



INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE  
IN THE ARAB COUNTRIES

UNDER THE THEME

**"MANAGING MAINTENANCE WITHIN INDUSTRY 4.0"**  
CONICIDE WITH THE 16<sup>TH</sup> ARAB MAINTENANCE EXHIBITION

## **Applying Reliability Centered Maintenance (RCM) on Critical Systems**

**Impact on Equipment Availability and Cost Optimization**

**Abdulaziz A. Bubshait & Alawi H. Basurrah**

A large, stylized graphic of the number "4.0" in white, set against a dark teal background. The background also features a faint image of a person in a blue uniform working on a piece of machinery.

**4.0**



# OUTLINES

---



- Introduction
- Definitions
- Changing view of Maintenance
- RCM advantages
- How equipment fails
- RCM flow chart
- Criticality Assessment
- Case studies
- Conclusion

# Introduction

---



- ✓ Assets used in plants are very costly and require huge investment.
- ✓ Giving a great attention to **design a solid reliability maintenance strategy** will positively impact the plants reliability and the systems availability

Reliability Centered Maintenance



# Definitions

---



## Reliability Center Maintenance (RCM)

is a **methodology** used to determine **the Right Maintenance Tasks** to **ensure** that any physical asset or system continues what ever **is users want it to do**, in its present operation context.

# Definitions

---



## Reliability

- ✓ The Probability that equipment will not fail in a given time.
- ✓ A measure of the frequency of downtime.

Text

40

## ***Changing Views of Maintenance***

### **1<sup>st</sup> Generation**

- Fix it when it breaks

### **2<sup>nd</sup> Generation**

- Higher availability
- Lower costs
- Longer asset life

### **3<sup>rd</sup> Generation**

- Higher availability, reliability and throughput
- Greater cost-effectiveness
- Greater safety
- Better product quality
- No damage to the environment
- Longer asset life

1930

1940

1950

1960

1970

1980

1990

2000

2010

....

Text

# Maintenance Development

MAINTENANCE TOWARDS RCM

- To repair when failure happens

CORRECTIVE

- Scheduled.
- Inspections based on components wear and life expectation.
- Weak point based on the average time between fails.

CORRECTIVE  
PREVENTIVE

- Anticipate the mistakes by evaluating the state of the machine.
- Preventive diagnosis by Thermography, Ultrasonics, oil analysis etc.

CORRECTIVE  
PREVENTIVE  
PREDICTIVE

- Reliability centered Maintenance.
- Maintenance costs Optimization.
- Recurrent process.

RCM

40

# RCM Advantages

---



- ✓ It can be the **most efficient** maintenance program.
- ✓ It **lowers costs** by eliminating unnecessary equipment maintenance.
- ✓ It **minimizes** the frequency of overhauls.
- ✓ It **reduces** the probability of sudden equipment failures.
- ✓ It focuses **on critical system** components.
- ✓ It **increases** component reliability.



# RCM investigations how equipment fails

---



## **Failure**

A failure is the inability of an equipment, system or plant to fulfill one or more of its intended functions

## **Failure mode**

What is wrong?      What we need to prevent or physically fix?

## **Failure cause**

Why it went wrong?

## **Failure effect**

What is consequence of the failure mode, when it occurs?

## **Failure patterns**

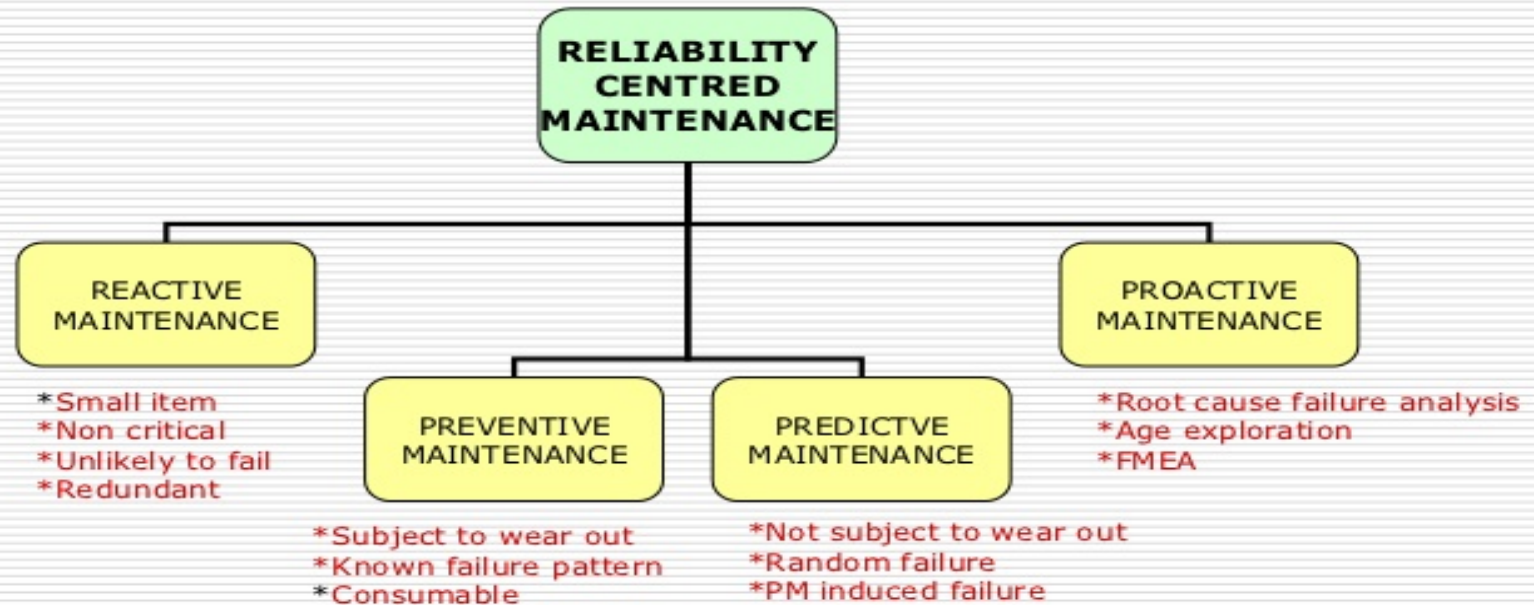
(failure @ specific age)

## **Recommendation**

Text

40

## RELIABILITY CENTRED MAINTENANCE HIERARCHY



# Equipment Availability

---



**Consequence Categories:** There are five consequences categories that can be used to assess the impact of a risk. **1) Financial, 2) Reputation 3) Operational or Production Loss 4) Health & Safety, and 5) Environmental**

**Likelihood Scale:** There are 5 levels of likelihood. The type of scale to be used usually depends on the type of risk being frequency. **L1, L2, L3, L4, and L5**

# System Risk level calculation



Consequence	Score	Likelihood	Score	Measured Risk Score (Likelihood X Consequence)	Risk Level
C1 (Very High)	12	L1 (Very Likely)	8	32 - 96	RL 1 (Major)
C2 (High)	6	L2 (Likely)	6	12 - 24	RL 2 (Significant)
C3 (Moderate)	4	L3 (Possible)	4	6 - 8	RL 3 ( Minor)
C4 (Low)	2	L4 (Unlikely)	2	1 - 4	RL 4 (Insignificant)
C5 (Very Low)	1	L5 (Very Unlikely)	1	1 - 4	RL 4 (Insignificant)

# Criticality Assessment

	Financial (Corporate/Site) Direct Loss in \$	Reputation	Health & Safety	Environment	Operations (Production loss)	Likelihood					
						L5	L4	L3	L2	L1	
						Probability per annum (Operational)					
						<0.01%	>0.01%-0.1%	>0.1- 1%	>1 – 10%	>10%	
						Probability per annum (Financial & Strategic)					
						<1%	> 1-10%	>10-30%	>30-60%	>60%	
						Frequency					
The scenario is not foreseen to occur and is not recorded in the industry/branch*	The scenario may occur in exceptional circumstances but has been recorded in similar industry/branch*	The scenario has occurred in SABIC or has happened more than once per year in similar industry/branch*	The scenario has happened once before at the location / site or more than once per year in SABIC	The scenario is almost certain to occur and has happened several times per year at the location / site							
Very Unlikely	Unlikely	Possible	Likely	Very Likely							
<b>Consequence</b>	C1 Corporate >100M Site >10M	Regional media coverage over multiple days Or Global media coverage	SHEM-10 Class A/ PSI Level-1:		Equivalent to > 5 days	Very High	2 C1-L5	2 C1-L4	1 C1-L3	1 C1-L2	1 C1-L1
			Multiple fatalities to SABIC employees/contractors or public fatality	Chemical release of > than 20 times the Threshold Quantity Release/ spillage > 10 MT of Hazardous Chemicals/ Substance or Hazardous Waste							
	C2 Corporate >10-100M Site >1-10M	National media coverage over multiple days Or Single regional media coverage	SHEM-10 Class A/ PSI Level-2:		Equivalent to >3-5 days	High	3 C2-L5	2 C2-L4	2 C2-L3	1 C2-L2	1 C2-L1
			Fatality or multiple lost workday injuries to SABIC employees/contractors or public injuries	Chemical release between 9 – 20 times the Threshold Quantity Release/ spillage > 10 MT of Hazardous Chemicals/ Substance or Hazardous Waste							
	C3 Corporate >1-10M Site >100K-1M	Local media coverage over multiple days Or Single national media coverage	SHEM-10 Class B/ PSI Level-3:		Equivalent to >1 – 3 days	Moderate	4 C3-L5	3 C3-L4	2 C3-L3	2 C3-L2	1 C3-L1
Lost workday injuries to SABIC employees/contractors			Chemical release between 3 – 9 times the Threshold Quantity Release/ spillage between 4-10 MT of Hazardous Chemicals/ Substance or Hazardous Waste Release/spillage of > 50 MT of Non-Hazardous Chemicals/ Substance								
C4 Corporate >100K-1M Site >10K-100K	Single local media coverage	SHEM-10 Class C/ PSI Level-4:		Equivalent to >8-24 hours	Low	4 C4-L5	4 C4-L4	3 C4-L3	2 C4-L2	2 C4-L1	
		Medical treatment to SABIC employees/contractors	Chemical release between 1 – 3 times the Threshold Quantity Release/ spillage between 0.1-4 MT of Hazardous Chemicals/ Substance or Hazardous Waste Release/spillage btw 20-50 MT of Non-Hazardous Chemicals/ Substance								
C5 Corporate <100K Site <10K	Only internal communications	SHEM-10 Class D/ PSI Level NA:		Equivalent to < 8hrs	Very Low	4 C5-L5	4 C5-L4	4 C5-L3	3 C5-L2	3 C5-L1	
		First aid to SABIC employees/contractors	All other chemical release that does not meet the Threshold Quantity Release/ spillage <0.1 MT of Hazardous Chemicals/ Substance or Hazardous Waste All other incident release/spillage <20 MT of Non-Hazardous Chemicals/Substance								

# RCM Analysis Report

Reliability Centered Maintenance



<b>Function:</b>	5563-1 : To drive cracked gas compressor train with required speed and power.	To drive cracked gas compressor train with required RPM (max speed 3707 RPM) and power (55 MW to 62MW).
<b>Functional Failure:</b>	5563-1-1 : No speed at all.	No speed at all.

Failure Mode	Failure Effect	Risk Assessment				Recommendation Description	Category / Type	Interval	Resource
		Soft.	Env.	Oper.	Reput.				
5563-1-1-1 : Sudden closure of trip and throttle valve, governor valve and extrction valve due to solenoid failure: 12-XV-2854 A (D)	5563-1-1-1-1 : Turbine will trip as trip and throttle valve, governor valve and extrction valve suddenly close due to solenoid failure.	2	2	12		5563-1-1-1-1 ~ To be studied by RIS.	Control System -		
Sudden closure of trip and throttle valve, governor valve and extrction valve due to solenoid failure	Turbine will trip as trip and throttle valve, governor valve and extrction valve suddenly close due to solenoid failure, if solenoid fail it will release all control oil hence all the above valve will be closed. There is a direct impact on operation as without CGC compressor running its not possible to circulate hydrocarbon at required pressure.  TTR: 8 Hours.	Consequence: Operational			To be studied by RIS.This task should also assigned for following tag.  CGC Turbine KT-1200 :12-XV-2854B.				

# RCM implementation flow chart action



**System criticality Assessment**

**RCM implementation flow chart Action**

**Select the System to Analyzed under RCM**

**Perform RCM Analysis**

**Generate Recommendations**

**Implement the generated recommendation**

**Assess the recommendation effectiveness**

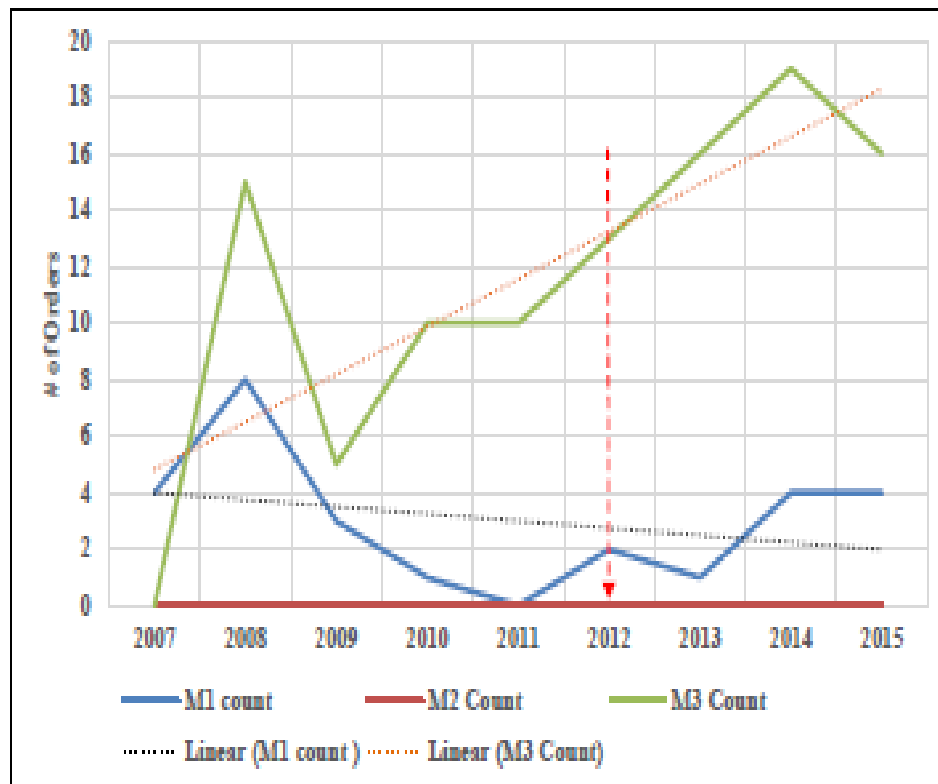
# Case1: Oxygen Supply System Criticality : RL1 with total risk score of

77

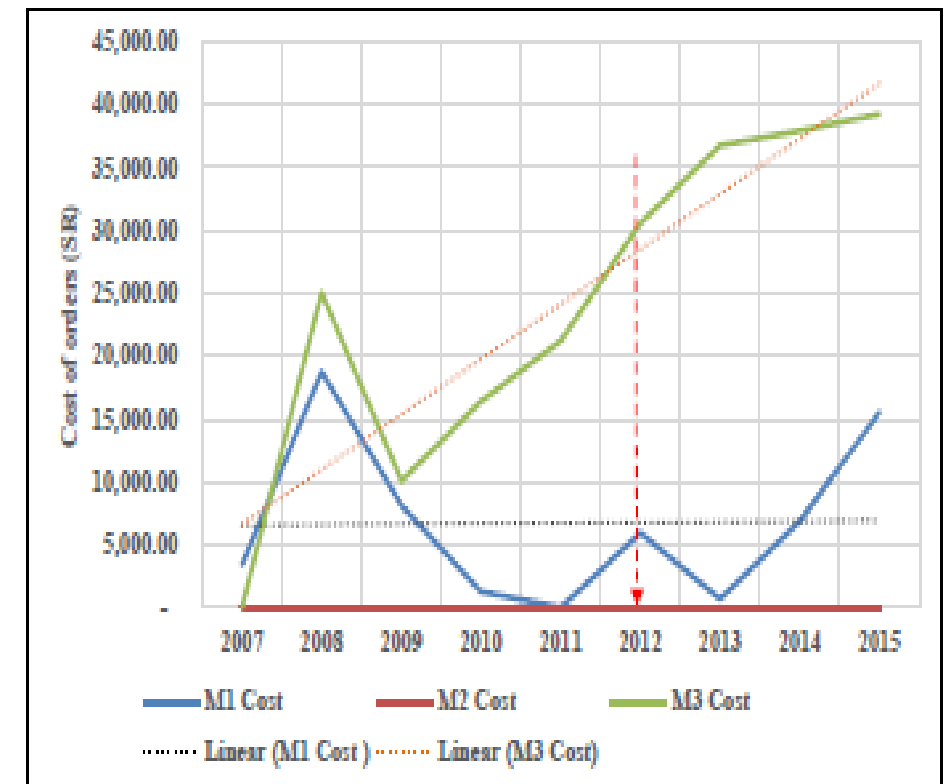
Text

(M1): corrective maintenance orders, (M2): breakdown maintenance orders and  
(M3): planned maintenance orders

### Number of Maintenance orders



### Cost of Maintenance orders



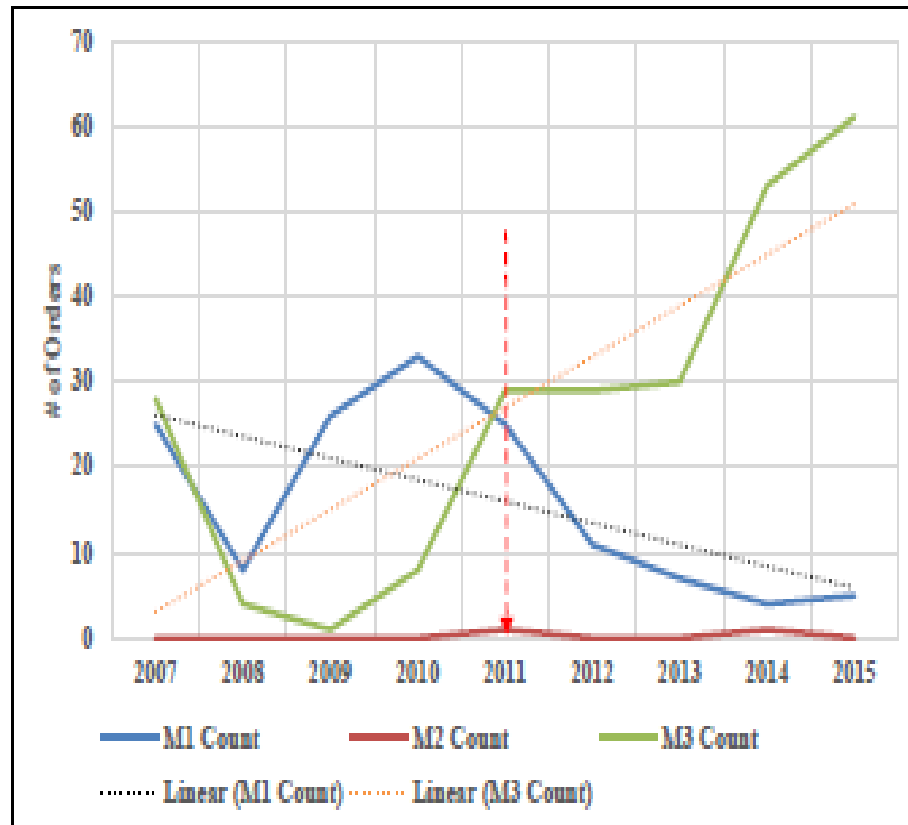
40



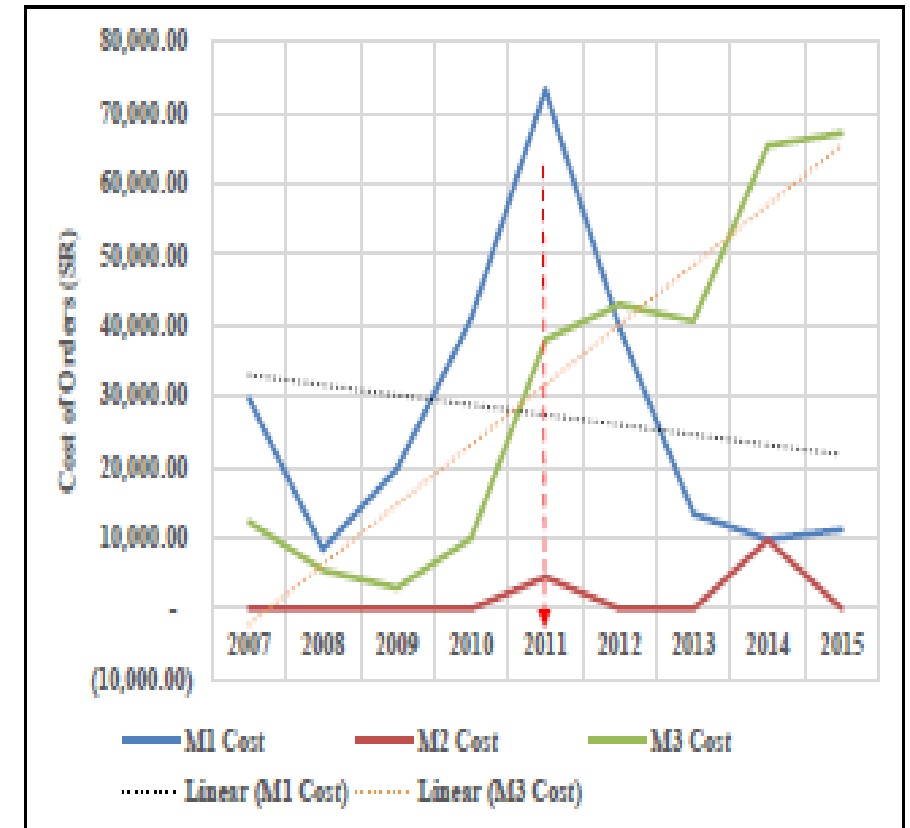
# Case 2: Demineralized Neutralization system criticality:RL1 Total risk score



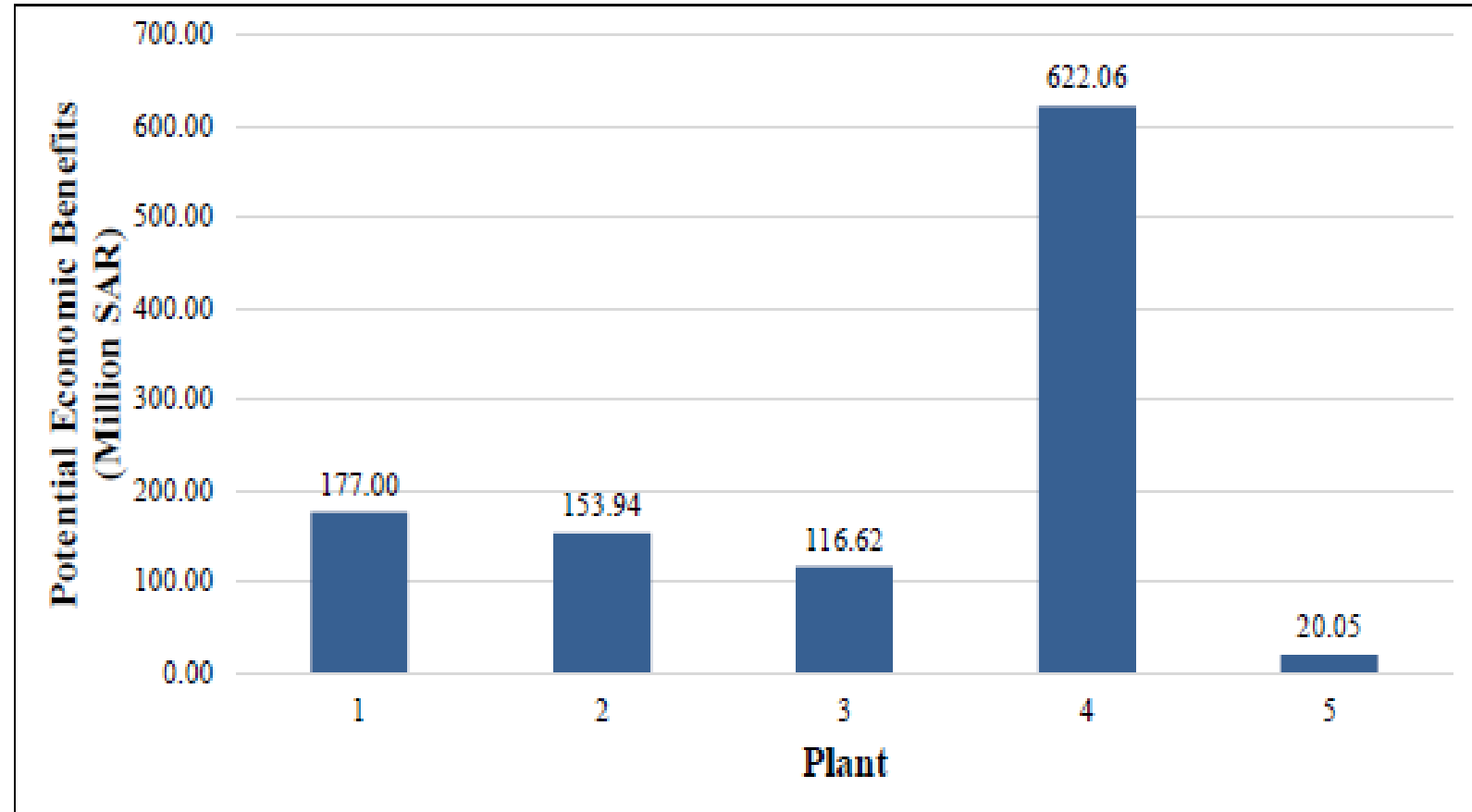
## Number of Maintenance orders



## Cost of Maintenance orders



# RCM Potential Economic benefit (SAR) vs. Plants

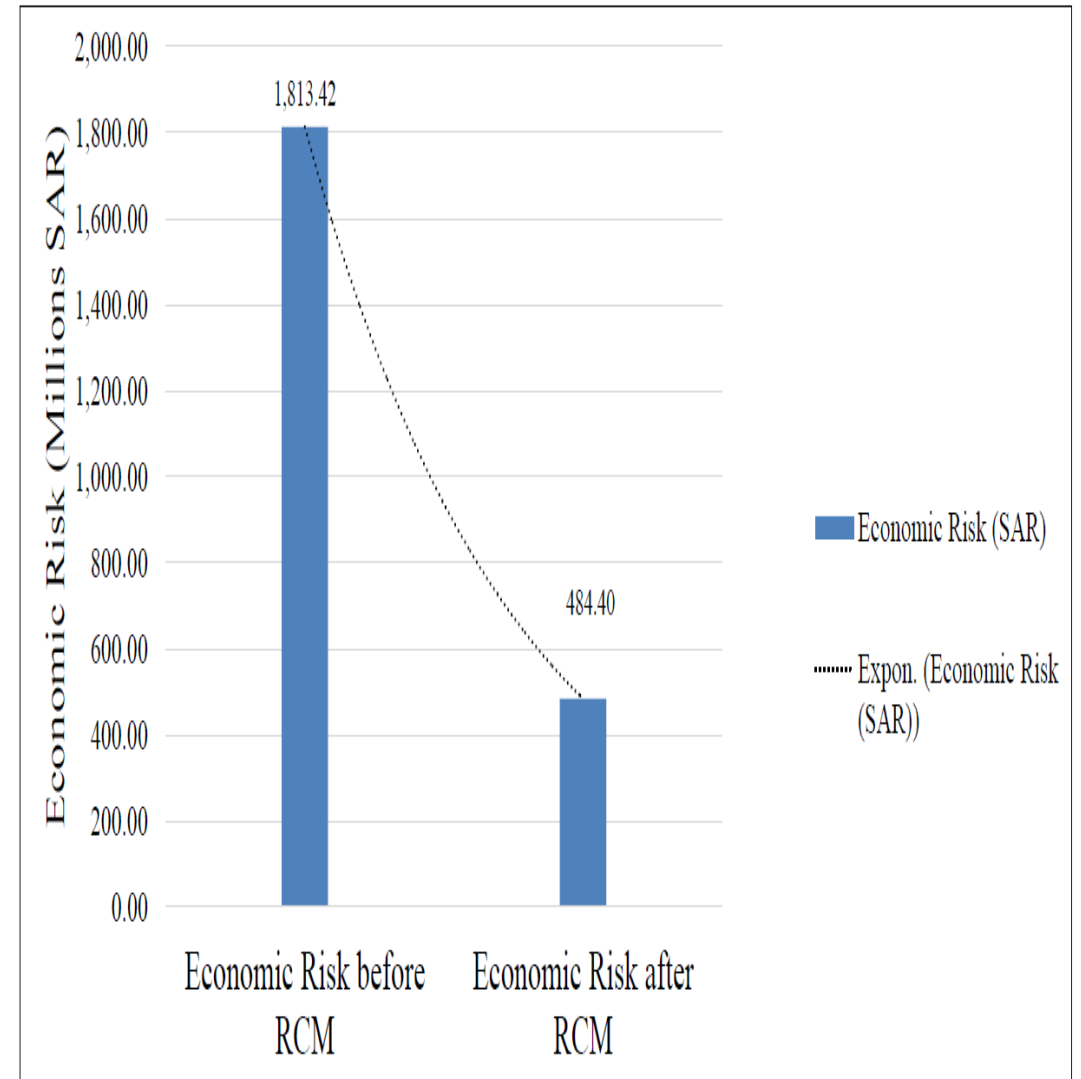


# Economic Risk (SAR) before & after RCM



**The potential economic benefits of RCM will include the followings**

- Reduced production losses and maintenance cost (Economic Benefit)
- Increased reliability and up time of an asset
- Reduced failure consequences
- Improved mechanical integrity
- Improved product quality

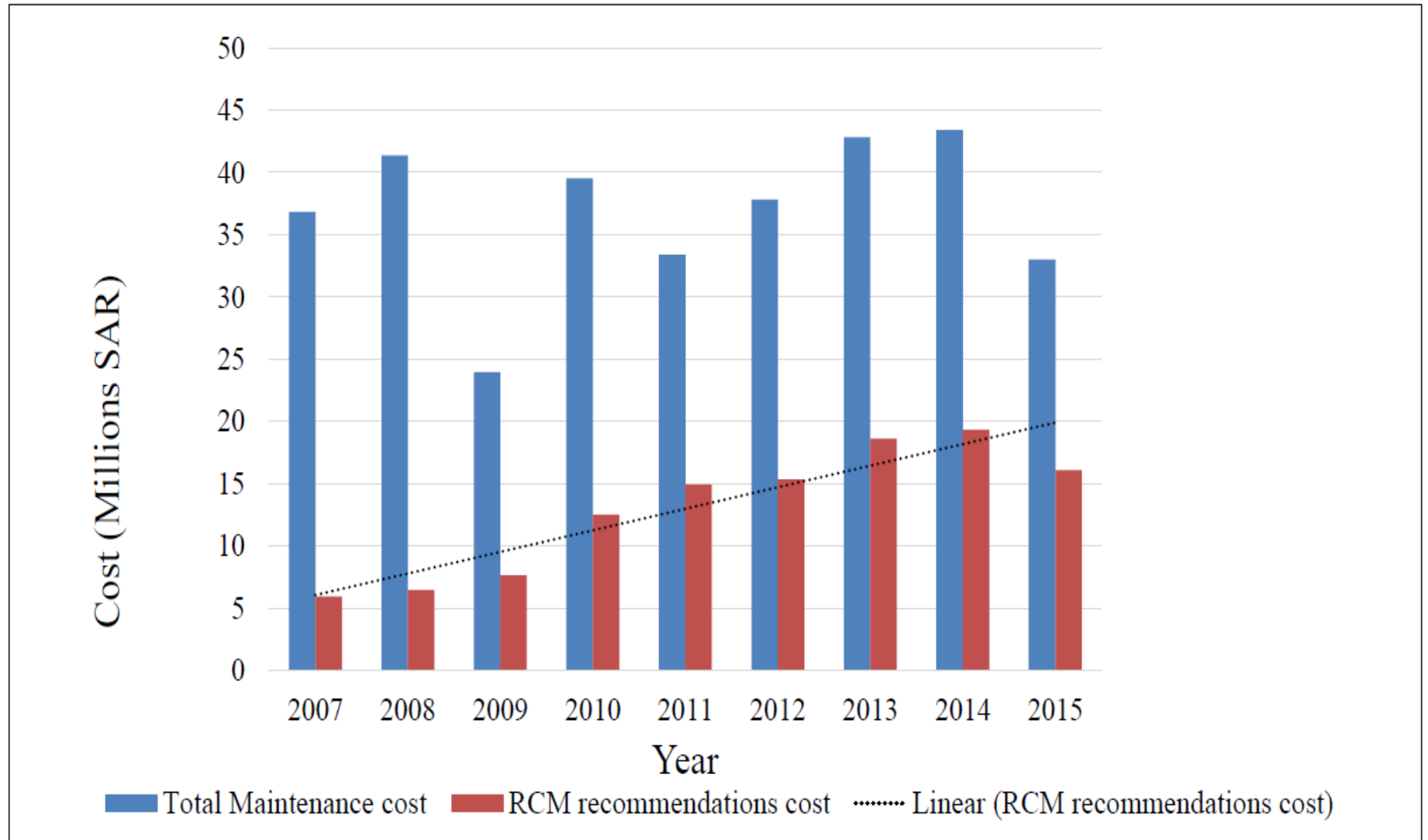


# RCM Recommendation Cost to Total Maintenance

cost

Text

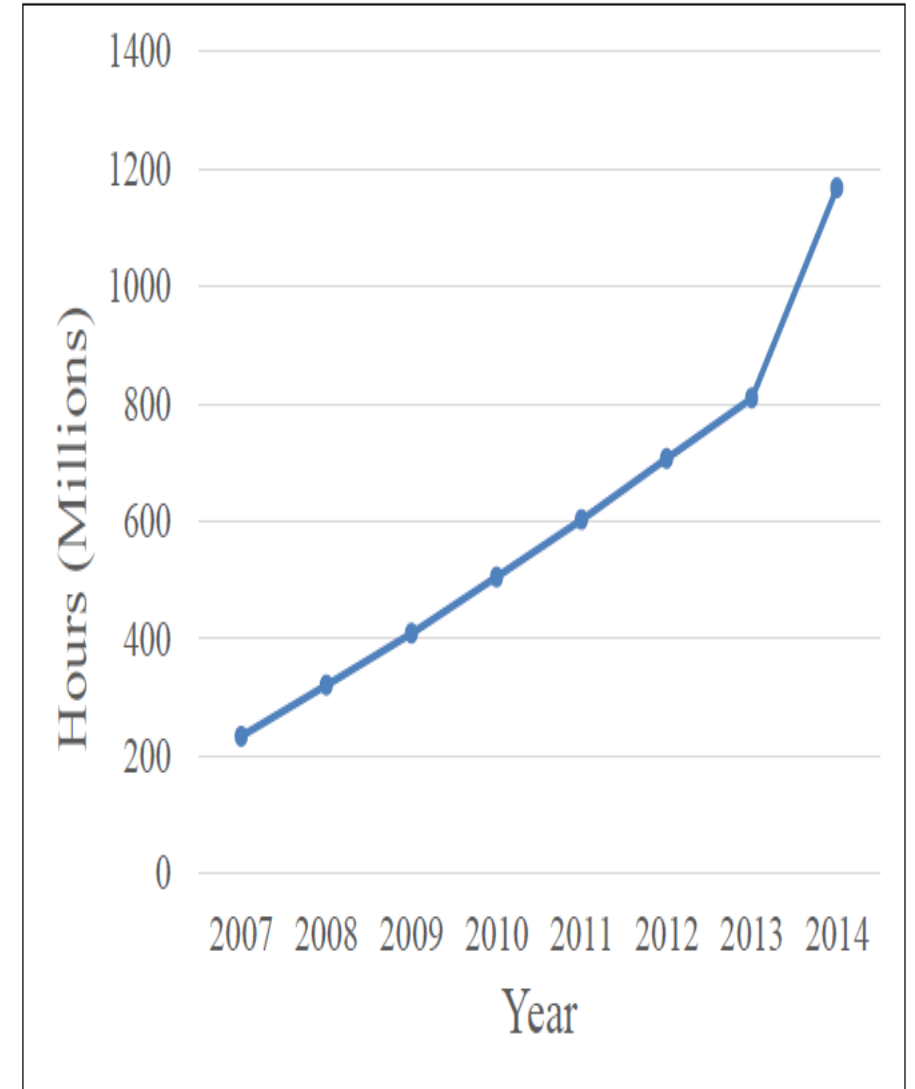
40



# Equipment Availability



Year	Sum of Downtime (Hours)	Sum of Equipment Availability Time (Hours)
2007	776.99	233,833,800
2008	1751.16	321,025,512
2009	10693.16	409,031,184
2010	13668.04	505,272,840
2011	13897.4	602,684,952
2012	14565.03	706,952,064
2013	17552.56	809,871,768
2014	17843.91	1,167,750,672



# Conclusion

---



- ✓ **RCM reduce the maintenance cost and improve the equipment availability.**
- ✓ **By implementing the RCM, a lot of improvement will be gained**
- ✓ **RCM study consume a lot of efforts and cost a lot of money, Organization will have a good return later, financial return & reliability advantages.**
- ✓ **RCM is an effective tool for deciding the right maintenance strategies and eliminating the unwanted maintenance tasks.**
- ✓ **In the case studies, implementing RCM the risk level of the critical systems has been declined**