for the identified risks are obtained from the pharmacist.

Table 5. 7 "Rating the detect ability of failure mode effects" (Greenall et al., 2012)

Detect ability	***Score***
Always	1
Likely	2
Unlikely	3
Very unlikely	4
Never	5

Table 5. 8 RPN for the identified risks in the drug dispensing process at pharmacy

Risk event	O	S	D	RPN	FMEA rank	FIS rank
Transcription error	3	3	4	36	4	4
Patient misidentification	2	4	4	32	5	6
Labelling error	5	2	3	30	6	5
Interruptions	5	4	4	90	1	2
Wrong drug delivery	4	5	3	60	2	1
Pharmacist distraction	3	4	4	48	3	3

Table 5. 8 shows the risk ranking on application of FMEA method and developed FIS risk analysis method on drug dispensing process at pharmacy. The results from the Table 5. 4 and 5. 8 were compared with each other. They are agreeable with each other and hence it shows the verification of the FIS risk analysis tool.

5.10. Preventive Measures and Protective Measures for the Identified Risk Events

Preventive measures and protective measures are very important to avoid the occurrence of risk event and to reduce the impact of occurred risk event, respectively (Aqlan and Ali, 2014). This section discusses the

suggested preventive measures and protective measures for the drug dispensing process .

Transcription Error

Preventive measures: The Information exchanged between a doctor and a pharmacist should be done electronically, Usage of non-standard abbreviations for the drug names must be avoided. Protective measures: Pharmacist should read the complete drug name. If phone call transcription arrives to pharmacy, then the pharmacist should read back to the caller and document the clarifications. (Minimising medication errors, 2009)

Patient Misidentification

Preventive measures: Every pharmacy should design a standardised process which requires the verification of the second identifier of the patient especially for the high alert medications and information regarding verification process importance can be posted on the pharmacy walls to create awareness among patients. Protective measures: Pharmacist should cross check with the patient's address and also with medication allergies. (Greenall et al., 2012)

Labelling Error

Preventive measures: Organising the pharmacist table often, Educate all pharmacy technicians on their roles and responsibilities. Protective measures: Proper training should be given to the technicians, Serious action should be taken on the person who does not deliver their duties properly.

Interruptions

Preventive measures: Separate phone line for communication between doctor and pharmacist, enough space for the pharmacist to perform the dispensing functions, adequate staff scheduling. Protective measures : Specific staff to attend phone calls (Minimising medication errors, 2009)

Wrong Drug Dispensing

Preventive measures: Provide image of the drug on the computer screen especially for high alert medications, all drug bottles in the storage should be arranged alphabetically and their labels facing forward. In each drug dispensing stage, secondary check should be performed, expiration of the medications should be checked periodically (Minimising medication errors, 2012). Protective measures: Follow "show & tell medication" method in patient's counselling, perform final check on the prescription container contents with the prescribed label.

Pharmacist Distraction

Preventive measures: Proper scheduling of meal breaks to the pharmacists, pharmacist service counter should be separated from the non-drug dispensing functions. Protective measures: Always check should be done for filled in prescription, labels and drugs in the container by the second pharmacist.

Hence by following proper preventive and protective measures, risk events in a pharmacy can be controlled.

CHAPTER 6 - PROPOSED TOOL APPLICATION ON CHEMICAL INDUSTRY

In this Chapter, proposed FIS risk analysis tool and Lean fuzzy bow-tie analysis (Aqlan and Ali, 2014) methods were applied on a chemical industry and the results were compared. Also, the FMEA method was applied to chemical industry and the results were compared against proposed FIS risk analysis tool results.

6.1. Application in Chemical Process Industry

Aqlan and Ali (2014) proposed an integrated framework which is a combination of lean manufacturing principles, fuzzy set theory and Bow-tie analysis. They identified seven risk events based on the surveys, questionnaires and history of events. They are as follows (Aqlan and Ali, 2014) :

- Non-confirming Product – CR1
- Personal Injuries – CR2
- Fire risk – CR3
- Exposure to toxic materials – CR4
- Leakage of chemicals – CR5

- Explosion Risk – CR6
- Occupational Ergonomic Risk – CR7

The risk factors and impacts for each risk event are tabulated in Table 6. 1 (Aqlan and Ali, 2014).

Table 6. 1 Risk factors and impacts of chemical industry risk events (Aqlan and Ali, 2014)

Risks	**Risk factors**	**Risk impacts**
CR1	F11 = Release of wrong raw materials F12 = Addition of wrong chemical into certain batch by mistake F13 = Insufficient cleaning of tanks & pipes	L11 = Customer dissatisfaction L12 = Loss of reputation L13 = Waste of money
CR2	F21 = Safety procedures not followed by an employee F22 = Lack of awareness and supervision	L21 = Absence of work L22 = Compensation L23 = Medication costs
CR3	F31 = A cigarette lighted by a visitor in production area F32 = Electrostatic spark F33 = Electrical spark	L31 = Fire L32 = Explosion
CR4	F41 = Dealing with hazardous chemicals for long time F42 = Safety equipment not wore by worker	L41 = Infection to operators L42 = Compensation L43 = Medication
CR5	F51 = Float valve didn't close	L51 = Loss of money because of

	F52 = Unfastened cam lock F53 = Clogged filter or pipe line	spills L52 = Severe injuries due to slipping
CR6	F61 = Flammable materials storage under direct sun	L61 = Explosion due to reactivity under direct sun
CR7	R71 = Extreme bending R72 = Lifting of heavy materials	L71 = Absence of work L72 = Decrease of productivity L73 = Compensation

Aqlan and Ali (2014) obtained the fuzzy estimates of risk likelihood and risk impact from the experts working in the chemical industry. They used fuzzy set theory to analyse the risks in chemical industry. The risk factors and impacts are related to each other either by "OR" relation or "AND" relation. They used the following equations to find the total probability and total impact of a identified risk.

"For AND rule

$$P_k(t) = \prod_{i=1}^{n} p_i(t)$$

For OR rule

$$p_i(t)$$

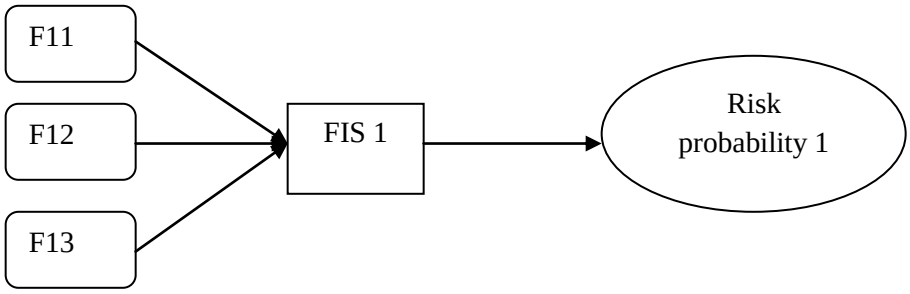
$$P_k(t) = 1 - (\prod_{i=1}^{n} 1 - p_i(t))$$

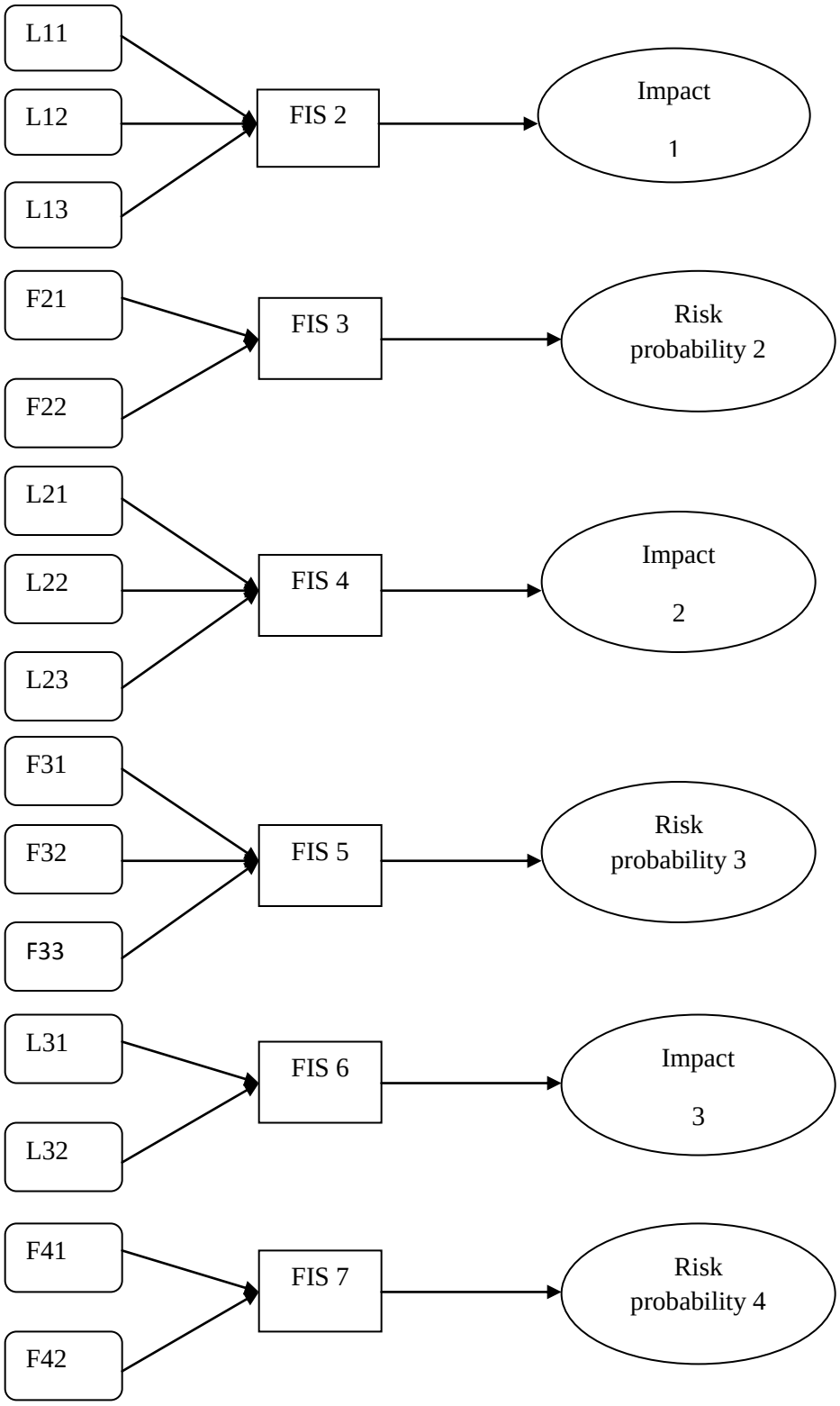
The impact of the risk event k is calculated as:

$$L_k(t) = \frac{\sum_{i=1}^{n} p_i(t) l_i(t)}{\sum_{i=1}^{n} p_i(t)}$$

Where $P_k(t)$ is the probability of occurrence of risk event k during the planning horizon t, $p_i(t)$ is the probability of occurrence of risk factor i and $l_i(t)$ is the intensity of the impact i" (Aqlan and Ali, 2014).

If the situation involves both OR rule and AND rule, then the equations and computations would be lengthy. Whenever there is a change in the inputs by the experts, all the computations should be made from the scratch. Whereas in the proposed FIS risk analysis tool there are no computations involved; the Mamdani FIS is used to replace the heavy formulae calculation section. In this tool, computations can be eliminated by defining the fuzzy IF....THEN rules based on the type of problem. The FIS risk analysis tool is also applied in the chemical process industry and the results are tabulated and compared in the next section.

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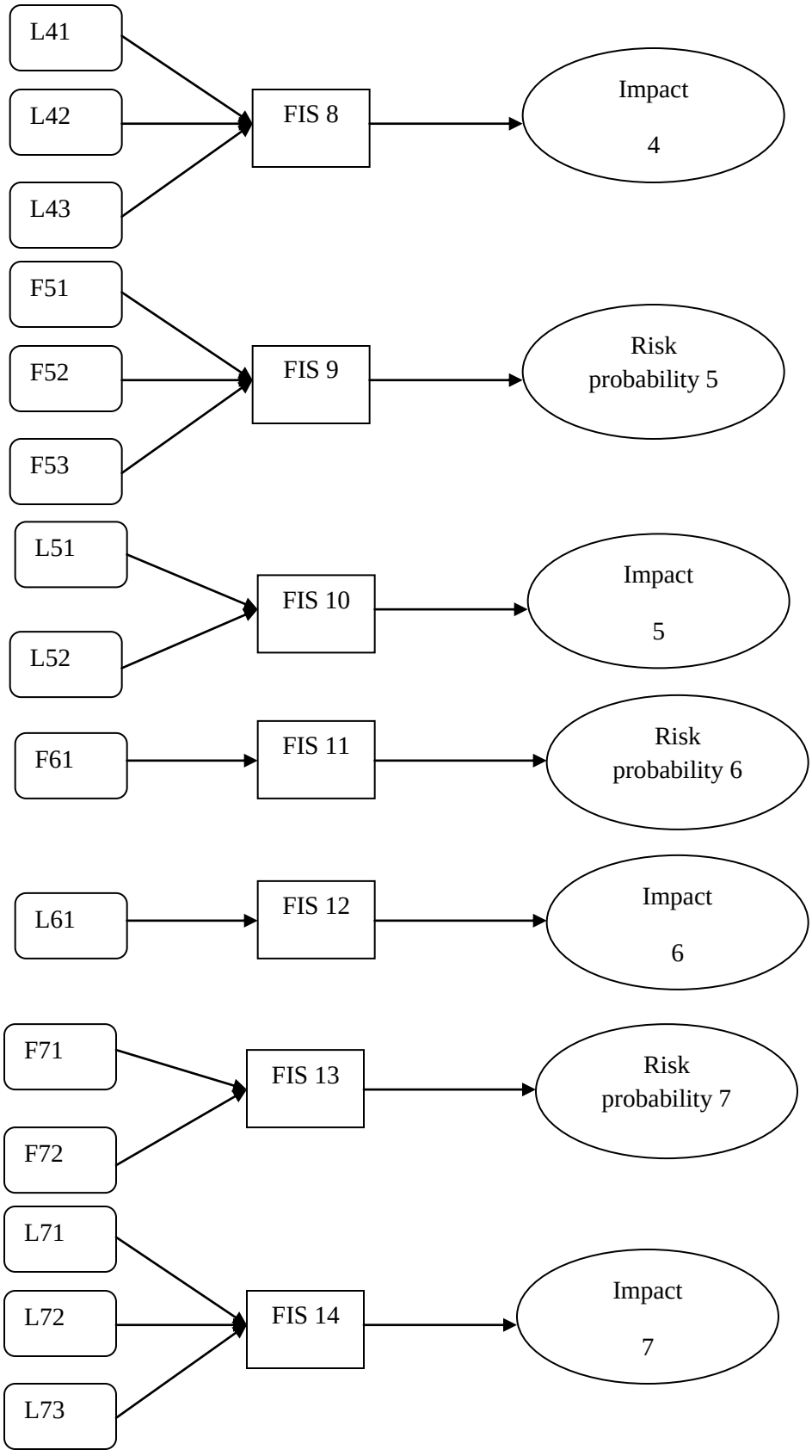
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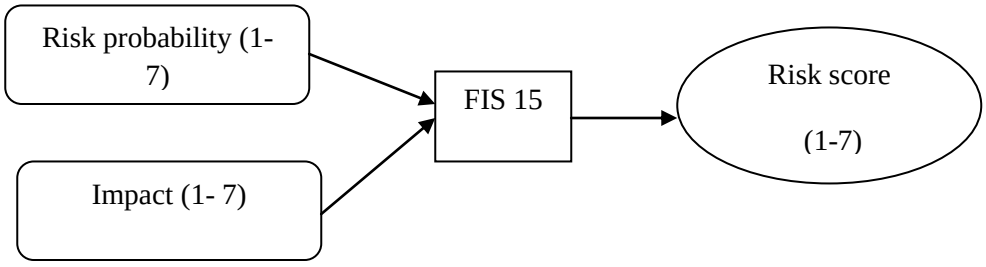

Figure 6. 1 FIS models to calculate probability of occurrence score and Impact score of all risks considering their risk factors and impacts in chemical industry.

6.2. Comparison of Lean Fuzzy Bow-tie Analysis and the FIS risk analysis tool Results:

The results obtained from the application of "Lean Fuzzy Bow-tie analysis" (Aqlan and Ali, 2014) and proposed FIS risk analysis tool are shown below. The risk event 3 got the highest score in both methods and the probability of occurrence score and impact score for the remaining risk events are also in the same range. These results verify the proposed method.

Table 6. 2 Probability of occurrence score, impact score and risk score for the identified risks in chemical industry

Risk event no.	Risk factors	Occurrence score	FIS occ score	Impacts	Impact score	FIS impact score	Risk score	FIS risk score	FIS Risk rank
CRE1	0.5,0.4,0.6	(0.51,0.79,0.94)	0.514	7.6,6.8,6	(4.58,6.17,7.6)	5.01	Medium	42.7	6
CRE2	0.8,0.86	(0.76,0.88,0.97)	0.588	5,5,5	(3.86,5.63,7.23)	4.92	Medium	41.7	7
CRE3	0.175,0.35,0.5	0.20,0.51,0.8)	0.506	9,10	(7,9,10)	8.88	**High**	**73.6**	1
CRE4	0.8,0.7	(0.58,0.85,0.96)	0.599	8.8,5,6	(3.22,4.93,6.75)	5.12	Medium	45.9	4
CRE5	0.8,0.7,0.8	(0.78,0.94,0.99)	0.53	5,4.7	(3.67,5.62,7.35)	6.85	Medium	47.5	3
CRE6	0.6	(0.2,0.4,0.6)	0.59	7	(5,7,8.20)	6.82	Medium	59.9	2
CRE7	0.6,0.5	(0.3,0.58,0.8)	0.51	6,7,6.5	(3.71,5.34,7.13)	5.61	Medium	44.8	5

6.3. Comparison of FMEA and FIS risk analysis tool Results

FMEA is one of the mostly used risk analysis methods. The method FMEA and its occurrence, severity and detect ability scale tables are explained in the previous chapter. The occurrence score, severity score and detect ability score for each identified risk event are obtained from the expert knowledge and the Risk Priority Number (RPN) is calculated. Table

6. 3 shows the comparison of FMEA and FIS risk analysis tool results on the Chemical industry.

Risk event	O	S	D	RPN	FMEA rank	FIS rank
CR1	3	4	3	36	6	6
CR2	4	2	4	32	7	7
CR3	5	5	4	100	1	1
CR4	5	4	4	80	3	4
CR5	4	5	3	60	4	3
CR6	4	5	4	90	2	2
CR7	4	3	4	48	5	5

Table 6. 3 RPN for the identified risks in the chemical process industry

From the Table 6. 3 it is clear that the results from the FMEA method are in agreement with the FIS risk analysis tool results. The FIS risk analysis tool considers the risk factors and impacts of each risk event to compute the risk score; whereas FMEA method does not consider them. This is the reason for the difference in ranking for the risk events CR4 and CR5 in these methods.

6.4. Advantages of FIS Risk Analysis Tool Over Lean Fuzzy Bow-tie Analysis and FMEA

- From the Table 6. 2 It is clearly seen that CR1, CR2, CR4, CR5, CR6, CR7 are classified in the medium category. But, it is not possible to determine which risk should be taken care of first, since all the risks except CR3 fell under medium category. This can be overcome by the proposed FIS risk analysis tool, since it assigns a unique score to each risk event. Based on the Risk score ranking preventive/protective measures can be taken.
- As discussed in section 6.1 , in FMEA method, RPN is calculated using rate of occurrence, severity and ease of detection. Let's consider the following example.

  R1 - O X S X D - 4 X 3 X 2 = 24

  R2 - O X S X D - 8 X 3 X 1 = 24

  R3 - O X S X D - 2 X 6 X 2 = 24

  All the risks R1, R2 and R3 have the same RPN which makes the decision making a bit difficult; also the FMEA does not consider the risk factors and impacts of a risk event in calculating the risk score of a risk event.

CHAPTER 7 - SUMMARY AND CONCLUSIONS

The objectives as outlined in the chapter - 1 have been met. That is, to develop a tool that can improve patient safety by performing risk analysis in drug dispensing process at a pharmacy. The tool was tested by applying in a chemical industry and the results are compared with Lean fuzzy Bow-tie analysis method (Aqlan and Ali, 2014). Also, the FMEA method was applied on both cases and its results were similar with the proposed FIS risk analysis tool results. This intelligent risk analysis tool was created by combining the Bow - tie risk analysis method and a Fuzzy Inference System concept.

Development of the tool was completed in three stages. In the first stage, Bow-tie analysis method was applied to the pharmacy drug dispensing process and in chemical industry to identify all the potential risk events, their risk factors and impacts. All risk factors that contribute to the risk events and the impacts of the risk events were listed.

In the second stage, different Mamdani Fuzzy Inference Systems were used to calculate the probability of occurrence score for a risk event by considering all the risk factors contributing to the risk events. An additional six different Mamdani Fuzzy Inference Systems were used to calculate the

impact score of the risk events. Finally, the risk score for each risk event was calculated by using another Mamdani FIS by considering the corresponding probability of occurrence score and impact score of each risk event.

In the third stage, all the risk events are priorities based on the risk score and proper mitigation plans that are implemented in the organisation to avoid the occurrence of the risk events.

7.1. Summary

On implementing this intelligent risk analysis tool in the pharmacy drug dispensing process, it was found that the risk events - wrong drug delivery and error due to interruptions occur frequently. Hence suggested protective and preventive measures in the Chapter 5 should be implemented to reduce the medication errors. However, the risk score to the risk events is completely based on the inputs given by the pharmacist. Hence the ranking of the risk events may vary dynamically based on the type of errors that occur in the pharmacy. The application of the FIS risk analysis tool in the chemical industry showed that the risk event CR3 - Fire risk has highest score among other risks. Hence it should be taken care of first, by following appropriate preventive measures.

This thesis demonstrates that fuzzy modelling can be applied to drug dispensing process and to chemical process industry, providing an important and relevant improvement for risk analysis and related problems. These traits characterised this application as literature resources provided a large amount of data. But, with mandatory error reporting not required, the information is incomplete and based on the interview to define risk, uncertainty may be present.

The advantages of the proposed model over FMEA are as follows:

- As discussed in CHAPTER - 6, in some cases FMEA assigns same Risk Priority Number (RPN) to different risks irrespective of the severity, occurrence, and detection of ability scores. Whereas FIS risk analysis tool assigns a different risk score to each risk event. This makes easier for an organization to choose the mitigation strategies.
- The risk analysis tool developed in this research is very useful as it provides an outlook of errors happening in the drug dispensing process and in the chemical process industry.

- The proposed FIS risk analysis tool assigns risk score to each risk event by considering both risk factors and impacts of a risk based on the expert's knowledge.

The advantages of the proposed model over the Bow-tie Analysis are as follows:

- When Bow-tie analysis with fuzzy probability theory is used to compute risk score, calculations are made for each change in inputs i.e., probability of occurrence of risk factors and intensity level of impacts. Since OR and AND gates are involved in each relation of risk factors and impacts, computational effort is increased.
- Whereas by using the proposed model, for every change in the inputs, the result is obtained based on the FIS rules. This reduces the computational effort and assigns a unique score to the risk event rather than assigning a range (example: high, medium, low) to the risk.

7.2. Future Developments

- In this research, only one pharmacist contributed the inputs based on the experience. If more number of pharmacists participate in this research, then the accuracy of the Intelligent risk analysis tool can be increased.
- Develop a testing and validation process for the application.
- The Fuzzy inference systems used in the thesis can be validated strictly by constructing a performance index considering the system output in terms of the membership function parameters. The performance index can be optimized to get the optimal membership function parameter; so, the fuzzy inference system will be optimal with respect to the performance index and membership function parameters.
- This research is focused on drug dispensing process. In the future, this work can be extended by considering all the process in the medication use process; Drug prescribing, Drug dispensing and Drug administration.

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APPENDIX A

Mamdani FIS Fuzzy (If - Then) Rules

The output of a FIS can be obtained depending on the combination of inputs and this is defined by the antecedent - consequent of the fuzzy rules that are defined in the FIS. The If - Then rules used in all the Fuzzy Inference Models are provided in the following sections.

Section 1 - Fuzzy rules used in FIS 1

1. If Probability of occurrence of Ambiguous prescription is NOT EXPECTED or Probability of occurrence of Incorrect prescription entry is NOT EXPECTED then Probability of occurrence of Transcription error is NOT EXPECTED
2. If Probability of occurrence of Ambiguous prescription is NOT EXPECTED or Probability of occurrence of Incorrect prescription entry is VERY UNLIKELY then Probability of occurrence of Transcription error is NOT EXPECTED
3. If Probability of occurrence of Ambiguous prescription is NOT EXPECTED or Probability of occurrence of Incorrect prescription entry is UNLIKELY then Probability of occurrence of Transcription error is VERY UNLIKELY
4. If Probability of occurrence of Ambiguous prescription is NOT EXPECTED or Probability of occurrence of Incorrect prescription entry is POSSIBLE then Probability of occurrence of Transcription error is POSSIBLE
5. If Probability of occurrence of Ambiguous prescription is NOT EXPECTED or Probability of occurrence of Incorrect prescription entry is EXPECTED then Probability of occurrence of Transcription error is EXPECTED
6. If Probability of occurrence of Ambiguous prescription is VERY UNLIKELY or Probability of occurrence of Incorrect prescription entry is NOT EXPECTED then Probability of occurrence of Transcription error is NOT EXPECTED
7. If Probability of occurrence of Ambiguous prescription is VERY UNLIKELY or Probability of occurrence of Incorrect prescription entry is VERY UNLIKELY then Probability of occurrence of Transcription error is UNLIKELY
8. If Probability of occurrence of Ambiguous prescription is VERY UNLIKELY or Probability of occurrence of Incorrect prescription entry is UNLIKELY then Probability of occurrence of Transcription error is UNLIKELY

9. If Probability of occurrence of Ambiguous prescription is VERY UNLIKELY or Probability of occurrence of Incorrect prescription entry is POSSIBLE then Probability of occurrence of Transcription error is POSSIBLE
10. If Probability of occurrence of Ambiguous prescription is VERY UNLIKELY or Probability of occurrence of Incorrect prescription entry is EXPECTED then Probability of occurrence of Transcription error is EXPECTED
11. If Probability of occurrence of Ambiguous prescription is UNLIKELY or Probability of occurrence of Incorrect prescription entry is NOT EXPECTED then Probability of occurrence of Transcription error is UNLIKELY
12. If Probability of occurrence of Ambiguous prescription is UNLIKELY or Probability of occurrence of Incorrect prescription entry is VERY UNLIKELY then Probability of occurrence of Transcription error is UNLIKELY
13. If Probability of occurrence of Ambiguous prescription is UNLIKELY or Probability of occurrence of Incorrect prescription entry is UNLIKELY then Probability of occurrence of Transcription error is UNLIKELY
14. If Probability of occurrence of Ambiguous prescription is UNLIKELY or Probability of occurrence of Incorrect prescription entry is POSSIBLE then Probability of occurrence of Transcription error is EXPECTED
15. If Probability of occurrence of Ambiguous prescription is UNLIKELY or Probability of occurrence of Incorrect prescription entry is EXPECTED then Probability of occurrence of Transcription error is EXPECTED
16. If Probability of occurrence of Ambiguous prescription is POSSIBLE or Probability of occurrence of Incorrect prescription entry is NOT EXPECTED then Probability of occurrence of Transcription error is UNLIKELY
17. If Probability of occurrence of Ambiguous prescription is POSSIBLE or Probability of occurrence of Incorrect prescription entry is VERY UNLIKELY then Probability of occurrence of Transcription error is UNLIKELY
18. If Probability of occurrence of Ambiguous prescription is POSSIBLE or Probability of occurrence of Incorrect prescription entry is UNLIKELY then Probability of occurrence of Transcription error is POSSIBLE
19. If Probability of occurrence of Ambiguous prescription is POSSIBLE or Probability of occurrence of Incorrect prescription entry is POSSIBLE then Probability of occurrence of Transcription error is EXPECTED

20. If Probability of occurrence of Ambiguous prescription is POSSIBLE or Probability of occurrence of Incorrect prescription entry is EXPECTED then Probability of occurrence of Transcription error is EXPECTED
21. If Probability of occurrence of Ambiguous prescription is EXPECTED or Probability of occurrence of Incorrect prescription entry is NOT EXPECTED then Probability of occurrence of Transcription error is UNLIKELY
22. If Probability of occurrence of Ambiguous prescription is EXPECTED or Probability of occurrence of Incorrect prescription entry is VERY UNLIKELY then Probability of occurrence of Transcription error is POSSIBLE
23. If Probability of occurrence of Ambiguous prescription is EXPECTED or Probability of occurrence of Incorrect prescription entry is UNLIKELY then Probability of occurrence of Transcription error is POSSIBLE
24. If Probability of occurrence of Ambiguous prescription is EXPECTED or Probability of occurrence of Incorrect prescription entry is POSSIBLE then Probability of occurrence of Transcription error is EXPECTED
25. If Probability of occurrence of Ambiguous prescription is EXPECTED or Probability of occurrence of Incorrect prescription entry is EXPECTED then Probability of occurrence of Transcription error is EXPECTED

Section 2 - Fuzzy Rules used in FIS 2

1. If impact due to Wrong medication to the patient is VERY LOW then impact due to transcription error is VERY LOW
2. If impact due to Wrong medication to the patient is LOW then impact due to transcription error is LOW
3. If impact due to Wrong medication to the patient is MEDIUM then impact due to transcription error is MEDIUM
4. If impact due to Wrong medication to the patient is HIGH then impact due to transcription error is HIGH
5. If impact due to Wrong medication to the patient is VERY HIGH then impact due to transcription error is VERY HIGH

Section 3 - Fuzzy Rules used in FIS 3

1. If probability of occurrence of Patient with similar names scenario is NOT EXPECTED then probability of occurrence of Patient misidentification error is NOT EXPECTED
2. If probability of occurrence of Patient with similar names scenario is VERY UNLIKELY then probability of occurrence of Patient misidentification error is VERY UNLIKELY
3. If probability of occurrence of Patient with similar names scenario is UNLIKELY then probability of occurrence of Patient misidentification error is UNLIKELY
4. If probability of occurrence of Patient with similar names scenario is POSSIBLE then probability of occurrence of Patient misidentification error is POSSIBLE
5. If probability of occurrence of Patient with similar names scenario is EXPECTED then probability of occurrence of Patient misidentification error is NOT EXPECTED

Section 4 - Fuzzy Rules used in FIS 4

1. If impact due to Incorrect prescription released is VERY LOW or impact due to side effects to patient is VERY LOW then Impact on patient safety is VERY LOW
2. If Impact due to Incorrect prescription released is VERY LOW or Impact due to side effects to patient is LOW then Impact on patient safety is VERY LOW
3. If Impact due to Incorrect prescription released is VERY LOW or Impact due to side effects to patient is MEDIUM then Impact on patient safety is VERY LOW
4. If Impact due to Incorrect prescription released is VERY LOW or Impact due to side effects to patient is HIGH then Impact on patient safety is LOW
5. If Impact due to Incorrect prescription released is VERY LOW or Impact due to side effects to patient is VERY HIGH then Impact on patient safety is LOW
6. If Impact due to Incorrect prescription released is LOW or Impact due to side effects to patient is VERY LOW then Impact on patient safety is LOW
7. If Impact due to Incorrect prescription released is LOW or Impact due to side effects to patient is LOW then Impact on patient safety is LOW
8. If Impact due to Incorrect prescription released is LOW or Impact due to side effects to patient is MEDIUM then Impact on patient safety is MEDIUM

9. If Impact due to Incorrect prescription released is LOW or Impact due to side effects to patient is HIGH then Impact on patient safety is HIGH
10. If Impact due to Incorrect prescription released is LOW or Impact due to side effects to patient is VERY HIGH then Impact on patient safety is HIGH
11. If Impact due to Incorrect prescription released is MEDIUM or Impact due to side effects to patient is VERY LOW then Impact on patient safety is LOW
12. If Impact due to Incorrect prescription released is MEDIUM or Impact due to side effects to patient is LOW then Impact on patient safety is LOW
13. If Impact due to Incorrect prescription released is MEDIUM or Impact due to side effects to patient is MEDIUM then Impact on patient safety is MEDIUM
14. If Impact due to Incorrect prescription released is MEDIUM or Impact due to side effects to patient is HIGH then Impact on patient safety is MEDIUM
15. If Impact due to Incorrect prescription released is MEDIUM or Impact due to side effects to patient is VERY HIGH then Impact on patient safety is HIGH
16. If Impact due to Incorrect prescription released is HIGH or Impact due to side effects to patient is VERY LOW then Impact on patient safety is MEDIUM
17. If Impact due to Incorrect prescription released is HIGH or Impact due to side effects to patient is LOW then Impact on patient safety is MEDIUM
18. If Impact due to Incorrect prescription released is HIGH or Impact due to side effects to patient is MEDIUM then Impact on patient safety is MEDIUM
19. If Impact due to Incorrect prescription released is HIGH or Impact due to side effects to patient is HIGH then Impact on patient safety is HIGH
20. If Impact due to Incorrect prescription released is HIGH or Impact due to side effects to patient is VERY HIGH then Impact on patient safety is HIGH
21. If Impact due to Incorrect prescription released is VERY HIGH or Impact due to side effects to patient is VERY LOW then Impact on patient safety is LOW
22. If Impact due to Incorrect prescription released is VERY HIGH or Impact due to side effects to patient is LOW then Impact on patient safety is LOW
23. If Impact due to Incorrect prescription released is VERY HIGH or Impact due to side effects to patient is MEDIUM then Impact on patient safety is MEDIUM
24. If Impact due to Incorrect prescription released is VERY HIGH or Impact due to side effects to patient is HIGH then Impact on patient safety is HIGH
25. If Impact due to Incorrect prescription released is VERY HIGH or Impact due to side effects to patient is VERY HIGH then Impact on patient safety is HIGH

Section 5 - Fuzzy Rules used in FIS 5

1. If Clutter on table is NOT EXPECTED or Untrained staff is NOT EXPECTED then Probability of occurrence of Labelling error is NOT EXPECTED
2. If Clutter on table is NOT EXPECTED or Untrained staff is VERY UNLIKELY then Probability of occurrence of Labelling error is VERY UNLIKELY
3. If Clutter on table is NOT EXPECTED or Untrained staff is UNLIKELY then Probability of occurrence of Labelling error is POSSIBLE
4. If Clutter on table is NOT EXPECTED or Untrained staff is POSSIBLE then Probability of occurrence of Labelling error is EXPECTED
5. If Clutter on table is NOT EXPECTED or Untrained staff is EXPECTED then Probability of occurrence of Labelling error is EXPECTED
6. If Clutter on table is VERY UNLIKELY or Untrained staff is NOT EXPECTED then Probability of occurrence of Labelling error is NOT EXPECTED
7. If Clutter on table is VERY UNLIKELY or Untrained staff is VERY UNLIKELY then Probability of occurrence of Labelling error is NOT EXPECTED
8. If Clutter on table is VERY UNLIKELY or Untrained staff is UNLIKELY then Probability of occurrence of Labelling error is UNLIKELY
9. If Clutter on table is VERY UNLIKELY or Untrained staff is POSSIBLE then Probability of occurrence of Labelling error is EXPECTED
10. If Clutter on table is VERY UNLIKELY or Untrained staff is EXPECTED then Probability of occurrence of Labelling error is EXPECTED
11. If Clutter on table is UNLIKELY or Untrained staff is NOT EXPECTED then Probability of occurrence of Labelling error is NOT EXPECTED
12. If Clutter on table is UNLIKELY or Untrained staff is VERY UNLIKELY then Probability of occurrence of Labelling error is VERY UNLIKELY
13. If Clutter on table is UNLIKELY or Untrained staff is UNLIKELY then Probability of occurrence of Labelling error is UNLIKELY
14. If Clutter on table is UNLIKELY or Untrained staff is POSSIBLE then Probability of occurrence of Labelling error is EXPECTED
15. If Clutter on table is UNLIKELY or Untrained staff is EXPECTED then Probability of occurrence of Labelling error is EXPECTED

16. If Clutter on table is POSSIBLE or Untrained staff is NOT EXPECTED then Probability of occurrence of Labelling error is UNLIKELY
17. If Clutter on table is POSSIBLE or Untrained staff is VERY UNLIKELY then Probability of occurrence of Labelling error is UNLIKELY
18. If Clutter on table is POSSIBLE or Untrained staff is UNLIKELY then Probability of occurrence of Labelling error is POSSIBLE
19. If Clutter on table is POSSIBLE or Untrained staff is POSSIBLE then Probability of occurrence of Labelling error is EXPECTED
20. If Clutter on table is POSSIBLE or Untrained staff is EXPECTED then Probability of occurrence of Labelling error is EXPECTED
21. If Clutter on table is EXPECTED or Untrained staff is NOT EXPECTED then Probability of occurrence of Labelling error is VERY UNLIKELY
22. If Clutter on table is EXPECTED or Untrained staff is VERY UNLIKELY then Probability of occurrence of Labelling error is UNLIKELY
23. If Clutter on table is EXPECTED or Untrained staff is UNLIKELY then Probability of occurrence of Labelling error is POSSIBLE
24. If Clutter on table is EXPECTED or Untrained staff is POSSIBLE then Probability of occurrence of Labelling error is EXPECTED
25. If Clutter on table is EXPECTED or Untrained staff is EXPECTED then Probability of occurrence of Labelling error is EXPECTED

Section 6 - Fuzzy Rules used in FIS 6

1. If impact due to delivery of wrong drug to the patient is VERY LOW then impact due to Labelling error is VERY LOW
2. If impact due to delivery of wrong drug to the patient is LOW then impact due to Labelling error is LOW
3. If impact due to delivery of wrong drug to the patient is MEDIUM then impact due to Labelling error is MEDIUM
4. If impact due to delivery of wrong drug to the patient is HIGH then impact due to Labelling error is HIGH

5. If impact due to delivery of wrong drug to the patient is VERY HIGH then impact due to Labelling error is VERY HIGH

Section 7 - Fuzzy Rules used in FIS 7

1. If Phone calls is NOT EXPECTED or Under staffing is NOT EXPECTED then Probability of occurrence of Error due to Interruptions is NOT EXPECTED
2. If Phone calls is NOT EXPECTED or Under staffing is VERY UNLIKELY then Probability of occurrence of Error due to Interruptions is NOT EXPECTED
3. If Phone calls is NOT EXPECTED or Under staffing is UNLIKELY then Probability of occurrence of Error due to Interruptions is VERY UNLIKELY
4. If Phone calls is NOT EXPECTED or Under staffing is POSSIBLE then Probability of occurrence of Error due to Interruptions is UNLIKELY
5. If Phone calls is NOT EXPECTED or Under staffing is EXPECTED then Probability of occurrence of Error due to Interruptions is POSSIBLE
6. If Phone calls is VERY UNLIKELY or Under staffing is NOT EXPECTED then Probability of occurrence of Error due to Interruptions is NOT EXPECTED
7. If Phone calls is VERY UNLIKELY or Under staffing is VERY UNLIKELY then Probability of occurrence of Error due to Interruptions is NOT EXPECTED
8. If Phone calls is VERY UNLIKELY or Under staffing is UNLIKELY then Probability of occurrence of Error due to Interruptions is UNLIKELY
9. If Phone calls is VERY UNLIKELY or Under staffing is POSSIBLE then Probability of occurrence of Error due to Interruptions is POSSIBLE
10. If Phone calls is VERY UNLIKELY or Under staffing is EXPECTED then Probability of occurrence of Error due to Interruptions is EXPECTED
11. If Phone calls is UNLIKELY or Under staffing is NOT EXPECTED then Probability of occurrence of Error due to Interruptions is NOT EXPECTED
12. If Phone calls is UNLIKELY or Under staffing is VERY UNLIKELY then Probability of occurrence of Error due to Interruptions is VERY UNLIKELY
13. If Phone calls is UNLIKELY or Under staffing is UNLIKELY then Probability of occurrence of Error due to Interruptions is UNLIKELY
14. If Phone calls is UNLIKELY or Under staffing is POSSIBLE then Probability of occurrence of Error due to Interruptions is POSSIBLE

15. If Phone calls is UNLIKELY or Under staffing is EXPECTED then Probability of occurrence of Error due to Interruptions is POSSIBLE
16. If Phone calls is POSSIBLE or Under staffing is NOT EXPECTED then Probability of occurrence of Error due to Interruptions is UNLIKELY
17. If Phone calls is POSSIBLE or Under staffing is VERY UNLIKELY then Probability of occurrence of Error due to Interruptions is UNLIKELY
18. If Phone calls is POSSIBLE or Under staffing is UNLIKELY then Probability of occurrence of Error due to Interruptions is POSSIBLE
19. If Phone calls is POSSIBLE or Under staffing is POSSIBLE then Probability of occurrence of Error due to Interruptions is EXPECTED
20. If Phone calls is POSSIBLE or Under staffing is EXPECTED then Probability of occurrence of Error due to Interruptions is EXPECTED
21. If Phone calls is EXPECTED or Under staffing is NOT EXPECTED then Probability of occurrence of Error due to Interruptions is UNLIKELY
22. If Phone calls is EXPECTED or Under staffing is VERY UNLIKELY then Probability of occurrence of Error due to Interruptions is UNLIKELY
23. If Phone calls is EXPECTED or Under staffing is UNLIKELY then Probability of occurrence of Error due to Interruptions is POSSIBLE
24. If Phone calls is EXPECTED or Under staffing is POSSIBLE then Probability of occurrence of Error due to Interruptions is EXPECTED
25. If Phone calls is EXPECTED or Under staffing is EXPECTED then Probability of occurrence of Error due to Interruptions is EXPECTED

Section 8 - Fuzzy Rules used in FIS 8

1. If impact due to Delay in medication dispensing is VERY LOW or impact due to Pharmacist Inefficiency is VERY LOW then Impact on Patient safety is VERY LOW
2. If Impact due to Delay in medication dispensing is VERY LOW or Impact due to Pharmacist Inefficiency is LOW then Impact on Patient safety is VERY LOW
3. If Impact due to Delay in medication dispensing is VERY LOW or Impact due to Pharmacist Inefficiency is MEDIUM then Impact on Patient safety is LOW
4. If Impact due to Delay in medication dispensing is VERY LOW or Impact due to Pharmacist Inefficiency is HIGH then Impact on Patient safety is MEDIUM

5. If Impact due to Delay in medication dispensing is VERY LOW or Impact due to Pharmacist Inefficiency is VERY HIGH then Impact on Patient safety is HIGH
6. If Impact due to Delay in medication dispensing is LOW or Impact due to Pharmacist Inefficiency is VERY LOW then Impact on Patient safety is VERY LOW
7. If Impact due to Delay in medication dispensing is LOW or Impact due to Pharmacist Inefficiency is LOW then Impact on Patient safety is LOW
8. If Impact due to Delay in medication dispensing is LOW or Impact due to Pharmacist Inefficiency is MEDIUM then Impact on Patient safety is MEDIUM
9. If Impact due to Delay in medication dispensing is LOW or Impact due to Pharmacist Inefficiency is HIGH then Impact on Patient safety is HIGH
10. If Impact due to Delay in medication dispensing is LOW or Impact due to Pharmacist Inefficiency is VERY HIGH then Impact on Patient safety is VERY HIGH
11. If Impact due to Delay in medication dispensing is MEDIUM or Impact due to Pharmacist Inefficiency is VERY LOW then Impact on Patient safety is LOW
12. If Impact due to Delay in medication dispensing is MEDIUM or Impact due to Pharmacist Inefficiency is LOW then Impact on Patient safety is MEDIUM
13. If Impact due to Delay in medication dispensing is MEDIUM or Impact due to Pharmacist Inefficiency is MEDIUM then Impact on Patient safety is MEDIUM
14. If Impact due to Delay in medication dispensing is MEDIUM or Impact due to Pharmacist Inefficiency is HIGH then Impact on Patient safety is HIGH
15. If Impact due to Delay in medication dispensing is MEDIUM or Impact due to Pharmacist Inefficiency is VERY HIGH then Impact on Patient safety is VERY HIGH
16. If Impact due to Delay in medication dispensing is HIGH or Impact due to Pharmacist Inefficiency is VERY LOW then Impact on Patient safety is MEDIUM
17. If Impact due to Delay in medication dispensing is HIGH or Impact due to Pharmacist Inefficiency is LOW then Impact on Patient safety is HIGH
18. If Impact due to Delay in medication dispensing is HIGH or Impact due to Pharmacist Inefficiency is MEDIUM then Impact on Patient safety is HIGH
19. If Impact due to Delay in medication dispensing is HIGH or Impact due to Pharmacist Inefficiency is HIGH then Impact on Patient safety is VERY HIGH
20. If Impact due to Delay in medication dispensing is HIGH or Impact due to Pharmacist Inefficiency is VERY HIGH then Impact on Patient safety is VERY HIGH
21. If Impact due to Delay in medication dispensing is VERY HIGH or Impact due to Pharmacist Inefficiency is VERY LOW then Impact on Patient safety is HIGH

22. If Impact due to Delay in medication dispensing is VERY HIGH or Impact due to Pharmacist Inefficiency is LOW then Impact on Patient safety is HIGH
23. If Impact due to Delay in medication dispensing is VERY HIGH or Impact due to Pharmacist Inefficiency is MEDIUM then Impact on Patient safety is HIGH
24. If Impact due to Delay in medication dispensing is VERY HIGH or Impact due to Pharmacist Inefficiency is HIGH then Impact on Patient safety is VERY HIGH
25. If Impact due to Delay in medication dispensing is VERY HIGH or Impact due to Pharmacist Inefficiency is VERY HIGH then Impact on Patient safety is VERY HIGH

Section 9 - Fuzzy Rules used in FIS 9

1. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is NOT EXPECTED
2. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is NOT EXPECTED
3. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
4. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is POSSIBLE then probability of occurrence of Wrong drug dispensing is POSSIBLE
5. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is EXPECTED then probability of occurrence of Wrong drug dispensing is EXPECTED
6. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is NOT EXPECTED then probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
7. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is VERY UNLIKELY then probability of occurrence of Wrong drug dispensing is UNLIKELY

8. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is UNLIKELY then probability of occurrence of Wrong drug dispensing is UNLIKELY
9. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is POSSIBLE then probability of occurrence of Wrong drug dispensing is POSSIBLE
10. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
11. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
12. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
13. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
14. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
15. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
16. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
17. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
18. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED

19. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
20. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
21. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
22. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
23. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
24. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
25. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is NOT EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
26. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
27. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
28. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
29. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE

30. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
31. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
32. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
33. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
34. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
35. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
36. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is NOT EXPECTED
37. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
38. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
39. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE
40. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED

41. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
42. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
43. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
44. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
45. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
46. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
47. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
48. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
49. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE
50. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is VERY UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
51. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is NOT EXPECTED

52. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
53. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
54. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE
55. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
56. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
57. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
58. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
59. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE
60. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
61. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
62. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY

63. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
64. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is POSSIBLE
65. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
66. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
67. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
68. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
69. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
70. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
71. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
72. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
73. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE

74. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
75. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is UNLIKELY or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
76. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
77. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
78. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
79. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
80. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
81. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
82. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
83. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
84. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED

85. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
86. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY
87. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKLEY
88. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is UNLIKELY thenProbability of occurrence of Wrong drug dispensing is POSSIBLE
89. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
90. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is POSSIBLE or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
91. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is POSSIBLE or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
92. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is POSSIBLE or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
93. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is POSSIBLE or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
94. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is POSSIBLE or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
95. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is POSSIBLE or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED

96. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
97. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED
98. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED
99. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
100. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is POSSIBLE or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
101. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is VERY UNLIKELY
102. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY
103. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE
104. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
105. If Look alike/ sound alike drugs is NOT EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
106. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY

107. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is UNLIKELY

108. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE

109. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED

110. If Look alike/ sound alike drugs is VERY UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED

111. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is UNLIKELY

112. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE

113. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE

114. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED

115. If Look alike/ sound alike drugs is UNLIKELY or Skip patient's counseling is EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED

116. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE

117. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is POSSIBLE

118. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is EXPECTED or Unorganized work flow is UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED
119. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
120. If Look alike/ sound alike drugs is POSSIBLE or Skip patient's counseling is EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED
121. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is NOT EXPECTED then Probability of occurrence of Wrong drug dispensing is POSSIBLE
122. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is VERY UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED
123. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is EXPECTED or Ineffective communications UNLIKELY then Probability of occurrence of Wrong drug dispensing is EXPECTED
124. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is POSSIBLE then Probability of occurrence of Wrong drug dispensing is EXPECTED
125. If Look alike/ sound alike drugs is EXPECTED or Skip patient's counseling is EXPECTED or Unorganized work flow is EXPECTED then Probability of occurrence of Wrong drug dispensing is EXPECTED

Section 10 - Fuzzy Rules used in FIS 10

1. If impact due to Patient side effects is VERY LOW or impact due to Patient mortality is VERY LOW then Impact on Patient safety & health care costs is VERY LOW
2. If Impact due to Patient side effects is VERY LOW or Impact due to Patient mortality is LOW then Impact on Patient safety & health care costs is MEDIUM
3. If Impact due to Patient side effects is VERY LOW or Impact due to Patient mortality is MEDIUM then Impact on Patient safety & health care costs is MEDIUM

4. If Impact due to Patient side effects is VERY LOW or Impact due to Patient mortality is HIGH then Impact on Patient safety & health care costs is VERY HIGH
5. If Impact due to Patient side effects is VERY LOW or Impact due to Patient mortality is VERY HIGH then Impact on Patient safety & health care costs is VERY HIGH
6. If Impact due to Patient side effects is LOW or Impact due to Patient mortality is VERY LOW then Impact on Patient safety & health care costs is LOW
7. If Impact due to Patient side effects is LOW or Impact due to Patient mortality is LOW then Impact on Patient safety & health care costs is MEDIUM
8. If Impact due to Patient side effects is LOW or Impact due to Patient mortality is MEDIUM then Impact on Patient safety & health care costs is HIGH
9. If Impact due to Patient side effects is LOW or Impact due to Patient mortality is HIGH then Impact on Patient safety & health care costs is VERY HIGH
10. If Impact due to Patient side effects is LOW or Impact due to Patient mortality is VERY HIGH then Impact on Patient safety & health care costs is VERY HIGH
11. If Impact due to Patient side effects is MEDIUM or Impact due to Patient mortality is VERY LOW then Impact on Patient safety & health care costs is MEDIUM
12. If Impact due to Patient side effects is MEDIUM or Impact due to Patient mortality is LOW then Impact on Patient safety & health care costs is HIGH
13. If Impact due to Patient side effects is MEDIUM or Impact due to Patient mortality is MEDIUM then Impact on Patient safety & health care costs is HIGH
14. If Impact due to Patient side effects is MEDIUM or Impact due to Patient mortality is HIGH then Impact on Patient safety & health care costs is VERY HIGH
15. If Impact due to Patient side effects is MEDIUM or Impact due to Patient mortality is VERY HIGH then Impact on Patient safety & health care costs is VERY HIGH
16. If Impact due to Patient side effects is HIGH or Impact due to Patient mortality is VERY LOW then Impact on Patient safety & health care costs is MEDIUM
17. If Impact due to Patient side effects is HIGH or Impact due to Patient mortality is LOW then Impact on Patient safety & health care costs is HIGH
18. If Impact due to Patient side effects is HIGH or Impact due to Patient mortality is MEDIUM then Impact on Patient safety & health care costs is HIGH
19. If Impact due to Patient side effects is HIGH or Impact due to Patient mortality is HIGH then Impact on Patient safety & health care costs is VERY HIGH
20. If Impact due to Patient side effects is HIGH or Impact due to Patient mortality is VERY HIGH then Impact on Patient safety & health care costs is VERY HIGH

21. If Impact due to Patient side effects is VERY HIGH or Impact due to Patient mortality is VERY LOW then Impact on Patient safety & health care costs is HIGH
22. If Impact due to Patient side effects is VERY HIGH or Impact due to Patient mortality is LOW then Impact on Patient safety & health care costs is HIGH
23. If Impact due to Patient side effects is VERY HIGH or Impact due to Patient mortality is MEDIUM then Impact on Patient safety & health care costs is HIGH
24. If Impact due to Patient side effects is VERY HIGH or Impact due to Patient mortality is HIGH then Impact on Patient safety & health care costs is VERY HIGH
25. If Impact due to Patient side effects is VERY HIGH or Impact due to Patient mortality is VERY HIGH then Impact on Patient safety & health care costs is VERY HIGH

Section 11 - Fuzzy Rules used in FIS 11

1. If Meal breaks issue is NOT EXPECTED or Improper room conditions is NOT EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is NOT EXPECTED
2. If Meal breaks issue is NOT EXPECTED or Improper room conditions is VERY UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is VERY UNLIKELY
3. If Meal breaks issue is NOT EXPECTED or Improper room conditions is UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
4. If Meal breaks issue is NOT EXPECTED or Improper room conditions is POSSIBLE then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
5. If Meal breaks issue is NOT EXPECTED or Improper room conditions is EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
6. If Meal breaks issue is VERY UNLIKELY or Improper room conditions is NOT EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is NOT EXPECTED
7. If Meal breaks issue is VERY UNLIKELY or Improper room conditions is VERY UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is UNLIKLEY
8. If Meal breaks issue is VERY UNLIKELY or Improper room conditions is UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is UNLIKELY

9. If Meal breaks issue is VERY UNLIKELY or Improper room conditions is POSSIBLE then Probability of occurrence of Error due to Pharmacist distraction is UNLIKLEY
10. If Meal breaks issue is VERY UNLIKELY or Improper room conditions is EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
11. If Meal breaks issue is UNLIKELY or Improper room conditions is NOT EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is UNLIKLEY
12. If Meal breaks issue is UNLIKELY or Improper room conditions is VERY UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is UNLIKLEY
13. If Meal breaks issue is UNLIKELY or Improper room conditions is UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
14. If Meal breaks issue is UNLIKELY or Improper room conditions is POSSIBLE then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
15. If Meal breaks issue is UNLIKELY or Improper room conditions is EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is UNLIKELY
16. If Meal breaks issue is POSSIBLE or Improper room conditions is NOT EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
17. If Meal breaks issue is POSSIBLE or Improper room conditions is VERY UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
18. If Meal breaks issue is POSSIBLE or Improper room conditions is UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
19. If Meal breaks issue is POSSIBLE or Improper room conditions is POSSIBLE then Probability of occurrence of Error due to Pharmacist distraction is EXPECTED
20. If Meal breaks issue is POSSIBLE or Improper room conditions is EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is EXPECTED
21. If Meal breaks issue is EXPECTED or Improper room conditions is NOT EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
22. If Meal breaks issue is EXPECTED or Improper room conditions is VERY UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
23. If Meal breaks issue is EXPECTED or Improper room conditions is UNLIKELY then Probability of occurrence of Error due to Pharmacist distraction is POSSIBLE
24. If Meal breaks issue is EXPECTED or Improper room conditions is POSSIBLE then Probability of occurrence of Error due to Pharmacist distraction is EXPECTED
25. If Meal breaks issue is EXPECTED or Improper room conditions is EXPECTED then Probability of occurrence of Error due to Pharmacist distraction is EXPECTED

Section 12 - Fuzzy Rules used in FIS 12

1. If impact due to Delivery of improper duties is VERY LOW or impact due to Prescription error is VERY LOW then Impact on Patient safety is VERY LOW
2. If Impact due to Delivery of improper duties is VERY LOW or Impact due to Prescription error is LOW then Impact on Patient safety is VERY LOW
3. If Impact due to Delivery of improper duties is VERY LOW or Impact due to Prescription error is MEDIUM then Impact on Patient safety is LOW
4. If Impact due to Delivery of improper duties is VERY LOW or Impact due to Prescription error is HIGH then Impact on Patient safety is MEDIUM
5. If Impact due to Delivery of improper duties is VERY LOW or Impact due to Prescription error is VERY HIGH then Impact on Patient safety is HIGH
6. If Impact due to Delivery of improper duties is LOW or Impact due to Prescription error is VERY LOW then Impact on Patient safety is LOW
7. If Impact due to Delivery of improper duties is LOW or Impact due to Prescription error is LOW then Impact on Patient safety is LOW
8. If Impact due to Delivery of improper duties is LOW or Impact due to Prescription error is MEDIUM then Impact on Patient safety is LOW
9. If Impact due to Delivery of improper duties is LOW or Impact due to Prescription error is HIGH then Impact on Patient safety is HIGH
10. If Impact due to Delivery of improper duties is LOW or Impact due to Prescription error is VERY HIGH then Impact on Patient safety is VERY HIGH
11. If Impact due to Delivery of improper duties is MEDIUM or Impact due to Prescription error is VERY LOW then Impact on Patient safety is MEDIUM
12. If Impact due to Delivery of improper duties is MEDIUM or Impact due to Prescription error is LOW then Impact on Patient safety is MEDIUM
13. If Impact due to Delivery of improper duties is MEDIUM or Impact due to Prescription error is MEDIUM then Impact on Patient safety is HIGH
14. If Impact due to Delivery of improper duties is MEDIUM or Impact due to Prescription error is HIGH then Impact on Patient safety is HIGH
15. If Impact due to Delivery of improper duties is MEDIUM or Impact due to Prescription error is VERY HIGH then Impact on Patient safety is HIGH
16. If Impact due to Delivery of improper duties is HIGH or Impact due to Prescription error is VERY LOW then Impact on Patient safety is HIGH

17. If Impact due to Delivery of improper duties is HIGH or Impact due to Prescription error is LOW then Impact on Patient safety is HIGH
18. If Impact due to Delivery of improper duties is HIGH or Impact due to Prescription error is MEDIUM then Impact on Patient safety is VERY HIGH
19. If Impact due to Delivery of improper duties is HIGH or Impact due to Prescription error is HIGH then Impact on Patient safety is VERY HIGH
20. If Impact due to Delivery of improper duties is HIGH or Impact due to Prescription error is VERY HIGH then Impact on Patient safety is VERY HIGH
21. If Impact due to Delivery of improper duties is VERY HIGH or Impact due to Prescription error is VERY LOW then Impact on Patient safety is VERY HIGH
22. If Impact due to Delivery of improper duties is VERY HIGH or Impact due to Prescription error is LOW then Impact on Patient safety is VERY HIGH
23. If Impact due to Delivery of improper duties is VERY HIGH or Impact due to Prescription error is MEDIUM then Impact on Patient safety is VERY HIGH
24. If Impact due to Delivery of improper duties is VERY HIGH or Impact due to Prescription error is HIGH then Impact on Patient safety is VERY HIGH
25. If Impact due to Delivery of improper duties is VERY HIGH or Impact due to Prescription error is VERY HIGH then Impact on Patient safety is VERY HIGH

Section 13 - Fuzzy Rules used in FIS 13

1. If Occurrence is NOT EXPECTED and Impact is HIGH then Risk Score is MEDIUM
2. If Occurrence is NOT EXPECTED and Impact is MEDIUM then Risk Score is LOW
3. If Occurrence is NOT EXPECTED and Impact is LOW then Risk Score is LOW
4. If Occurrence is NOT EXPECTED and Impact is VERY LOW then Risk Score is LOW
5. If Occurrence is NOT EXPECTED and Impact is NO EFFECT then Risk Score is LOW
6. If Occurrence is VERY UNLIKELY and Impact is HIGH then Risk Score is HIGH
7. If Occurrence is VERY UNLIKELY and Impact is MEDIUM then Risk Score is MEDIUM
8. If Occurrence is VERY UNLIKELY and Impact is LOW then Risk Score is LOW
9. If Occurrence is VERY UNLIKELY and Impact is VERY LOW then Risk Score is LOW
10. If Occurrence is VERY UNLIKELY and Impact is NO EFFECT then Risk Score is LOW
11. If Occurrence is UNLIKELY and Impact is HIGH then Risk Score is HIGH
12. If Occurrence is UNLIKELY and Impact is MEDIUM then Risk Score is MEDIUM

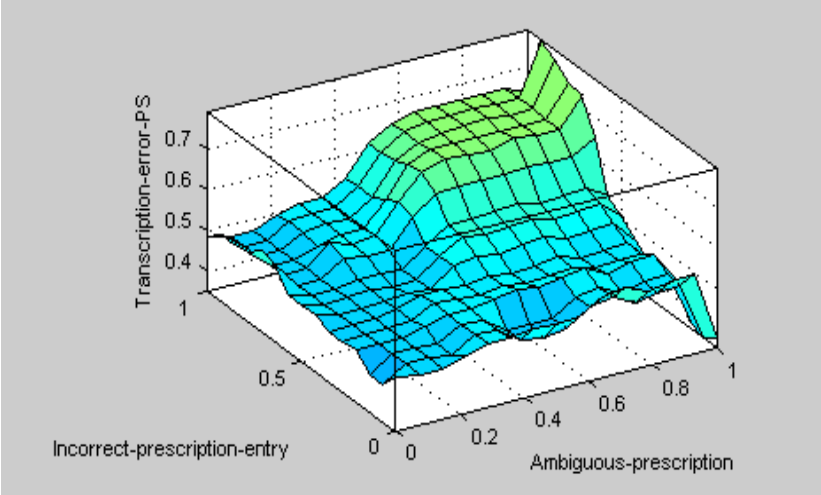
13. If Occurrence is UNLIKELY and Impact is LOW then Risk Score is MEDIUM
14. If Occurrence is UNLIKELY and Impact is VERY LOW then Risk Score is LOW
15. If Occurrence is UNLIKELY and Impact is NO EFFECT then Risk Score is LOW
16. If Occurrence is POSSIBLE and Impact is HIGH then Risk Score is HIGH
17. If Occurrence is POSSIBLE and Impact is MEDIUM then Risk Score is HIGH
18. If Occurrence is POSSIBLE and Impact is LOW then Risk Score is MEDIUM
19. If Occurrence is POSSIBLE and Impact is VERY LOW then Risk Score is LOW
20. If Occurrence is POSSIBLE and Impact is NO EFFECT then Risk Score is LOW
21. If Occurrence is EXPECTED and Impact is HIGH then Risk Score is HIGH
22. If Occurrence is EXPECTED and Impact is MEDIUM then Risk Score is HIGH
23. If Occurrence is EXPECTED and Impact is LOW then Risk Score is MEDIUM
24. If Occurrence is EXPECTED and Impact is VERY LOW then Risk Score is MEDIUM
25. If Occurrence is EXPECTED and Impact is NO EFFECT then Risk Score is LOW

APPENDIX B

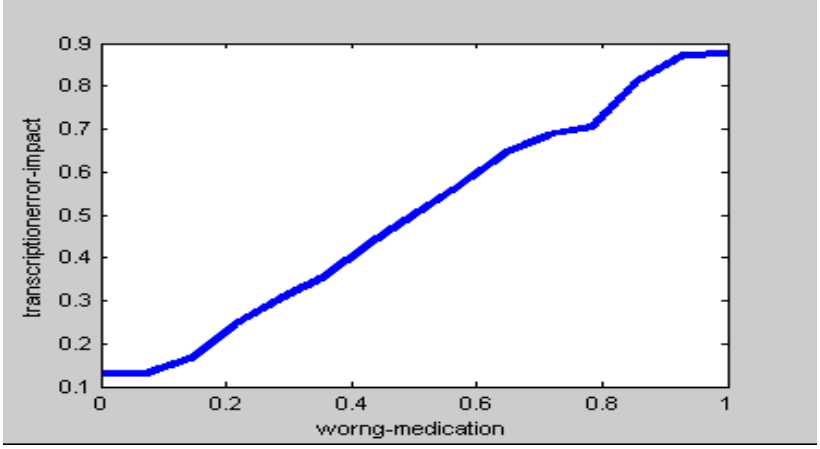
Mamdani FIS Surface Plots

Surface plots are the visual representation of the results obtained from different combinations of inputs and outputs. The images in this section displays the surface plots of each Fuzzy Inference System used in the research.

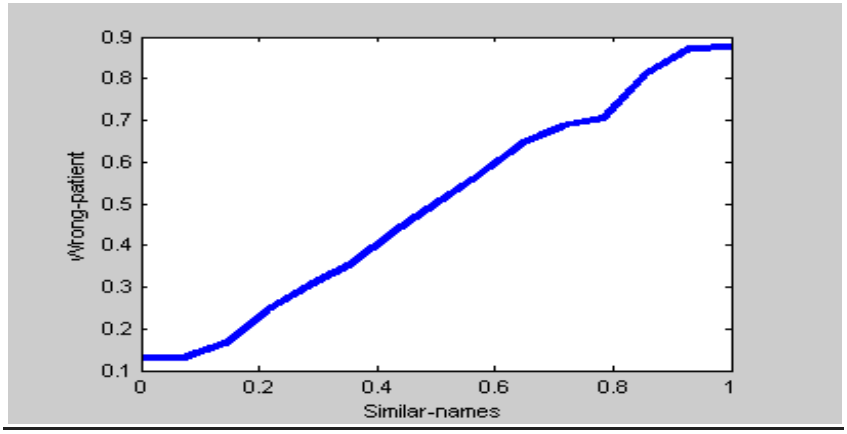
Section - 1 Surface plot of FIS 1



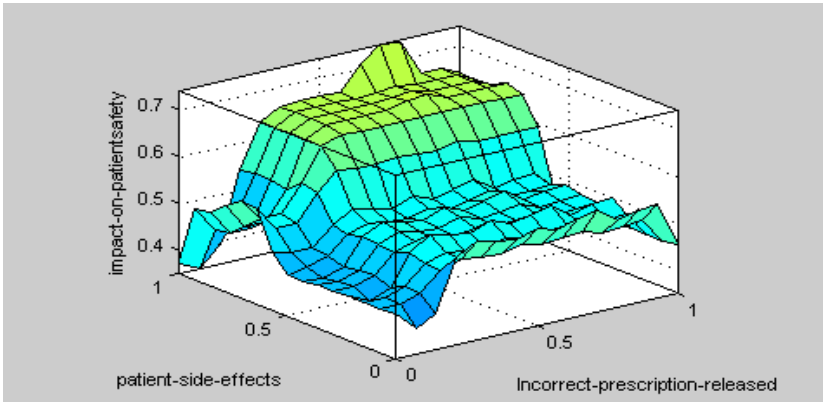
Section - 2 Surface plot of FIS 2



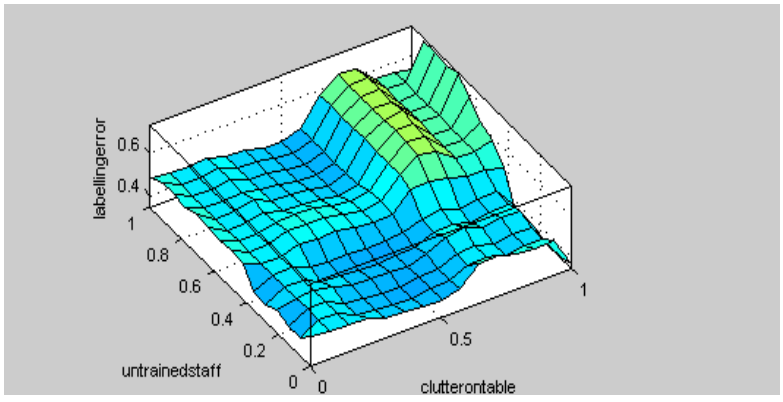
Section - 3 Surface plot of FIS 3



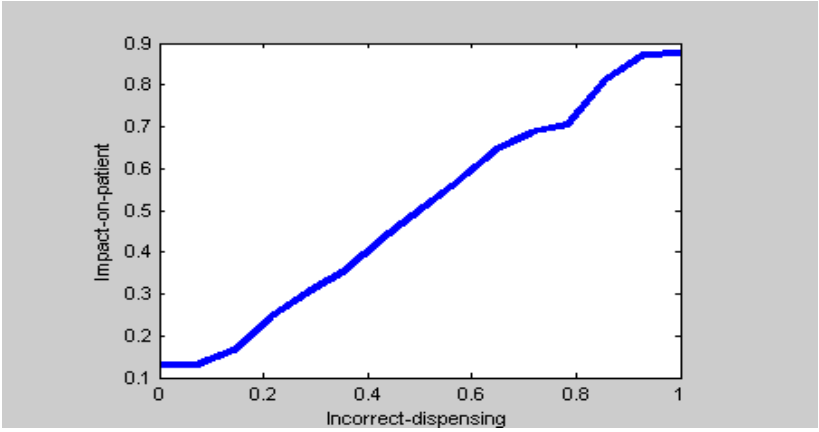
Section - 4 Surface plot of FIS 4



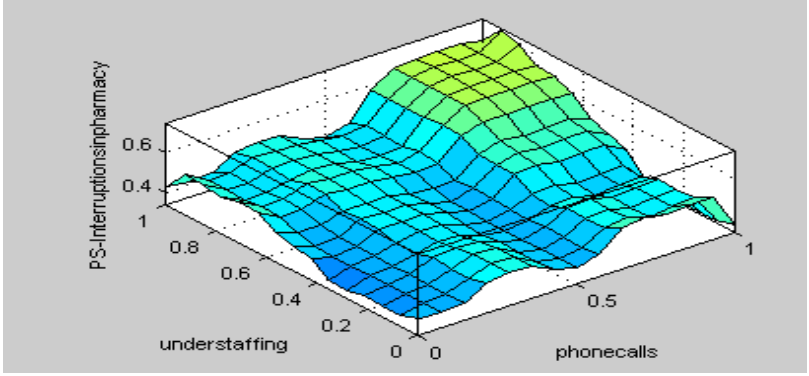
Section - 5 Surface plot of FIS 5



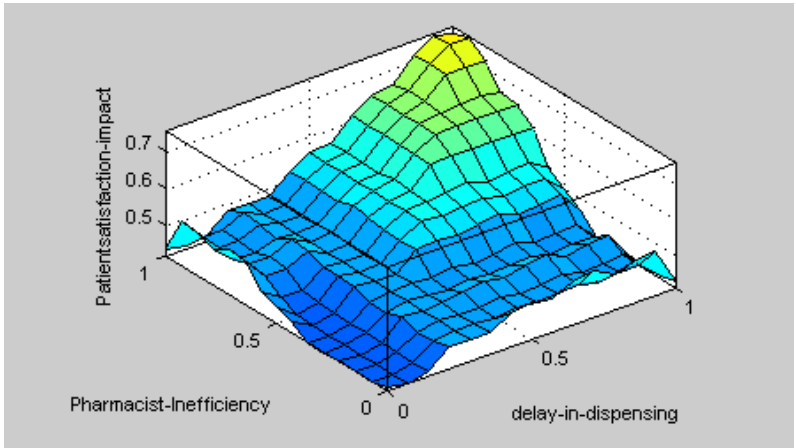
Section - 6 Surface plot of FIS 6



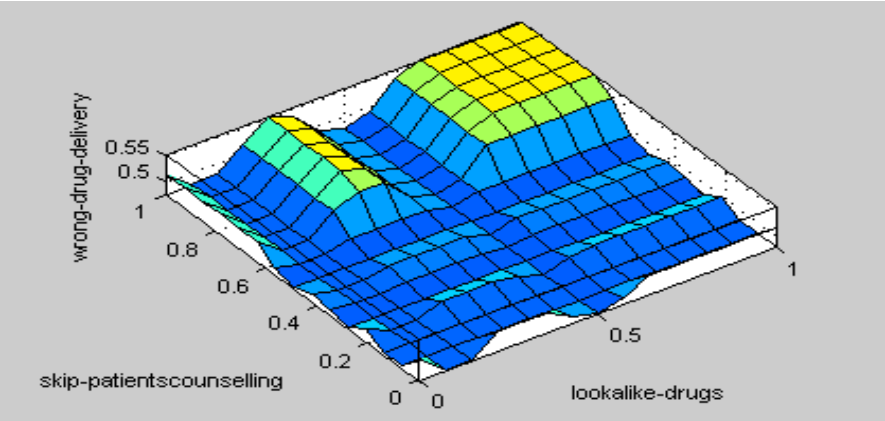
Section - 7 Surface plot of FIS 7



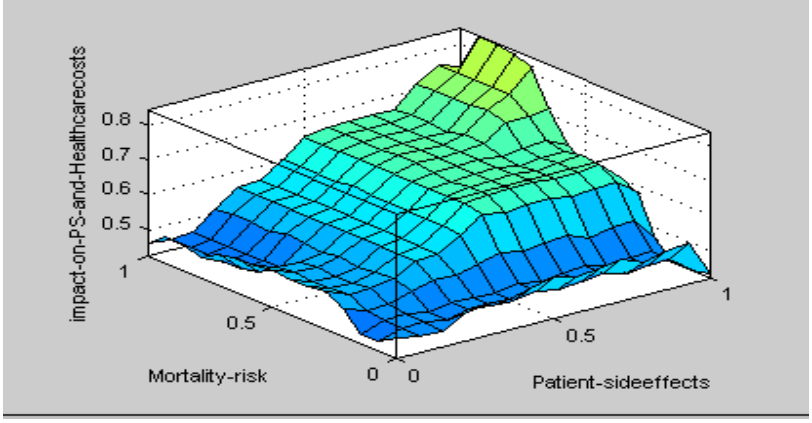
Section - 8 Surface plot of FIS 8



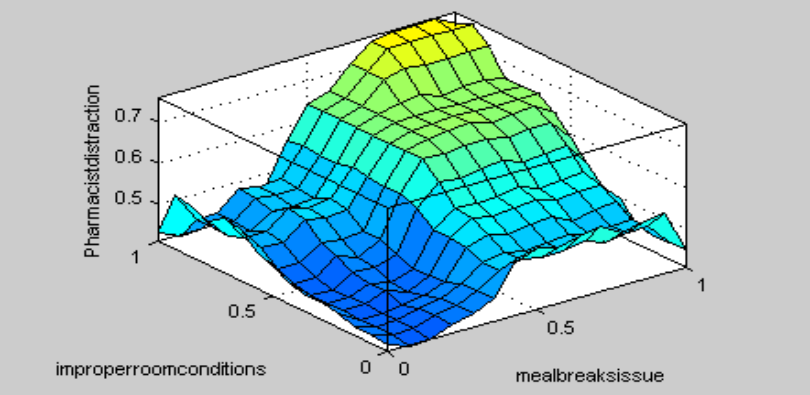
Section - 9 Surface plot of FIS 9



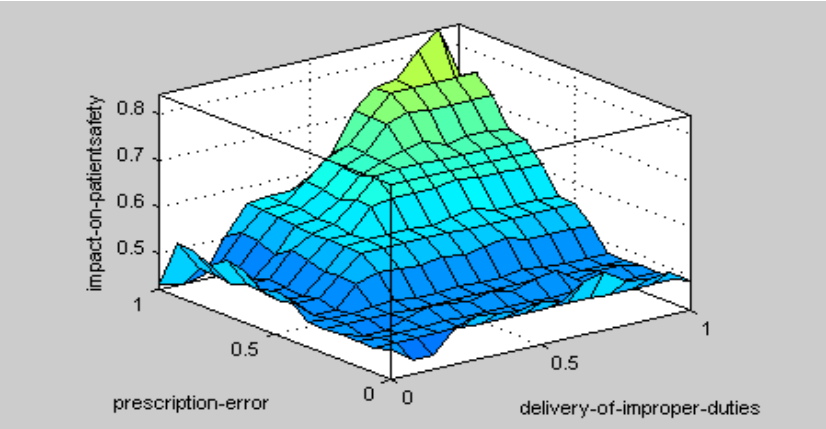
Section - 10 Surface plot of FIS 10



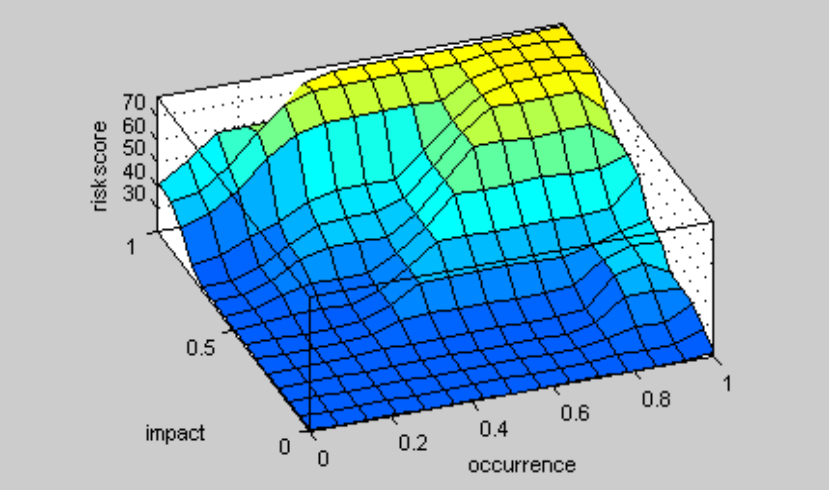
Section - 11 Surface plot of FIS 11



Section - 12 Surface plot of FIS 12



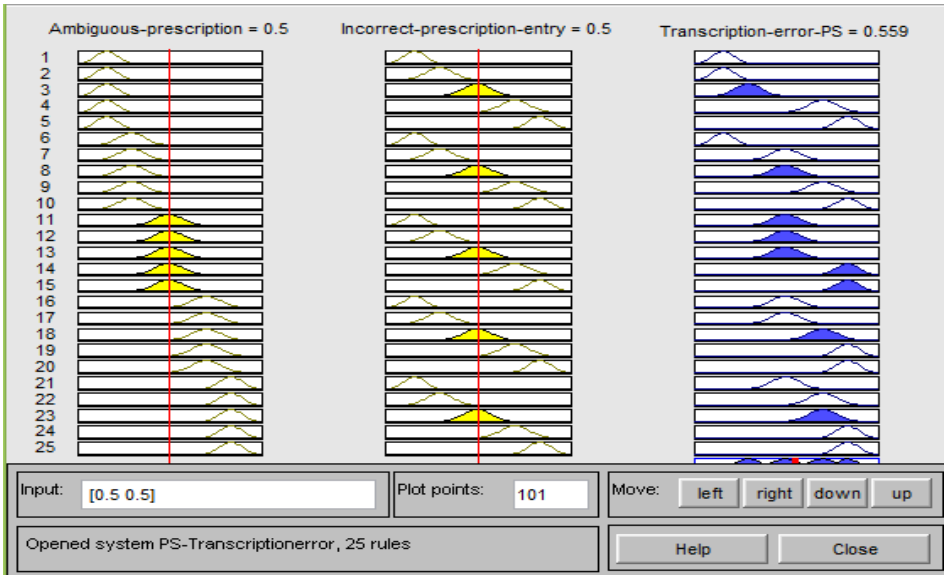
Section - 13 Surface plot of FIS 13



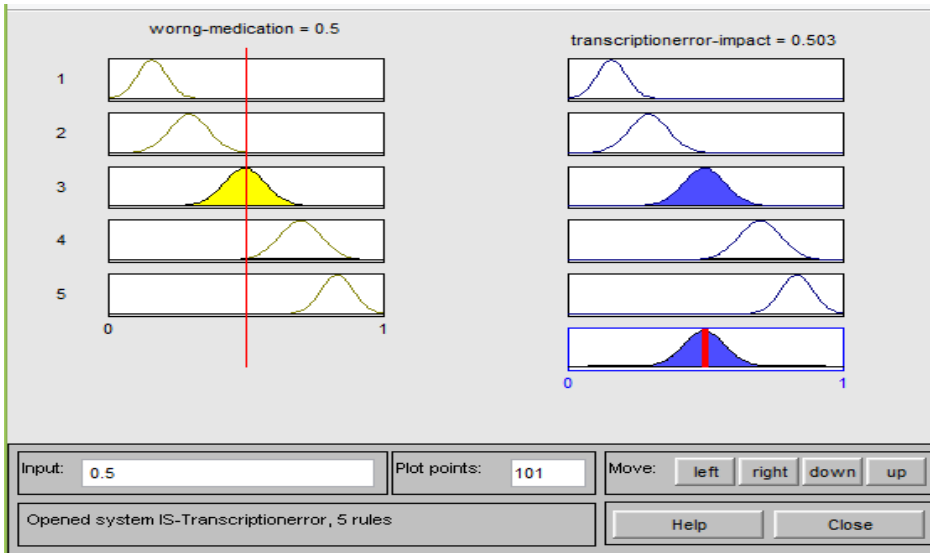
APPENDIX C

This section presents the experimental results of all the Mamdani Fuzzy Inference Systems that are used in this research.

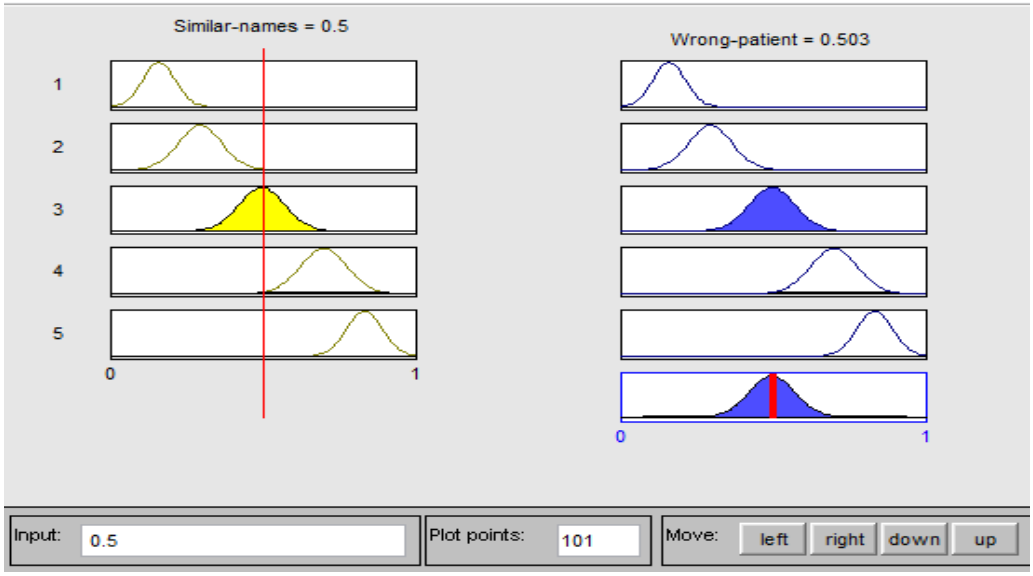
Section - 1 Experimental results of FIS 1



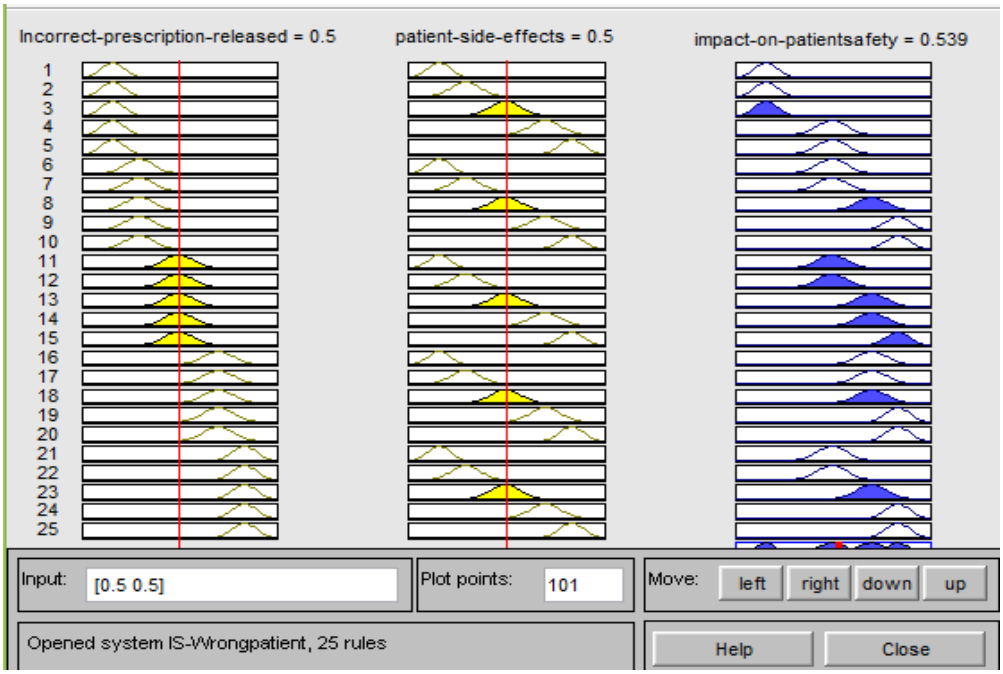
Section - 2 Experimental results of FIS 2



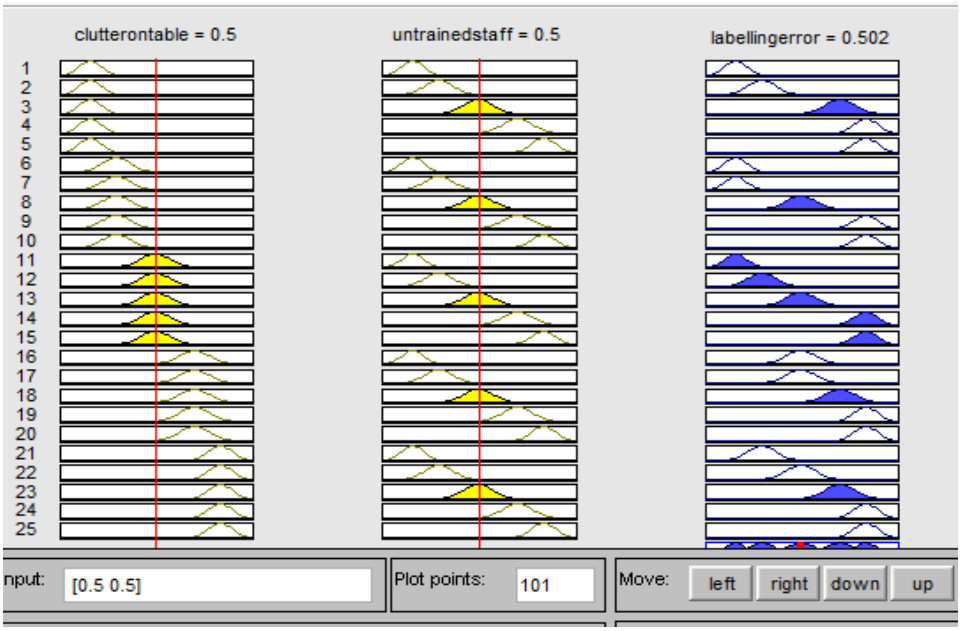
Section - 3 Experimental results of FIS 3



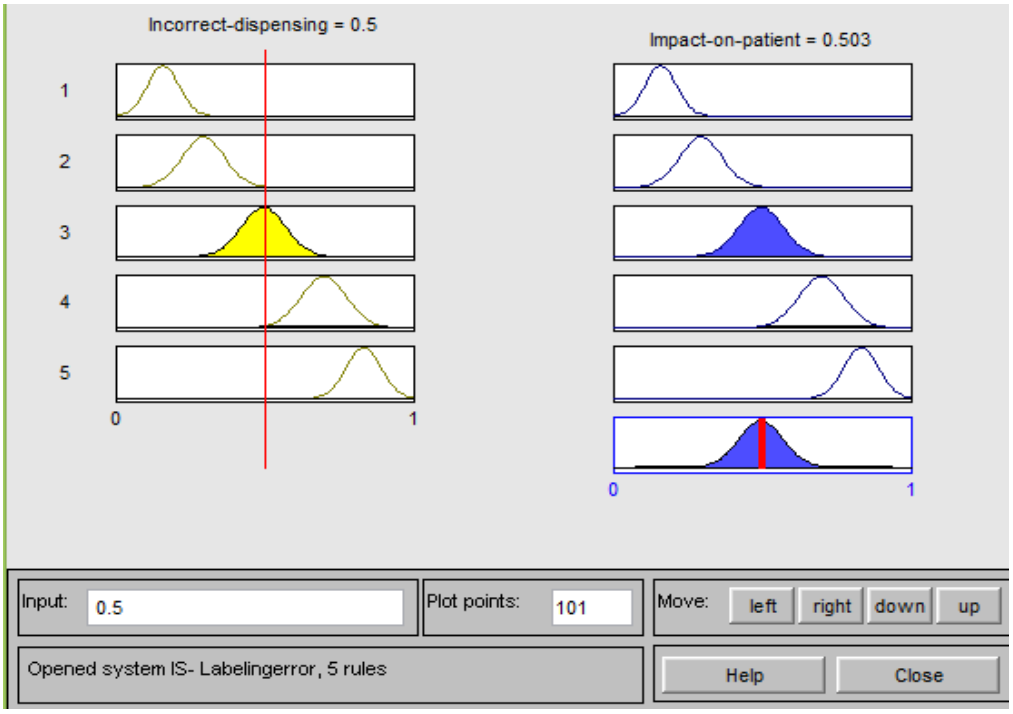
Section - 4 Experimental results of FIS 4



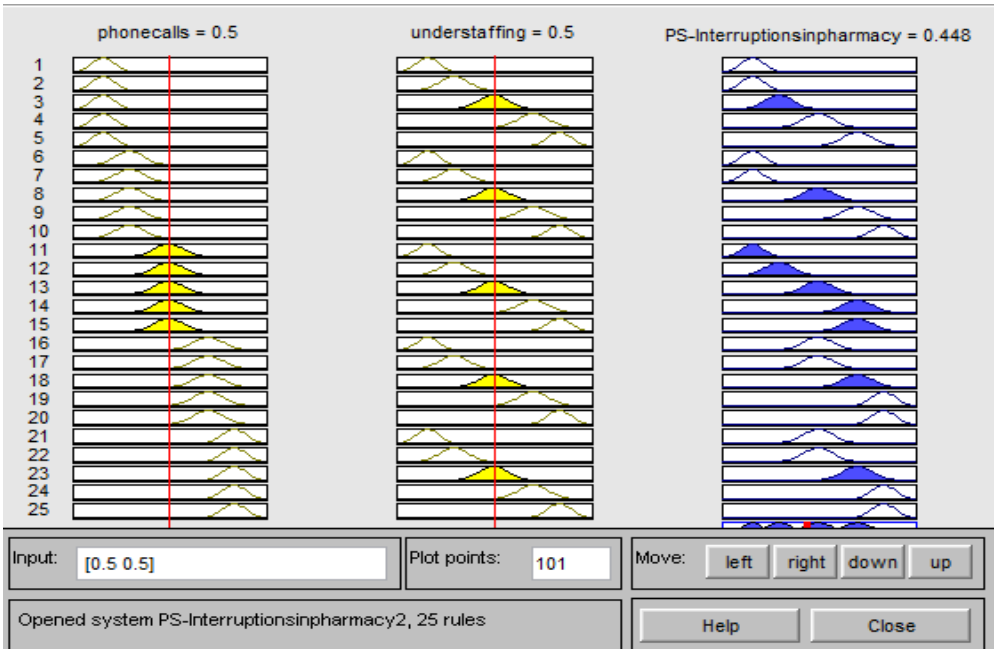
Section - 5 Experimental results of FIS 5



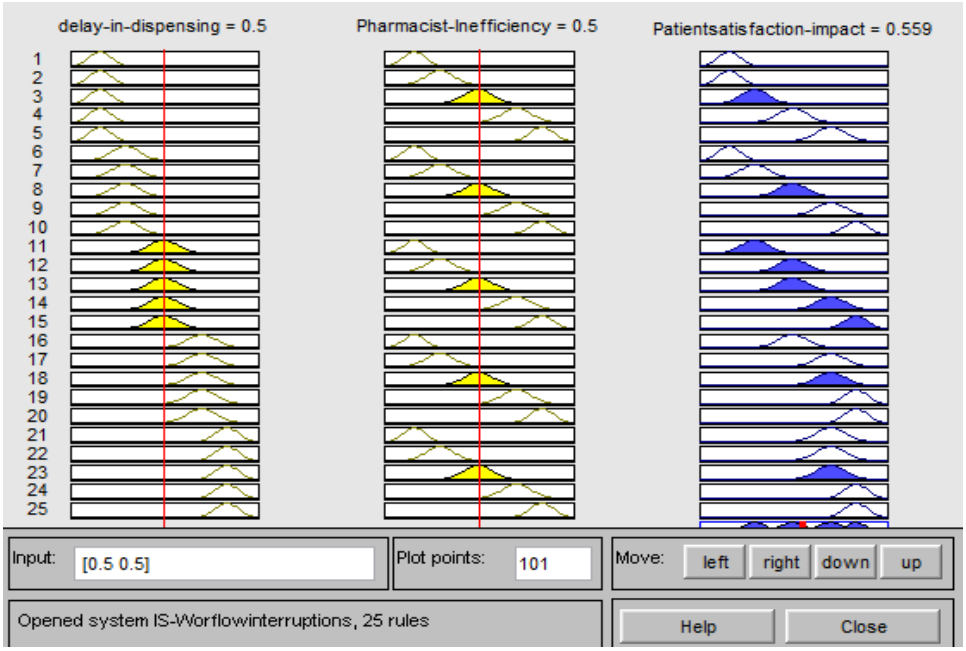
Section - 6 Experimental results of FIS 6



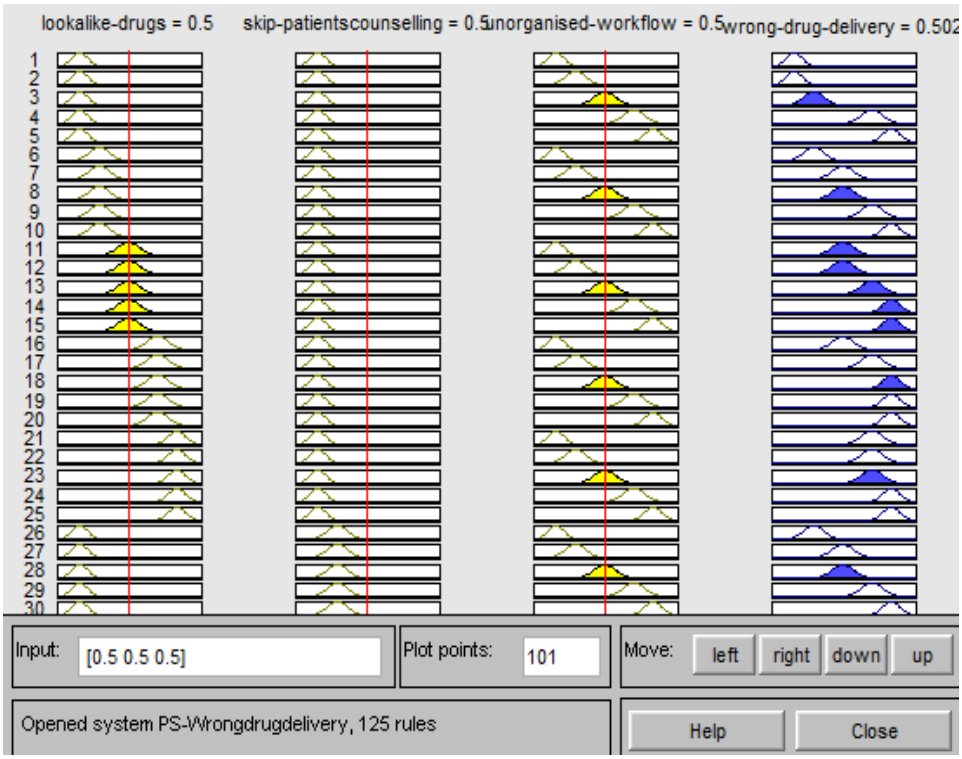
Section - 7 Experimental results of FIS 7



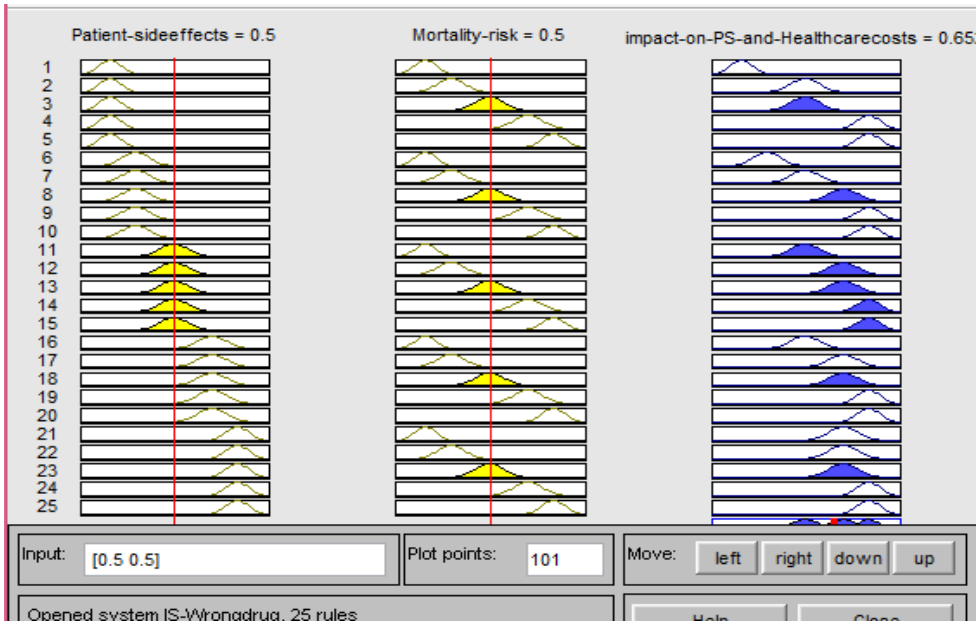
Section - 8 Experimental results of FIS 8



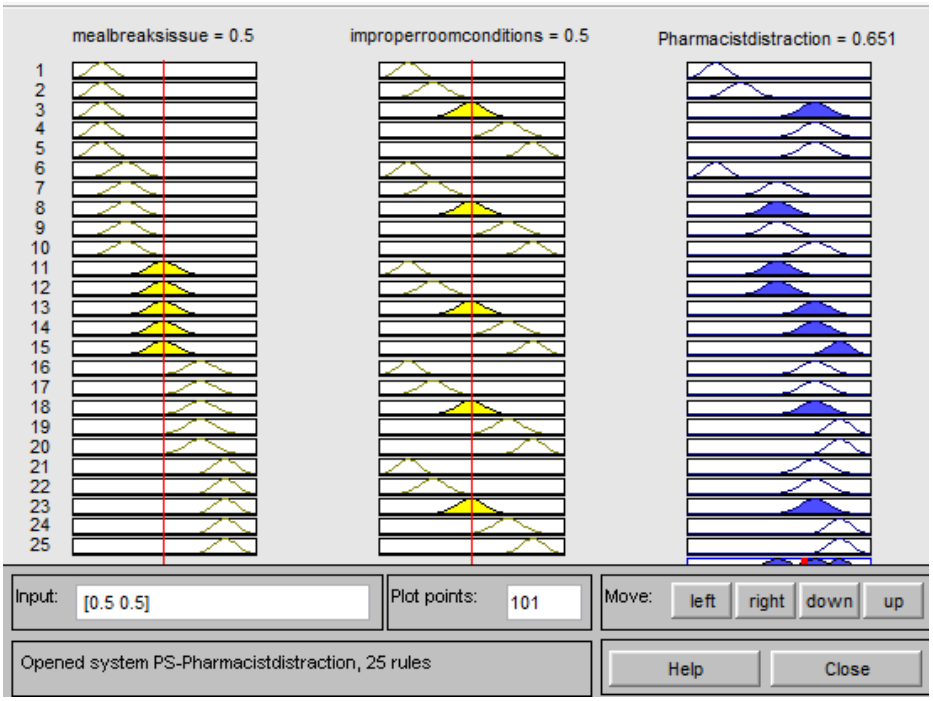
Section - 9 Experimental results of FIS 9



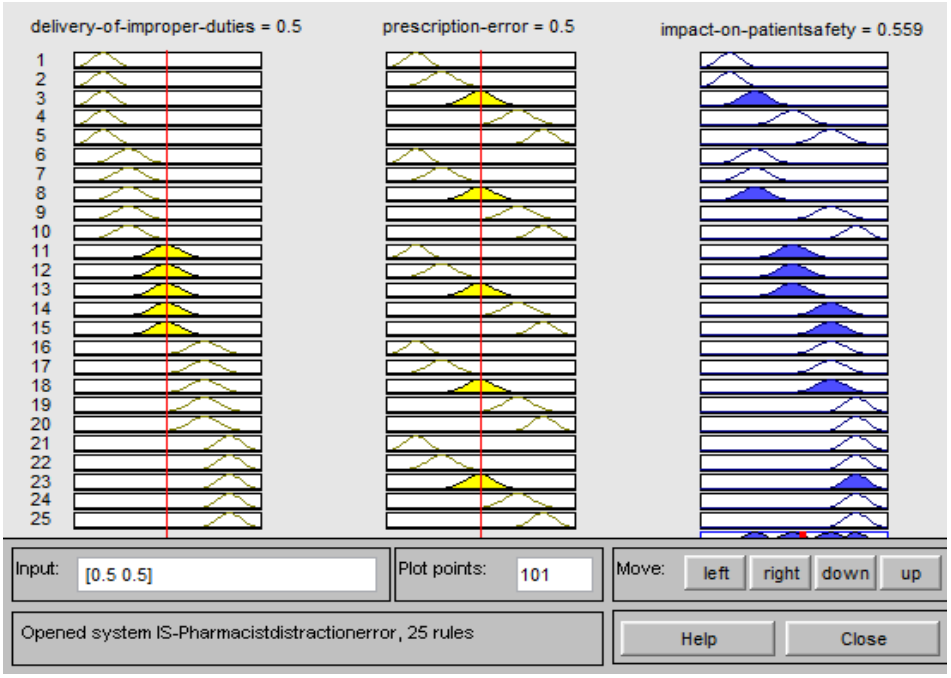
Section - 10 Experimental results of FIS 10



Section - 11 Experimental results of FIS 11



Section - 12 Experimental results of FIS 12



Section - 13 Experimental results of FIS 13