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International
Journal
Of Modern Engineering Research (IJMER)

Validation of Maintenance Policy of Steel Plant Machine Shop By Analytic Hierarchy Process (Ahp)

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ABSTRACT: *In this paper the maintenance activities of the Machine shop of Steel plant have been considered. As maintenance is a routine activity to keep a machine at its normal operating condition so that it can deliver its expected performance without causing any loose of time on account of accidental damage or breakdown and maintenance is a recurring activity. So for reduction of maintenance cost and safety of the operator as well as the residents of nearby area it is better to decide which machines should go for which type of maintenance. For this decision AHP is used and the Expert choice software is used for that calculations and this paper is for the validation of results.*
Keywords*: AHP Analytic Hierarchy process, Bath Tub Curve, Opportunistic maintenance, Consistency ratio.*

I. INTRODUCTION

The oldest and most common maintenance and repair strategy is “fix it when it breaks”. The appeal of this approach is that no analysis or planning is required. The problems with this approach include the occurrence of unscheduled downtime at times that may be inconvenient, perhaps preventing accomplishment of committed production schedules. But when an unscheduled downtime occurs it has more serious consequences in applications such as aircraft engines. So these problems provide motivation to perform maintenance and repair before the problem arises. Now simplest approach is to perform maintenance and repair at pre-established intervals, defined in terms of elapsed or operating hours.

Maintenance is a routine activity to keep a machine at its normal operating condition so that it can deliver its expected performance without causing any loose of time on account of accidental damage or breakdown and maintenance is a recurring activity. For any machine the failure rate as unit age over time and repeatedly obtain a graph is called as its shape like bath tub.

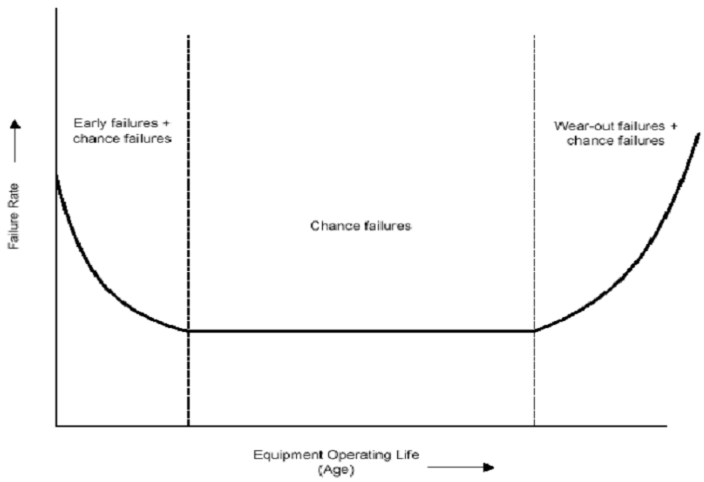


Figure 1. Illustrates the typical incidence of failure over the life of equipment.

At this bath tub curve the left, so-called “infant mortality” failures are plotted. Failure rates are low throughout the useful life of a piece of equipment, and rise towards the end of life. This curve however doesn’t capture the complex interactions between the components of a system and is loosely based on the assumption that the system progresses (or deteriorates) deterministically through a well defined sequence of states (however, the curve might in some cases be valid even if the sequence is not well defined). This assumption is not true especially in the case of discrete manufacturing systems and other complex environments where seemingly random failure behaviour is a function of the changes in the work content, schedule and environment effects, as well as unknowable variations between nominally identical components or systems. The only way to minimize both maintenance and repair costs and probability of failure is to perform ongoing assessment of machine health and ongoing prediction of future failures based on current health and operating and maintenance history. This is the motivation for prognostics: minimize repair and maintenance costs and associated operational disruptions, while also minimizing risk of unscheduled downtime.

Types Of Maintenance: - There are number of maintenance activities as under

(1) Preventive Maintenance: - This type of maintenance activity performed on any machine when that is going to breakdown. Then it is very important to stop the machine before breakdown. Any experienced operator or foreman may be able to take any decision for stopping the machine. Some guidelines given in the machine O&M and any previous accident in experience are the input to decision of stopping any machine. So there is no written brochure for this type of maintenance. Preventive maintenance is the strategy organized to perform maintenance at predetermined intervals to reduce the probability of failure or performance degradation.

(2) Corrective Maintenance: When inspection shows that corrective action is necessary the machine tool should be withdrawn from production. As the object of this inspection is to take action before a failure occurs, such action should be taken as quickly as possible, as, however, the machine is still capable of producing satisfactory work; this action can be taken at a time to meet both the convenience of production and the maintenance department.

(3) Opportunistic Maintenance: It means the opportunity to maintenance so this type of maintenance in the machine or plant that are already in Breakdown maintenance or when the machine is not having any work, then carried out.

(4) Breakdown Maintenance: - In all the plant number of general purpose machines are available they are not so costly. So these machines are generally left for breakdown maintenance like Pumps, compressors, lathes drilling milling machines etc.

Maintenance is a legacy practice: maintenance only after the manifestation of the defect, breakdown or stoppage. It is appropriate in facilities where the installed machinery is minimal and the plant is not totally dependent on the reliability of any individual machine.

In any heavy work shop the type of maintenance carried by different studies are as follows:

Sr. No.	Type of Maintenance	% of Machines covered
1.	Preventive Maintenance	25
2.	Corrective Maintenance	20
3.	Opportunistic Maintenance	10
4.	Breakdown Maintenance	45

Now it is a laborious work to select which type of machine should go for Preventive maintenance, Corrective, Opportunistic and Breakdown maintenance. So it is better if we use any software or related thing, in search of this I find AHP that may be suitable for this purpose.

II. OBJECTIVE

Validate the result of maintenance policies of machines find by AHP. The Analytical Hierarchy Process (AHP) is a decision making method developed by T. L. Saaty. It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process. Since a decision-maker bases judgments on knowledge and experience, then makes decisions accordingly, the AHP approach agrees well with the behaviour of a decision maker. The strength of this approach is that it organizes tangible and intangible factors in a systematic way, and provides a structured yet relatively simple solution to the decision making problems.

Analytical Hierarchy Process (AHP) is generally used for the making priority of anything (like purchase of any Robot, Air condition, car or even any machine). So for the selection of one type of maintenance activity to be adopted in one machine is to be priorities for all 270 machines. AHP is used in many different type of activities from selecting any fruit for eating to the prioritising the activities of difference (like selection of missile, tanks, radar etc.) also for selection of any investment decision, selection of any strategy etc.

Its validity is based on the many hundreds (now thousands) of actual applications in which the AHP results were accepted and used by the cognizant decision makers (DMs).

III. METHODOLOGY

AHP is a viable, usable decision-making tool. Saaty [24±27] developed the following steps for applying the AHP:

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.
3. Construct a set of pair-wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 1. The pair-wise comparisons are done in terms of which element dominates the other.
4. There are n (n- 1)/ judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows:

$$CI = (\lambda_{max} - n) \dagger / \ldots (n - 1) \dagger$$

where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.
7. Steps 3±6 are performed for all levels in the hierarchy.

Table 1. Pair-wise comparison scale for AHP preferences.

Numerical Rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 2. Average random consistency (RI)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Now days, number of software are available and calculations are faster and decision making is easier and one can review the decisions. ***Expert Choice*** Software has been used for calculation.

IV. CALCULATION

4.1 Details of machine shop:- A total of about 270 machine tools and other equipments are installed out of which 135 machines are earmarked in direct production group viz.

Table 3. Machines in Machine Shop

Sr. Number	Name of Machine	Quantity
1	Heavy & Medium Lathe	32
2	Light Lathe	35
3	Vertical & Horizontal Boring Machine	21
4	Slotting & Drilling Machine	12
5	Shaping & Planning Machine	11
6	Milling & Gear Cutting Machine	24

Remaining machine tools are to contribute indirectly towards production. There are 16 heat treatment / heating furnaces. Material handling equipments provided in all the bays include EOT, Jib, Telphers, Electrical transfer cars to connect different bays of machine shop and 2 cranes has been in open Gantry of CPD along with a battery trolleys etc. Railway wagons can inter into assembly bay at one end for the transportation of heavy spares and assemblies.

Table 4:- Details of Lathe Machine (Grading)

Sr. No.	Grade I(High Grade)	Grade II	Grade III
1.	Lt07	Lt04	Lt01
2.	Lt13	Lt05	Lt02
3.	Lt15	Lt06	Lt03
4.	Lt20	Lt08	Lt11
5.	Lt23	Lt09	Lt12
6.	Lt28	Lt10	Lt14
7.	Lt30	Lt16	Lt21
8.	Lt32	Lt17	Lt33
9.	Lt37	Lt18	Lt34
10.	Lt40	Lt19	Lt41
11.	Lt56	Lt22	Lt42
12.	Lt58	Lt24	Lt44
13.	Lt61	Lt25	Lt45
14.	Lt66	Lt26	Lt53
15.		Lt27	Lt54
16.		Lt29	Lt62
17.		Lt31	Lt63
18.		Lt35	
19.		Lt36	
20.		Lt38	
21.		Lt39	
22.		Lt43	
23.		Lt46	
24.		Lt47	
25.		Lt48	
26.		Lt49	
27.		Lt50	
28.		Lt51	
29.		Lt52	
30.		Lt55	
31.		Lt57	
32.		Lt59	
33.		Lt60	
34.		Lt64	
35.		Lt65	
36.		Lt67	

Table 5:- Preventive Maintenance Schedule for machines as under:

Date	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
1	Bv03		Lt23			Lt35	Lt07			Lt30	Lt60	
2	Lt07		Dr02	Bv08	Lt27		Bv03	Lt15	Lt50	Bv08		Lt65
3		Lt15				Lt56			Bh07	Bg06	Lt37	
4	Bh02			Lt30	Lt29		Gs01	Ml07	Lt61		Sh06	Ml08
5	Dr01	Bg04	Pl02		Bv09				Bg07	Bh06		
6					Lt37		Bh02					
7						Bh05				Ml01		
8	Gs01		Lt16	Gf01	Dr04		Ml03		Bg08			
9				Sl02								Sh08
10			Lt61				Sh04		Sh05			Lt58

11	Lt04	Sl03	Bh04							Bv09		
12				Bh06		Lt36				Lt55	Lt40	
13	Lt05	Lt08	Gs02					Lt47	Pl02			
14		Bv01		Lt18	Bv04	Lt58		Bv05		Lt57		Bv06
15	Lt06	Lt09	Bg01		Lt31			Lt48				Bv12
16		Bv07		Lt19	Bv12		Lt13	Bv07		Lt32		
17	Lt13	Lt10			Lt40	Bg03		Lt20	Lt51			
18		Ml02		Lt22	Sh03		Dr05					
19		Lt20	Lt17						Lt28			
20				Lt32		Bg05						Lt66
21			Lt28						Dr06	Sl04		
22	Sh02		Bg02			Lt38						Pl01
23				Ml01							Dr08	
24		Gf02				Lt66	Bg04	Sl03				Bh08
25	Ml03		Sh05					Lt49		Gf01		
26					Ml06		Lt39				Lt64	
27								Lt23				
28							Lt43			Lt59	Lt56	
29				Bg06								
30							Lt46		Lt52			Lt67
31												

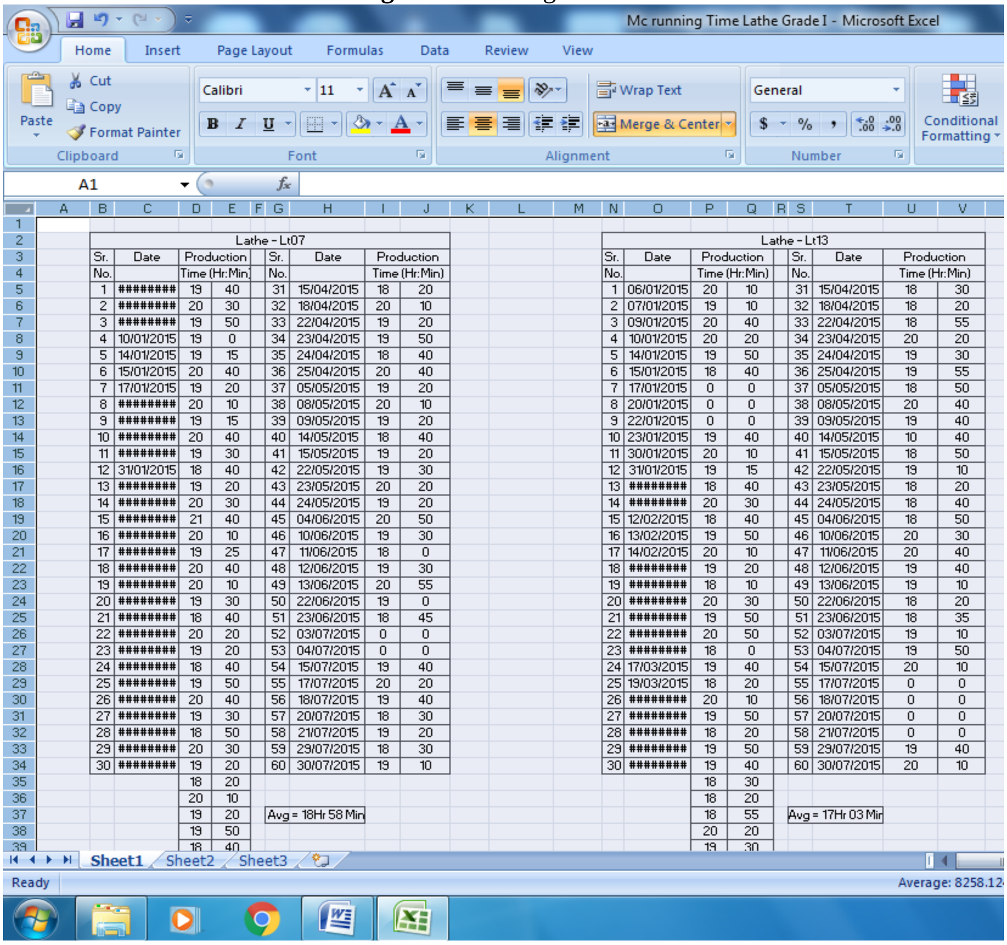
4.2 Testing of Machine :- The machines of shop are tested as per the rules given below :-

Table 6. Testing of Lathe: - Test chart for finish turning Lathe up to 400mm height of centres

Geometrical Test	1. Test to be applied – Bed	Permissible Error (mm)	
	Bed straight in longitudinal direction apron side (convex only)	0 – 0.02 per 1000mm	
	Same opposite (concave only)	0.02 per 1000mm	
	Bed level in transverse direction	± 0.02* per 1000mm	
	Straightness of sideways (for machines of more than 3m turning length only; measurements taken by measuring taut wire and microscope or long straight edge.)	0.02 per 1000mm	
	Tailstock guideways parallel with movement of carriage	0.02 per 1000mm	
	2. Test to be applied – Work Spindle	**Permissible Error (mm)**	
	Centre point of true running	0.01	
	Centre sleeve for true running	0.01	
	Work spindle for axial slip, measured at 2 points, displaced by 180^0	0.01	
	Taper of work spindle runs true (a) Nearest spindle nose (b) At a distance of 300 mm	0.01 0.03	
	Work spindle parallel with bed in vertical plane (rising towards the free end of mandrel only)	0 to 0.2 per 300 mm	
	Work spindle parallel with bed in horizontal plane (free end of mandrel inclined towards the direction of tool pressure)	0 – 0.02 per 300 mm	
	3. Test to be applied – Carriage	**Permissible Error (mm)**	
	Movement of upper slide parallel with work spindle in vertical plane (hand free) When automatic feed is provided in vertical plane In horizontal plane	0.03 per 150mm 0.03 per 300 mm 0.02 per 300 mm	
	4. Test to be applied – Tailstock	**Permissible Error (mm)**	
	Tailstock sleeve parallel with bed in vertical plane (front end rising)	0 to 0.02 per 100mm	
	Same in horizontal plane (front end inclined towards the direction of tool pressure)	0 to 0.01 per 100mm	
	Cone of sleeve parallel with bed in vertical plane (free end of mandrel rising)	0 to 0.03 per 300mm	

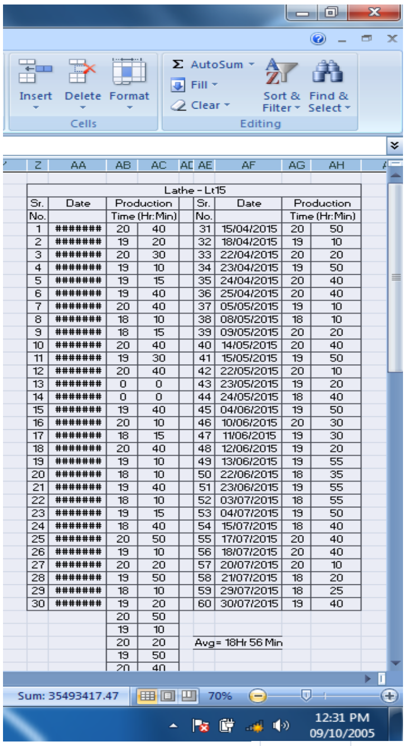
* Either + or – on full length, no twist permitted.

Table 7:-Machine Running Time Readings from 06/01/2015 to 30/07/ 2015

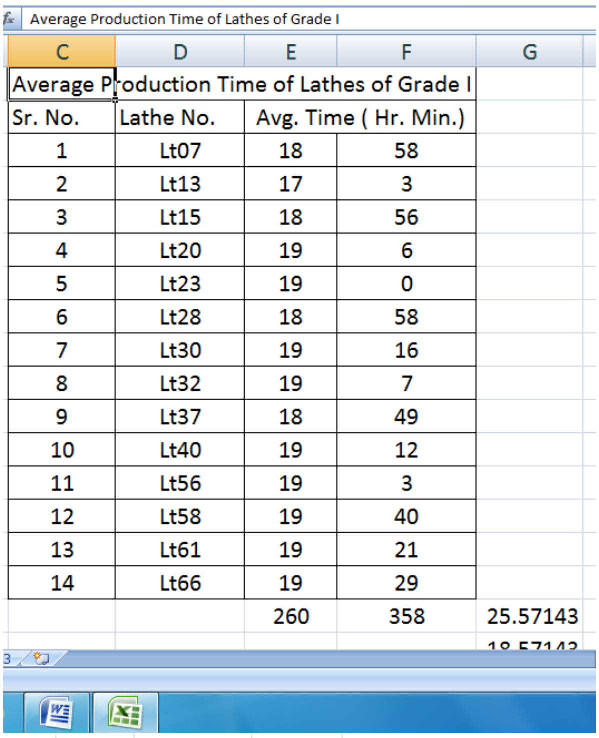


Lathe - Lt07							
Sr. No.	Date	Production Time (Hr:Min)		Sr. No.	Date	Production Time (Hr:Min)	
1	########	19	40	31	15/04/2015	18	20
2	########	20	30	32	18/04/2015	20	10
3	########	19	50	33	22/04/2015	19	20
4	10/01/2015	19	0	34	23/04/2015	19	50
5	14/01/2015	19	15	35	24/04/2015	18	40
6	15/01/2015	20	40	36	25/04/2015	20	40
7	17/01/2015	19	20	37	05/05/2015	19	20
8	########	20	10	38	08/05/2015	20	10
9	########	19	15	39	09/05/2015	19	20
10	########	20	40	40	14/05/2015	18	40
11	########	19	30	41	15/05/2015	19	20
12	31/01/2015	18	40	42	22/05/2015	19	30
13	########	19	20	43	23/05/2015	20	20
14	########	20	30	44	24/05/2015	19	20
15	########	21	40	45	04/06/2015	20	50
16	########	20	10	46	10/06/2015	19	30
17	########	19	25	47	11/06/2015	18	0
18	########	20	40	48	12/06/2015	19	30
19	########	20	10	49	13/06/2015	20	55
20	########	19	30	50	22/06/2015	19	0
21	########	18	40	51	23/06/2015	18	45
22	########	20	20	52	03/07/2015	0	0
23	########	19	20	53	04/07/2015	0	0
24	########	18	40	54	15/07/2015	19	40
25	########	19	50	55	17/07/2015	20	20
26	########	20	40	56	18/07/2015	19	40
27	########	19	30	57	20/07/2015	18	30
28	########	18	50	58	21/07/2015	19	20
29	########	20	30	59	29/07/2015	18	30
30	########	19	20	60	30/07/2015	19	10
		18	20				
		20	10				
		19	20	Avg = 18Hr 58 Min			
		19	50				
		18	40				

Lathe - Lt13							
Sr. No.	Date	Production Time (Hr:Min)		Sr. No.	Date	Production Time (Hr:Min)	
1	06/01/2015	20	10	31	15/04/2015	18	30
2	07/01/2015	19	10	32	18/04/2015	18	20
3	09/01/2015	20	40	33	22/04/2015	18	55
4	10/01/2015	20	20	34	23/04/2015	20	20
5	14/01/2015	19	50	35	24/04/2015	19	30
6	15/01/2015	18	40	36	25/04/2015	19	55
7	17/01/2015	0	0	37	05/05/2015	18	50
8	20/01/2015	0	0	38	08/05/2015	20	40
9	22/01/2015	0	0	39	09/05/2015	19	40
10	23/01/2015	19	40	40	14/05/2015	10	40
11	30/01/2015	20	10	41	15/05/2015	18	50
12	31/01/2015	19	15	42	22/05/2015	19	10
13	########	18	40	43	23/05/2015	18	20
14	########	20	30	44	24/05/2015	18	40
15	12/02/2015	18	40	45	04/06/2015	18	50
16	13/02/2015	19	50	46	10/06/2015	20	30
17	14/02/2015	20	10	47	11/06/2015	20	40
18	########	19	20	48	12/06/2015	19	40
19	########	18	10	49	13/06/2015	19	10
20	########	20	30	50	22/06/2015	18	20
21	########	19	50	51	23/06/2015	18	35
22	########	20	50	52	03/07/2015	19	10
23	########	18	0	53	04/07/2015	19	50
24	17/03/2015	19	40	54	15/07/2015	20	10
25	19/03/2015	18	20	55	17/07/2015	0	0
26	########	20	10	56	18/07/2015	0	0
27	########	19	50	57	20/07/2015	0	0
28	########	18	20	58	21/07/2015	0	0
29	########	19	50	59	29/07/2015	19	40
30	########	19	40	60	30/07/2015	20	10
		18	30				
		18	20				
		18	55	Avg = 17Hr 03 Min			
		20	20				
		19	30				



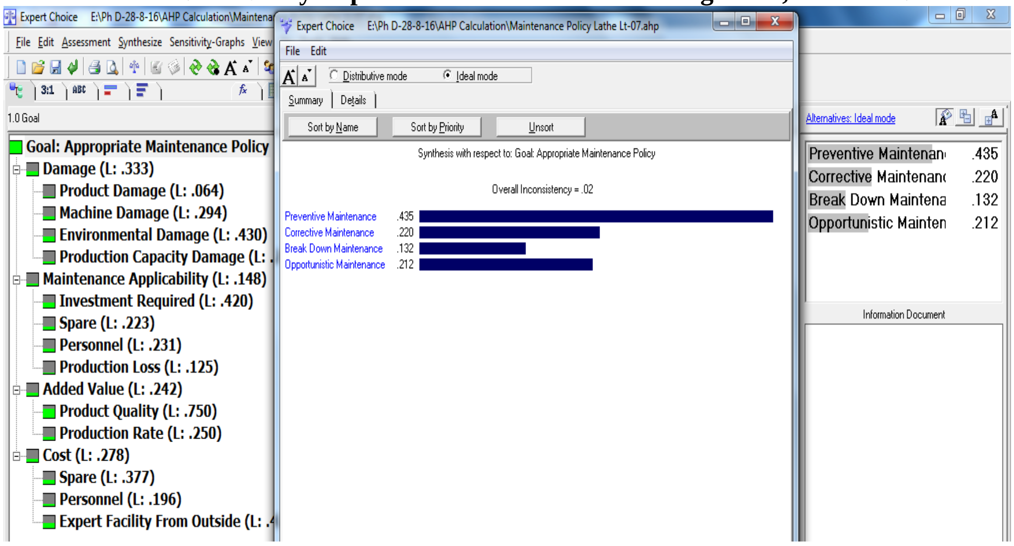
Lathe - Lt15							
Sr. No.	Date	Production Time (Hr:Min)		Sr. No.	Date	Production Time (Hr:Min)	
1	#######	20	40	31	15/04/2015	20	50
2	#######	19	20	32	18/04/2015	19	10
3	#######	20	30	33	22/04/2015	20	20
4	#######	19	10	34	23/04/2015	19	50
5	#######	19	15	35	24/04/2015	20	40
6	#######	19	40	36	25/04/2015	20	40
7	#######	20	40	37	05/05/2015	19	10
8	#######	18	10	38	08/05/2015	18	10
9	#######	18	15	39	09/05/2015	20	20
10	#######	20	40	40	14/05/2015	20	40
11	#######	19	30	41	15/05/2015	19	50
12	#######	20	40	42	22/05/2015	20	10
13	#######	0	0	43	23/05/2015	19	20
14	#######	0	0	44	24/05/2015	18	40
15	#######	19	40	45	04/06/2015	19	50
16	#######	20	10	46	10/06/2015	20	30
17	#######	18	15	47	11/06/2015	19	30
18	#######	20	40	48	12/06/2015	19	20
19	#######	19	10	49	13/06/2015	19	55
20	#######	18	10	50	22/06/2015	18	35
21	#######	19	40	51	23/06/2015	19	55
22	#######	18	10	52	03/07/2015	18	55
23	#######	19	15	53	04/07/2015	19	50
24	#######	18	40	54	15/07/2015	18	40
25	#######	20	50	55	17/07/2015	20	40
26	#######	19	10	56	18/07/2015	20	40
27	#######	20	20	57	20/07/2015	20	10
28	#######	19	50	58	21/07/2015	18	20
29	#######	18	10	59	29/07/2015	18	25
30	#######	19	20	60	30/07/2015	19	40
		20	50				
		19	10				
		20	20	Avg= 18Hr 56 Min			
		19	50				
		20	40				



Average Production Time of Lathes of Grade I				
Sr. No.	Lathe No.	Avg. Time (Hr. Min.)		
1	Lt07	18	58	
2	Lt13	17	3	
3	Lt15	18	56	
4	Lt20	19	6	
5	Lt23	19	0	
6	Lt28	18	58	
7	Lt30	19	16	
8	Lt32	19	7	
9	Lt37	18	49	
10	Lt40	19	12	
11	Lt56	19	3	
12	Lt58	19	40	
13	Lt61	19	21	
14	Lt66	19	29	
		260	358	25.57143

Average Time = 18:59 = 19 Hrs.

Table 8. Result by Expert choice software for Lathe grade I, II and III.



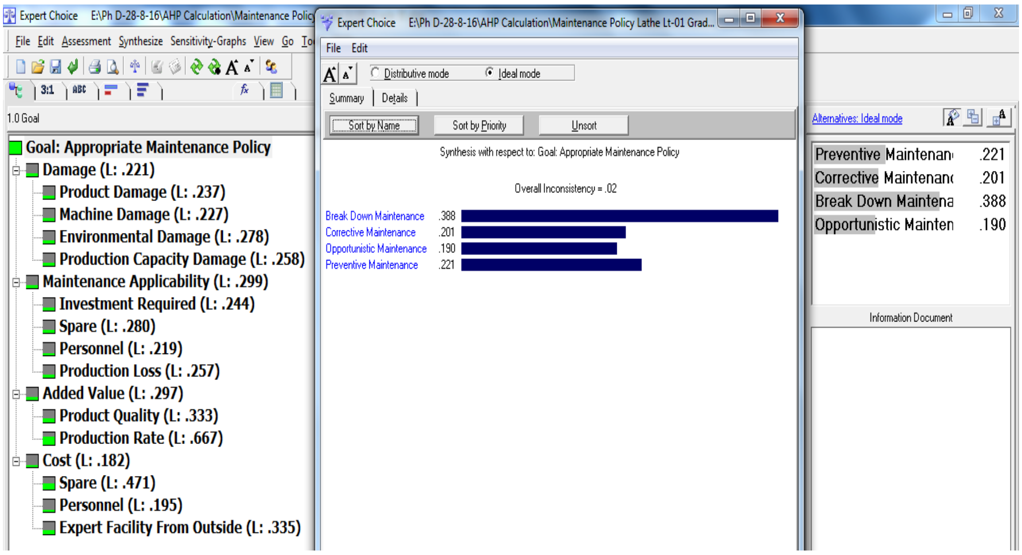
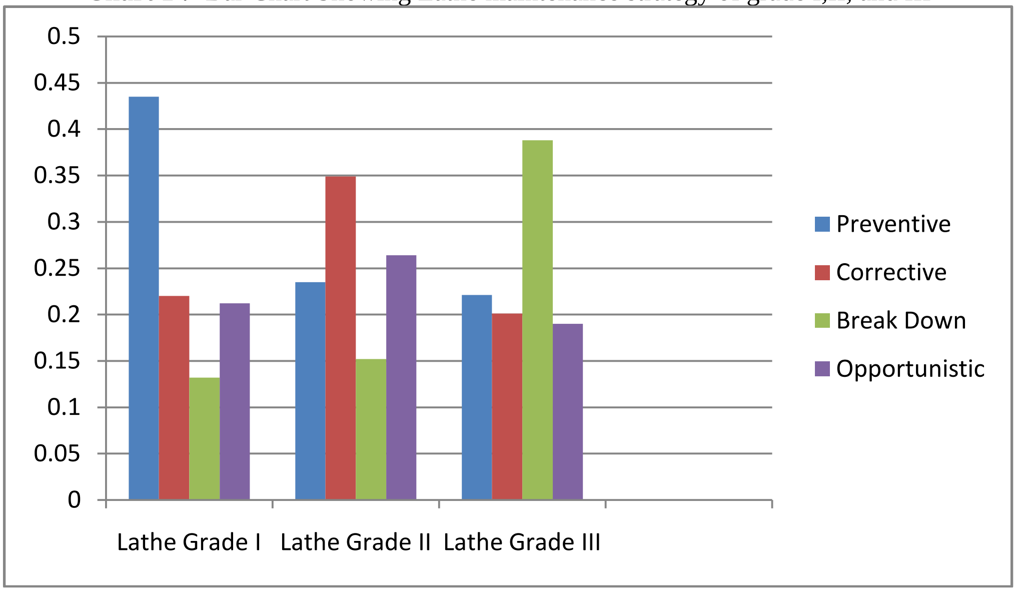


Table 9 :- Results of Maintenance Policies

Sr. No.	Machine Name	Grade	Priorities for type of Maintenance			
			Preventive	Corrective	Break Down	Opportunistic
1	Lathe	I	0.435	0.220	0.132	0.212
2	Lathe	II	0.235	0.349	0.152	0.264
3	Lathe	III	0.221	0.201	0.388	0.190
4	Boring Machine Horizontal	I	0.496	0.236	0.125	0.143
5	Boring Machine Horizontal	II	0.188	0.461	0.097	0.254
6	Boring Machine Horizontal	III	0.162	0.191	0.511	0.137
7	Boring Machine Vertical	I	0.488	0.224	0.127	0.161
8	Boring Machine Vertical	II	0.166	0.509	0.076	0.249
9	Boring Machine Vertical	III	0.162	0.191	0.501	0.147
10	Slotting Machine	I	0.502	0.190	0.113	0.195
11	Slotting Machine	II	0.246	0.276	0.083	0.395
12	Slotting Machine	III	0.186	0.148	0.448	0.218
13	Shaper	I	0.457	0.216	0.122	0.205
14	Shaper	II	0.195	0.462	0.110	0.234

15	**Shaper**	**III**	**0.152**	**0.191**	**0.521**	**0.137**
16	**Planner**	**I**	**0.526**	**0.217**	**0.089**	**0.168**
17	**Planner**	**II**	**0.199**	**0.510**	**0.088**	**0.204**
18	**Planner**	**III**	**0.152**	**0.182**	**0.557**	**0.109**
19	**Milling Machine**	**I**	**0.369**	**0.255**	**0.111**	**0.265**
20	**Milling Machine**	**II**	**0.207**	**0.380**	**0.135**	**0.278**
21	**Milling Machine**	**III**	**0.201**	**0.188**	**0.440**	**0.172**
22	**Bevel Gear**	**I**	**0.476**	**0.157**	**0.138**	**0.229**
23	**Bevel Gear**	**II**	**0.185**	**0.468**	**0.073**	**0.274**
24	**Gear Shapping Machine**	**I**	**0.529**	**0.145**	**0.127**	**0.199**
25	**Gear Shapping Machine**	**II**	**0.140**	**0.533**	**0.108**	**0.219**
26	**Gear Shaving Machine**	**I**	**0.475**	**0.205**	**0.092**	**0.227**
27	**Gear Shaving Machine**	**II**	**0.175**	**0.478**	**0.073**	**0.274**
28	**Gear Hobbing Machine**	**I**	**0.546**	**0.207**	**0.100**	**0.146**
29	**Gear Hobbing Machine**	**II**	**0.183**	**0.511**	**0.081**	**0.225**
30	**Gear Hobbing Machine**	**III**	**0.166**	**0.174**	**0.555**	**0.105**

Chart 1 :- Bar Chart Showing Lathe maintenance strategy of grade I,II, and III



V. CONCLUSION

The result of Lathe of Grade-I the priorities are 0.435 comes first for Preventive maintenance, 0.220 second corrective, 0.212 third opportunistic and 0.132 forth breakdown maintenance, similarly for other grade and different machines are shows in table 9. Chart 1 shows the Bar Chart Showing Lathe maintenance strategy of grade I,II, and III. Lathe grade-I should maintain Preventive, Lathe grade-II is corrective and Lathe grade-III got his first priorities on breakdown maintenance.

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