# Cascaded Fuzzy Inference System for Overall Equipment Effectiveness of a Manufacturing Process

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***Abstract*—** Overall equipment effectiveness (OEE) is one of the widely accepted performance evaluation methods most commonly employed for measuring the efficiency of a manufacturing process in a manufacturing industry. It plays a most prominent role in improving the efficiency of a manufacturing process which in turn ensures quality, consistency and productivity. The OEE parameters, availability, performance and quality are not single parameters. But these parameters in turn depend on several other parameters which introduce a cascaded effect in OEE computation. The variation in the value of lowest level parameters propagate to the higher levels making the OEE computation a complex process. To cater such situations, in this paper authors propose cascaded fuzzy inference system for measurement of Overall Equipment Effectiveness. In the simplified model proposed by the authors, only few prominent parameters up to two levels are considered. The model can be easily extended to incorporate more parameters and more levels to render it more realistic.

***Keywords-*** *Availability, Cascaded Fuzzy model, Performance, Quality, Simulink Model, Triangular Membership Functions*

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## I. INTRODUCTION

Overall equipment effectiveness (OEE) is one of the performance evaluation methods widely applicable in manufacturing industries and has proved to be one of the prime metrics for performance evaluation. It plays a vital role in improving the efficiency of a manufacturing process which in turn ensures quality, consistency and productivity. While managing change, organizations can deploy change management tools like total productive maintenance and six sigma to remove redundancies and elimination of rework. The objective of Total Productive Maintenance (TPM) is to manage equipment/machine to deliver the most it can by completely eliminating machine down time in all forms. The benefits flow both directly and tangentially, for instance the quality pay offs in terms of fewer defects and rejections mean lower cost and implementation of TPM can play a pivotal role in cost rationalization, resulting in direct cost advantage from reduction in man power, stocks, inventories and repairs. The basic approach is loss analysis, continuous improvement and maintenance of equipment to prevent downtime. This is a participatory management technique which significantly contributes in enhancing productivity and quality, reducing cost, improving adherence to delivery schedules, bettering safety conditions and increasing employee morale. Like all transformation imperatives TPM begins by understanding what is wrong and why it is so by applying rules like kaizen and employee involvement to maintenance. Overall Equipment Effectiveness can be attained with a focus on zero loss, zero break downs, zero defects and zero accidents. TPM is the ideal integrator and the extent of the change and impact on the cost can be huge one. The best approach to combat shop floor cost is through higher machine uptimes and better process capabilities. The measures are overall equipment efficiency, production cost efficiency and production lead time efficiency. Equipment availability is calculated on several fronts including break down, changeover, fixture change and startup time. OEE is one of the performance evaluation methods that is most common in manufacturing industries. OEE is a mechanism to continuously monitor and improve the efficiency of a manufacturing process. The three prime measuring metrics for OEE are Availability, Performance and Quality which help gauge manufacturing processes efficiency and effectiveness. Further they enable categorization of key productivity losses that occur within the manufacturing process. As such OEE aims towards improving manufacturing processes and in turn ensures quality, consistency, and productivity. By definition, OEE is the multiplication of Availability, Performance, and Quality. The formula to calculate Overall Equipment Effectiveness is as follows [1]:

$$OEE = Availability \times Performance \times Quality$$

The formula to calculate the three parameters are given below:

$$Availability = \frac{\text{Operating Time}}{\text{Planned Production Time}}$$

$$Performance = \frac{\text{Ideal Cycle Time}}{\text{Total Pieces}} = \frac{\text{Total Pieces/Operating Time}}{\text{Ideal Runtime}}$$

$$Quality = \frac{\text{Good Pieces}}{\text{Total Pieces}}$$

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The six major losses, which fall under three OEE loss categories are depicted in Table 1. along with possible causes of losses.

**Table 1. OEE Loss Categories**

| Six major loss category | Oee loss category | Reason |
|---|---|---|
| Breakdowns | Availability | 1. Equipment failure<br>2. Major component failure<br>3. Unplanned maintenance |
| Set up and adjustments | Availability | 1. Equipment setup<br>2. Raw material shortage<br>3. Operator shortage |
| Minor stops | Performance or, availability | 1. Equipment failure <5mins<br>2. Fallen product<br>3. Obstruction blockages |
| Speed loss | Performance | 1. Running lower than rated speed<br>2. Untrained operator not able to run at nominal speed<br>3. Machine idling |
| Production rejects | Quality | 1. Scrap<br>2. Rework<br>3. In process damage |
| Rejects on start up | Quality | 1. Scrap<br>2. Rework<br>3. In process damage |

**World class OEE**

World class standard for OEE parameters is shown in Table 2.

**Table 2. World Class Standard for OEE**

| Oee factor | World class |
|---|---|
| Availability | 90.0% |
| Performance | 95.0% |
| Quality | 99.9% |
| Oee | 85% |

**Availability Matrices**

The availability data for production line of a manufacturing organization is shown in Table 3.

**Table 3. Availability data**

| Serial no. | Production data | Value |
|---|---|---|
| 01 | Shift length (8 hours) | 60x8 = 480 min |
| 02 | Short breaks ( 2@15) | 2x15=30 min |
| 03 | Meal break (1@30) | 1x30=30 min |
| 04 | Down time | 47 min |

**Performance Matrices**

The performance data for production line of a manufacturing organization is shown in Table 4.

**Table 4. Performance data**

| Serial no. | Production data | Value |
|---|---|---|
| 01 | Ideal runtime | 60 pieces per min |
| 02 | Total pieces | 19,271 |

**Quality Matrices**

The quality data for production line of a manufacturing organization is shown in Table 5.

**Table 5. Quality data**

| Serial no. | Production data | Value |
|---|---|---|
| 01 | Total pieces | 19,271 |
| 02 | Rejection and rework | 423 |

In their earlier work authors have designed and implemented a simulation model for OEE computation [2]. The input data needed by the model was derived from XML files generated by the cost optimized production line based on multiple criteria such as (Work In Progress) WIP inventory minimization, idle time minimization and application of Theory of Constraints. Both the crisp model and the fuzzy model based on Mamdani inference system with triangular membership functions were compared. The OEE parameters, availability, performance and quality are not single parameters. But these parameters in turn depend on several other parameters which introduce a cascaded effect in OEE computation. The variation in the value of lowest level parameters propagate to the higher levels making the OEE computation a complex process. To cater such situations, in this paper authors propose cascaded fuzzy inference system for measurement of Overall Equipment Effectiveness. In the simplified model proposed by the authors, only few prominent parameters up to two levels are considered. The model can be easily extended to incorporate more parameters and more levels to render it more realistic. review of literature

In literature there are many papers which deal with total productive maintenance [3-7]. The authors of paper [8] have combined the analytical and simulation models for analyzing the effects of preventive, corrective and opportunistic maintenance. Policies on productivity of a flexible manufacturing cells which operate with increasing failure rate which can be attributed to wear outs and extensive utilization of equipments. The production output rate is measured as a function of availability which is determined under mean time between failures and different maintenance policies. They considered five maintenance policies. Mathematical model developed for analyzing their failure rates in order to identify their effects on production rate. Six simulation programs were developed employing SIMAN, simulation package. Their results reveal that maintenance of any firm has major effect on availability of flexible manufacturing cell. However, the type of maintenance applied should be carefully studied before implementation. This paper [9] focuses on a procedure which combines analytical and simulation models for analyzing the effects of corrective, opportunistic and preventive maintenance policies on productivity of a flexible manufacturing cell. The production output rate is determined between different mean time between failures. R.I. McIntosh et.al [10] has assessed machine maintenance for improvement of changeover performance directly. The authors argue that the techniques employed for improving changeovers can as well be applied in maintenance situations. They further conclude that focused maintenance activity can also influence changeover performance directly. Authors have discussed in their paper the role of design for improving either changeover or maintenance performance design rules which might be employed are introduced. This paper asserts that the focus should be on maintenance activity to significantly improve changeover performance. All manufacturing companies produce products with some competitive priorities such as quality, cost, flexibility etc. based on their manufacturing capabilities. Equipment maintenance is an integral part of manufacturing which can influence these competitive priorities. Hence it has direct influence on business strategy. In this paper, the authors have studied relationship between maintenance and business strategy by conducting a survey of about 150 companies in Belgium and Netherlands [11]. Their results indicate that quality competitors have better planning and control systems more proactive maintenance policies, decentralized maintenance organization structures as compared to others. et. al [12] focus on production control problem in a manufacturing system which is subject to random failures and repairs. Their study differentiates two types of repairs, without lockout/tagout and repairs with lockout/tagout. Their goal is to compute optimal production rate, repair rates and preventive maintenance rates for minimizing various cost components such as inventory cost, operating cost, backlog cost and unforseen cost resulting from accidents. The optimization criteria boils down to minimizing the total expected infinite horizon discount cost. Realistic analysis model is proposed for solving this problem in order to consider the effects of corrective maintenance policies and machine age dependent preventive policy on optimal safety stock level. The authors have developed a unified framework allowing preventive production and corrective maintenance to be considered jointly. Numerical methods are employed for obtaining machine age dependent optimal control policies. The authors [13] on the problem of preventive maintenance and production control in a stochastic manufacturing system subject to multiple uncertainties such as machine failures and repairs, processing time, random customer demand etc. A threshold type policies proposed for controlling the preventive maintenance operation and production rate simultaneously. The stationary distribution of the system state is derived analytically and is used for producing the formula for various steady state performance measures from which the optimal threshold values can be obtained by optimizing the requisite formula. This paper [14] focuses on the problem of preventive maintenance and production control in a stochastic manufacturing system subject to multiple uncertainties such as machine failures and repairs, processing time, random customer demand etc. A threshold type policies proposed for controlling the preventive maintenance operation and production rate simultaneously. The stationary distribution of the system state is derived analytically and is used for producing the formula for various steady state performance measures from which the optimal threshold values can be obtained by optimizing the requisite formula.

Despite of the strong correlation that exists between production, quality and maintenance, they are often modeled as separate problems. The authors of the paper [15] have proposed an integrated approach for joint optimization of preventive maintenance policy and production inventory control with an objective of minimizing overall cost comprising primarily of setup cost, inventory holding cost, and shortage costs. The model is implemented and validated through a suitable numerical example. Finally, a sensitivity analysis is carried out to illustrate the robustness of the model. Most of the maintenance policies are considered for an infinite time span. However, maintenance policies for finite time span are more realistic in their approach reflecting real world scenarios. This paper focuses on converting infinite time span policies into finite time span policies. The authors [16] claim that optimal policies for finite time span are more complex compared to their infinite counter parts. Three models, simple replacement, block replacement, periodic replacement with minimum repair are converted into finite time models. Optimal policies for each of these are analytically derived and computed numerically. This paper proposes an integrated model for integrating preventive maintenance and production planning for a system composed of parallel components [17]. There are two causes of system failure, the independent failure of single components and common cause failures. Common cause failures result in simultaneous failure of multiple components due to a common cause which is represented using β-factor model. The authors have proposed a model for an integrated lot-size preventive maintenance policy which minimizes the total cost of preventive and corrective maintenance costs, setup costs, productions costs, inventory holding costs, and backorder costs while satisfying demand of all the products. The model is illustrated with a suitable numerical example.

## II. TOOLS AND TECHNIQUES

MatLab is employed for implementation of the model employing fuzzy toolbox and simulink toolbox.

**Fuzzy ToolBox**

**Types of fuzzy inference systems**

There are two types of fuzzy inference systems Mamdani and Sugeno. These two types of inference systems vary somewhat in the way outputs are determined. Mamdani type inference expects the output member function to be fuzzy sets after the aggregation process. There is a fuzzy set for each output variable that needs defuzzification. Sugeno type systems can be used to model any inference system in which the output membership functions are either linear or constant.

Information flows from left to right from n inputs to a single output. The parallel nature of the rules is one of the most important aspects of fuzzy logic systems. Fuzzy inference process comprises of five steps.

- Fuzzification of input variable.
- Application of the fuzzy operators (AND/OR) in the antecedent.
- Implications from the antecedent to the consequent.
- Aggregation of the consequents across the rules.
- Defuzzification

**Step 1** : Fuzzify inputs.

The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. Fuzzification of the input amounts to a function evaluation.

**Step 2** : Apply fuzzy operators.
After the inputs are fuzzified we know the degree to which each part of the antecedent is satisfied for each rule. If the antecedent of a given rule has more than one part then the fuzzy operator is applied to obtain one number that represents the result of the antecedent of that rule. This number is then applied to the output function. The AND operator is modeled using Min function where as OR operator is modeled using Max function.

**Step 3** : Before applying the implication method, you must determine the rules weight. Every rule has a weight which is applied to a number given by the antecedent.

**Step 4** : Because decisions are based on the testing of all the rules in a FIS, the rules must be combined in some manner, in order to make decision. Aggregation is the process by which the fuzzy set that represents the outputs of each rule are combined in to a single fuzzy set.

**Step 5** : Defuzzifiction.
The input for defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. The most popular defuzzification method is a centroid calculation which returns center of area under the curve.

In the current work, authors have employed Mamdani type of FIS for implementation of a fuzzy model.

***SIMULINK***

Simulink is an extension of MATLAB which offers modeling, simulating, and analyzing of dynamic systems under a graphical user interface (GUI) environment. Simulink includes a comprehensive block library of toolboxes for both linear and non-linear analyses. In our simulation, we have used the following toolboxes.

**Fuzzy Logic** : It allows for manipulation for fuzzy systems and membership functions.

**Sources** : Sources are the blocks that provide input to the other blocks They allows input from desperate devices. From File is used for reading data from a mat file. Our model retrieves input from an Excel file and converts it into a mat file using xlsRead() and save() MATLAB commands as shown below:

a=xlsRead('Excel File Name', 'Range');
save a 'MAT File Name';

**Sink** : Sinks are the blocks that receive output from other blocks. They routes output to desperate devices. To File writes data to a mat file. Our model routes mat file output to an Excel file using xlsWrite() command as shown below:

xlsWrite('Excel File Name', 'MAT File Name');

**Signal Routing** : From this toolbox, we have employed Multiplexer, for creating a single vector by reading input from multiple MAT files and DeMultiplexer for splitting the vector and routing output to multiple MAT files.

In this paper we have developed a simulink model for 21 different inputs comprising of 16 manufacturing objectives and 5 classes and 10 outputs corresponding to 10 different manufacturing methods, for the time ranging from 1 to 16, at which different combinations of inputs are supplied. The input is read from 21 different Excel files which are converted into the corresponding MAT files and output is routed to 10 different MAT files which are converted into corresponding Excel Files. The output from 10 different files is then consolidated to generate a report for various needs of the organization. Figure 1. depicts the file transfer process.

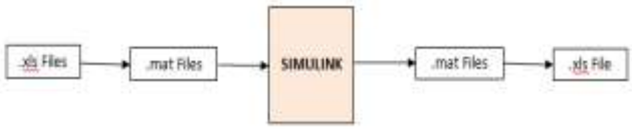



**Figure 1. File Transfer Process in Simulink**

## III. TOOLS AND TECHNIQUES

Figure 2. depicts the cascaded model for OEE clearly designating the different levels and parameters involved in the current study.

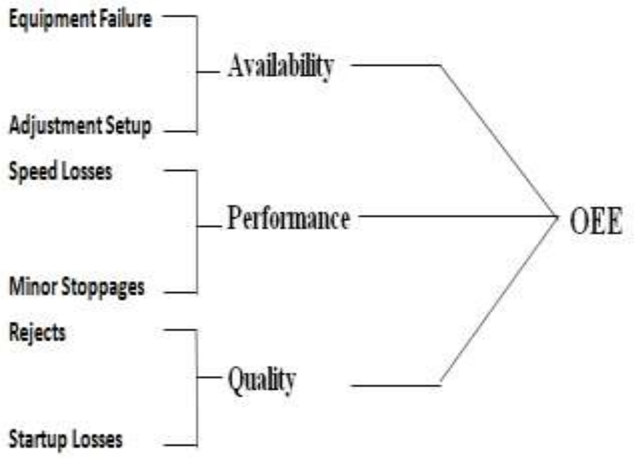



**Figure 2. Cascaded Model for Overall Equipment Effectiveness**

Figures 3-5 depict simulink models for the three OEE parameters availability, performance, and quality. Figure 6. exhibits their cascaded effect on OEE computation.

### *A. Simulink Model for Availability Computation*

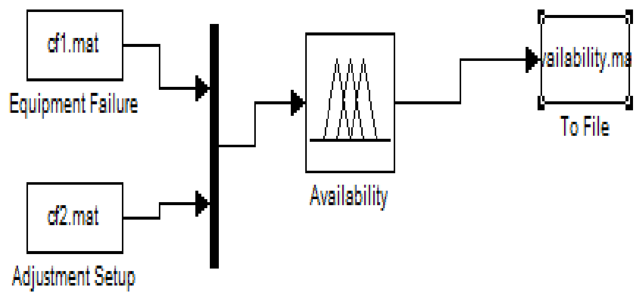


**Figure 3. Simulink Model for Availability Parameter**

*B. Simulink Model for Performance Computation*

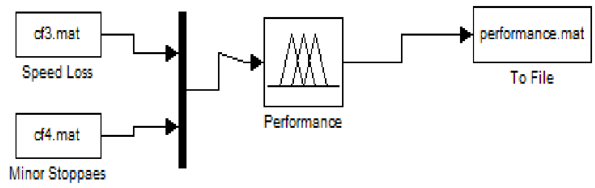



**Figure 4. Simulink Model for Performance Parameter**

*C. Simulink Model for QualityComputation*

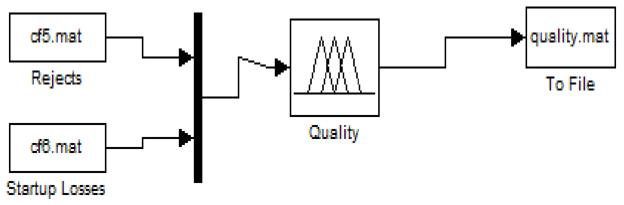



**Figure 5. Simulink Model for Quality Parameter**

*D. Cascaded Simulink Model*

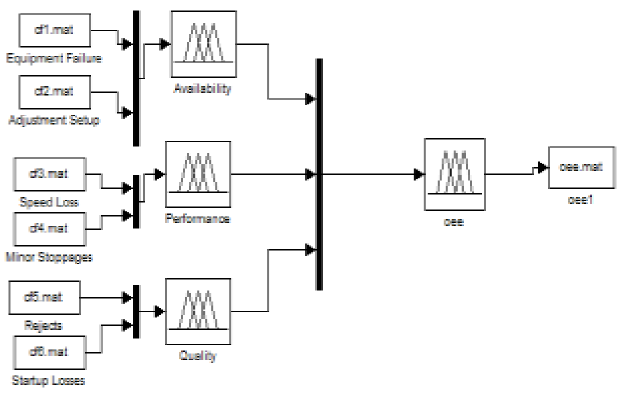



**Figure 6. Cascaded Simulink Model for OEE**

## IV. RESULTS AND DISCUSSIONS

The model presented above is implemented in MatLAB using Fuzzy toolbox and a simulink ToolBox. The M- file is dynamically generated for creating a cascaded fuzzy expert system. The generated M-File is depicted in Appendix A.

**Case Study in a Hypothetical Manufacturing Organization**
The input availability, performance and quality parameters employed in a production line of ABC organization are depicted in Table 6-8.

**Table 6. Availability Parameters**

| Variable Parameter | Value |
|---|---|
| Machine Setup Time | 15 |
| Machine Down Time | 30 |
| Short Break | 20 |
| Meal Break | 25 |
| Shift Period | 480 |

**Table 7. Performance Parameters**

| Variable Parameter | Value |
|---|---|
| Ideal Runtime | 60 |
| Total Pieces Produced | 22230 |

**Table 8. Quality Parameters**

| Variable Parameter | Value |
|---|---|
| Rejected Pieces | 423 |

The Fuzzy Inference System (FIS) and triangular membership functions utilized in FIS design are depicted in Figure 7(a) – 7(c) and Figure 8(a)-8(c), respectively. Figure 9 shows the overall effect. The mathematical representation of the membership function for 'Availability' parameter is represented below:

$$\mu_{Low}(x) = \begin{cases} x/15 & 0 < x < 15 \\ 1 & x=15 \\ (30-x)/15 & 15 < x < 30 \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} (x-30)/15 & 30 < x < 45 \\ 1 & x=45 \\ (60-x)/15 & 45 < x < 60 \end{cases}$$

$$\mu_{High}(x) = \begin{cases} (x-30)/20 & 60 < x < 80 \\ 1 & x=80 \\ (100-x)/20 & 80 < x < 100 \end{cases}$$

Similar membership functions exist for 'Performance' and 'Quality' parameters.

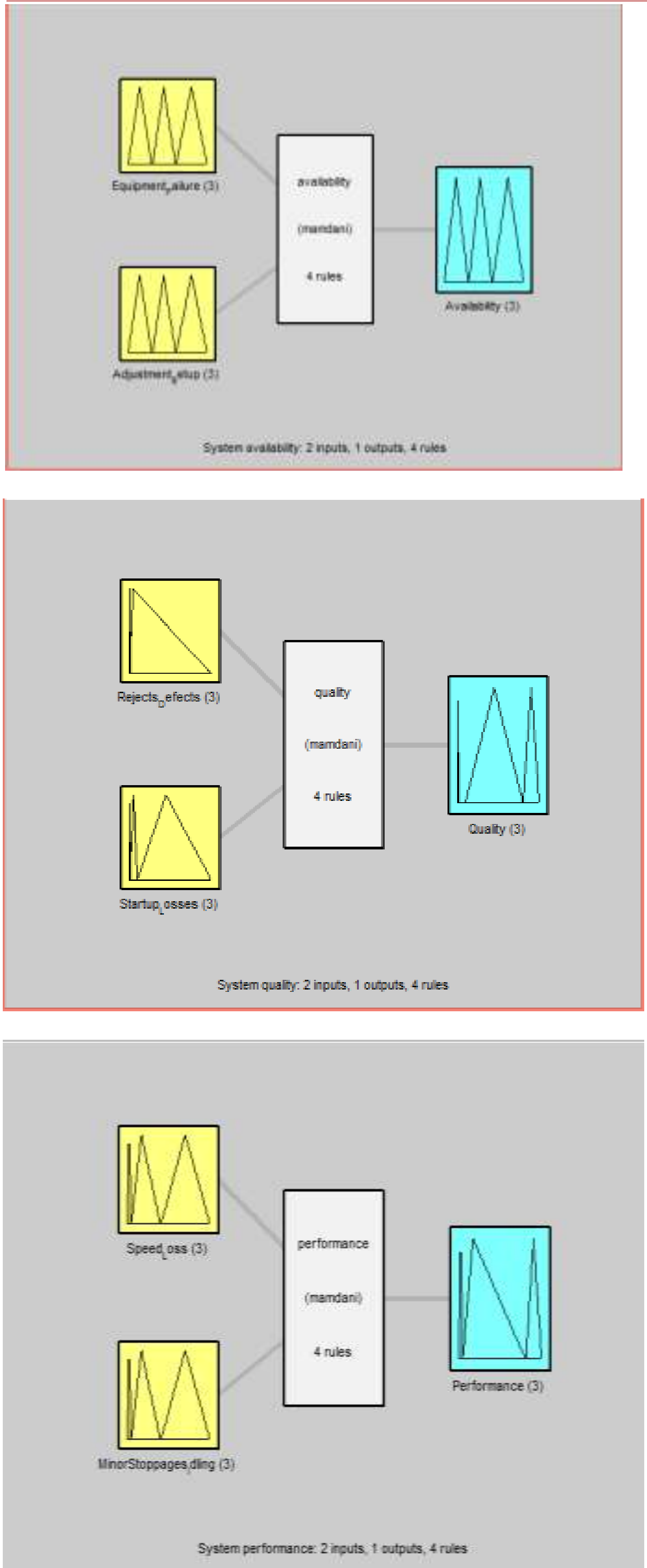



Figure 7(a)-7(c). FIS for OEE Parameters.

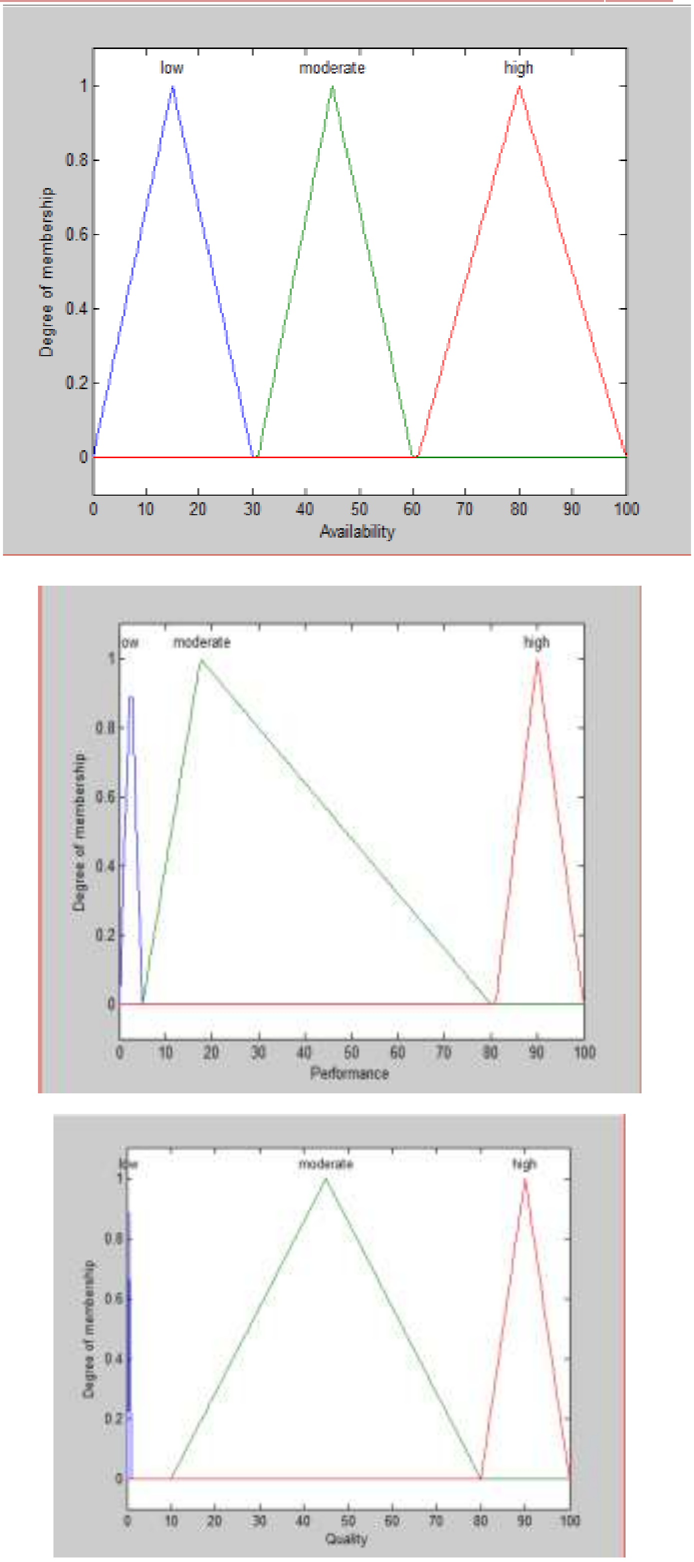



**Figure 8(a)-8(c). Structure of Triangular Membership Functions for OEE Parameters.**

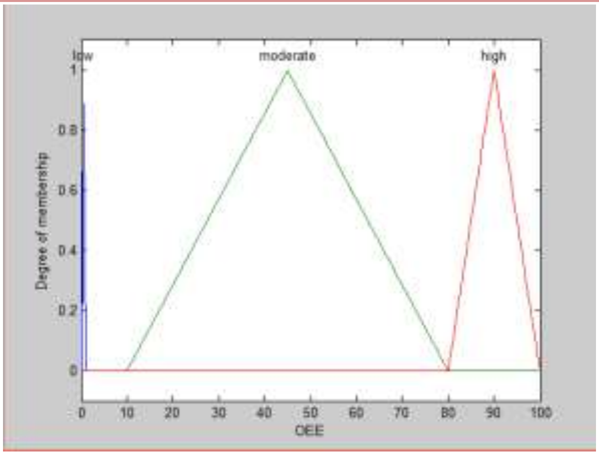
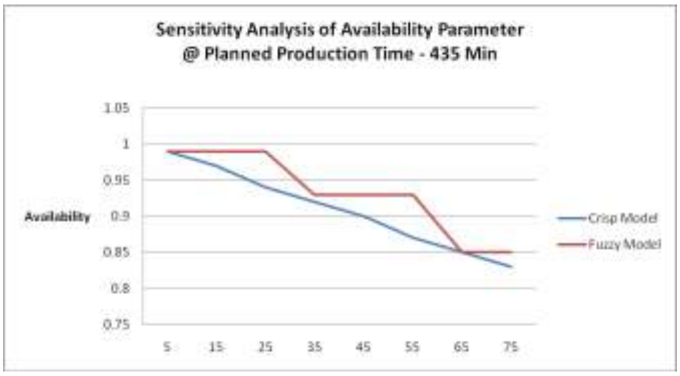
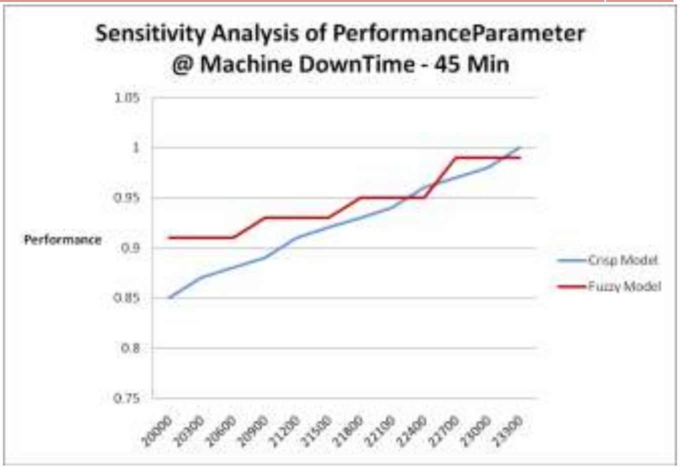



**Figure 9. Cumulative Effect on OEE.**

**Sensitivity Analysis**
**Comparison Between Cascaded Crisp and Fuzzy Models**

The sensitivity analysis to study the individual impact of small change in availability, performance and quality on OEE is carried out. Further, their cumulative effect on OEE is computed. It is found that availability and performance parameters show higher contribution and are more sensitive to OEE as compared to quality parameter. In each case the crisp model is compared with their fuzzy counterparts. Figure 10-12 show the comparison of crisp model with fuzzy model employed for sensitivity analysis. From the figures it follows that a crisp model is continuously changing and exhibits a monotonic change in corresponding OEE parameters as compared to fuzzy model which reflects the nature of membership functions employed. The overlap of membership functions do have a significant contribution in deciding the trend. The fuzzy model exhibits a step-like behavior in contrast to the monotonous behavior exhibited by crisp model which is more realistic behavior compared to crisp model.



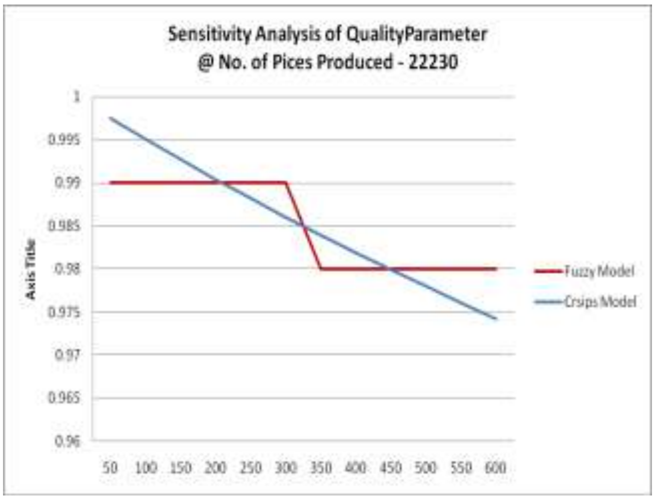




Figure (10)-(12). Comparison Between Crisp Model and Fuzzy Model.

## V. CONCLUSION AND SCOPE FOR FUTURE WORK

OEE is a mechanism to continuously monitor and improve the efficiency of a manufacturing process. Quality and quantity of production are some of the most critical factors in determining a company's success. As such OEE has become an important statistical method of figuring out the ROI on a specific piece of equipment. In this paper authors have proposed a cascaded fuzzy inference system for measurement of Overall Equipment Effectiveness. In the simplified model proposed by the authors, only few prominent parameters up to two levels are considered. The model can be easily extended to incorporate more parameters and more levels to render it more realistic. The sensitivity analysis is carried out in order to gauge the impact of availability, performance and quality parameters on OEE. The classical crisp model is compared with fuzzy model. The trend is decided by the type of membership functions considered and their overlaps. These parameters can be coined using NeuroFuzzy system which can effectively determine the type of membership functions and generate the rules by employing the past data in training the neural network.

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## Appendix A

### Structure of M File (OEE.m)

```
arr=zeros(1,3)
a=newfis('availability');
a=addvar(a,'input','Equipment_Failure',[0 100]);
a=addmf(a,'input',1,'low','trimf',[0 15 30]);
a=addmf(a,'input',1,'moderate','trimf',[31 45 60]);
a=addmf(a,'input',1,'high','trimf',[61 80 100]);

a=addvar(a,'input','Adjustment_Setup',[0 100]);
    a=addmf(a,'input',2,'low','trimf',[0 15 30]);
    a=addmf(a,'input',2,'moderate','trimf',[31 45 60]);
    a=addmf(a,'input',2,'high','trimf',[61 80 100]);

     a=addvar(a,'output','Availability',[0 100]);
a=addmf(a,'output',1,'low','trimf',[0 15 30]);
a=addmf(a,'output',1,'moderate','trimf',[31 45 60]);
a=addmf(a,'output',1,'high','trimf',[61 80 100]);
ruleList=[ ...
1 1 3 1 1
3 3 1 1 1
3 1 1 1 1
1 3 2 1 1 ];
a=addrule(a,ruleList);
showfis(a);
showrule(a);
ans
plotfis(a);
plotmf(a,'input',1);
plotmf(a,'input',2);
plotmf(a,'output',1);
arr(1)=evalfis([5 5],a);
arr(1);

writefis(a,'availability.fis');

a=newfis('performance');
a=addvar(a,'input','Speed_Loss',[0 100]);
a=addmf(a,'input',1,'low','trimf',[0 2.5 5]);
a=addmf(a,'input',1,'moderate','trimf',[5 17.5 40]);
a=addmf(a,'input',1,'high','trimf',[41 70 100]);

a=addvar(a,'input','MinorStoppages_Idling',[0 100]);
a=addmf(a,'input',2,'low','trimf',[0 2.5 5]);
a=addmf(a,'input',2,'moderate','trimf',[5 17.5 40]);
a=addmf(a,'input',2,'high','trimf',[41 70 100]);

 a=addvar(a,'output','Performance',[0 100]);
a=addmf(a,'output',1,'low','trimf',[0 2.5 5]);
a=addmf(a,'output',1,'moderate','trimf',[5 17.5 80]);
a=addmf(a,'output',1,'high','trimf',[81 90 100]);
ruleList=[ ...
1 1 3 1 1
3 3 1 1 1
3 1 1 1 1
1 3 2 1 1 ];
a=addrule(a,ruleList);
showfis(a);
showrule(a);
ans;
plotfis(a);
plotmf(a,'input',1);
plotmf(a,'input',2);
plotmf(a,'output',1);
arr(2)=evalfis([1 1],a);
arr(2);
writefis(a,'performance.fis');


a=newfis('quality');
a=addvar(a,'input','Rejects_Defects',[0 100]);
a=addmf(a,'input',1,'low','trimf',[0 0.05 0.1]);
a=addmf(a,'input',1,'moderate','trimf',[0.1 0.55 1]);
a=addmf(a,'input',1,'high','trimf',[1 4.5 100]);

a=addvar(a,'input','Startup_Losses',[0 10]);
```

```
a=addmf(a,'input',2,'low','trimf',[0 0.05 0.1]);
a=addmf(a,'input',2,'moderate','trimf',[0.1 0.55 1]);
a=addmf(a,'input',2,'high','trimf',[1 4.5 10]);

a=addvar(a,'output','Quality',[0 100]);
a=addmf(a,'output',1,'low','trimf',[0 0.5 1]);
a=addmf(a,'output',1,'moderate','trimf',[10 45 80]);
a=addmf(a,'output',1,'high','trimf',[80 90 100]);
ruleList=[ ...
1 1 3 1 1
3 3 1 1 1
3 1 1 1 1
1 3 2 1 1 ];
a=addrule(a,ruleList);
showfis(a);
showrule(a);
ans;
plotfis(a);
plotmf(a,'input',1);
plotmf(a,'input',2);
plotmf(a,'output',1);
arr(3)=evalfis([0.01 0.01],a);
arr(3);
writefis(a,'quality.fis');

a=newfis('oee');
a=addvar(a,'input','Availability',[0 100]);
a=addmf(a,'input',1,'low','trimf',[0 15 30]);
a=addmf(a,'input',1,'moderate','trimf',[30 45 60]);
a=addmf(a,'input',1,'high','trimf',[60 80 100]);
a=addvar(a,'input','Performance',[0 100]);
a=addmf(a,'input',2,'low','trimf',[0 2.5 5]);
a=addmf(a,'input',2,'moderate','trimf',[5 17.5 40]);
a=addmf(a,'input',2,'high','trimf',[41 70 100]);

a=addvar(a,'input','Quality',[0 100]);
a=addmf(a,'input',3,'low','trimf',[0 0.5 1]);
a=addmf(a,'input',3,'moderate','trimf',[10 45 80]);
a=addmf(a,'input',3,'high','trimf',[80 90 100]);

a=addvar(a,'output','OEE',[0 100]);
a=addmf(a,'output',1,'low','trimf',[0 0.5 1]);
a=addmf(a,'output',1,'moderate','trimf',[10 45 80]);
a=addmf(a,'output',1,'high','trimf',[80 90 100]);
ruleList=[ ...
1 1 3 3 1 1
3 3 1 1 1 1
3 1 2 1 1 1
1 3 2 2 1 1
3 3 3 3 1 1 ];
a=addrule(a,ruleList);
showfis(a);
showrule(a);
ans;
plotfis(a);
plotmf(a,'input',1);
plotmf(a,'input',2);
plotmf(a,'output',1);
b=evalfis(arr,a);
writefis(a,'oee.fis');
```