CONFERENCE OMAINTEC 2018 EXHIBITION

INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE
IN THE ARAB COUNTRIES

UNDER THE THEME
"MANAGING MAINTENANCE WITHIN INDUSTRY 4.0"
CONICIDE WITH THE 16TH ARAB MAINTENANCE EXHIBITION

An Effective and Efficient Model for the Selection of Maintenance Strategy

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How can you make the most out of our business assets?

1. Case Study.
2. Introduction.
3. Maintenance Strategies and IS Issues.
4. The Decision Making Grid Model.
5. Case Study Applications.
6. Conclusions.

Case Study – First Capital Connect

Winner of the Outstanding Award (2012) By the Emerald Literati Excellence Network, MCB Press

JQME
17,2

138

REVIEWS AND CASE STUDIES

Practical application of the Decision Making Grid (DMG)

Nafisah Aslam-Zainudeen
First Capital Connect, London, UK, and
Ashraf Labib
Portsmouth Business School (PBS), University of Portsmouth, Portsmouth, UK

Abstract

Purpose – The purpose of this paper is to explore the applicability of the Decision Making Grid (DMG) and its usefulness, in practice, in the maintenance of rolling stock in the railway industry. The Class 319 fleet operated by First Capital Connect (FCC) is used to demonstrate the application of the DMG.

Design/methodology/approach – The level of use of the data recorded in the CMMS, in the decision making process for reviewing, and updating the maintenance policy, was established through discussions with senior management at FCC. Available decision support systems were then researched, with emphasis on the DMG concept. The advantages of using the DMG and its application in the real world using data for the Class 319 fleet were then explored and are discussed in this paper.

Findings – This paper discusses the value in applying the DMG concept in the decision-making process for prioritising systems and the work that should be done to ensure the maintenance policy takes into account the performance of the units of rolling stock against the most important criteria for FCC. Through the research carried out, it was established that the existing CMMS already records the data required for the application of the DMG, although in itself, the CMMS does not have any decision support capabilities.

Originality/value – Although a number of different CMMSs are used in the railway industry, few or none of these are capable of providing decision support for maintenance. This paper explores the use of the DMG concept to demonstrate the use of data recorded in the CMMS to develop a more effective maintenance policy and to determine exactly which maintenance activities need to be carried out in order to remedy the worst performing systems in terms of the most important criteria as identified by the business.

Keywords Decision making, Analytic hierarchy process, Decision support systems, Railways, Maintenance, United Kingdom

Paper type Case study

1. Introduction

Computer maintenance management systems (CMMS) are widely used in the maintenance of rolling stock in the railway industry. All of these systems act as effective databases for storing the technical history of all the rolling stock operated by each train operating company (TOC). Some of the more contemporary CMMSs have the capability of producing trends in the data that are recorded, which engineers use to determine what changes need to be made to the maintenance policy. However, most if not all the CMMSs used for the purpose of maintaining rolling stock do not have the capability of providing maintenance engineers or asset managers with decision support – i.e. although the CMMSs are capable of analysing the data that are recorded,

Emerald

Journal of Quality in Maintenance Engineering
Vol. 17 No. 2, 2011
pp. 138-149

1355-2511
DOI 10.1108/13552511111134574

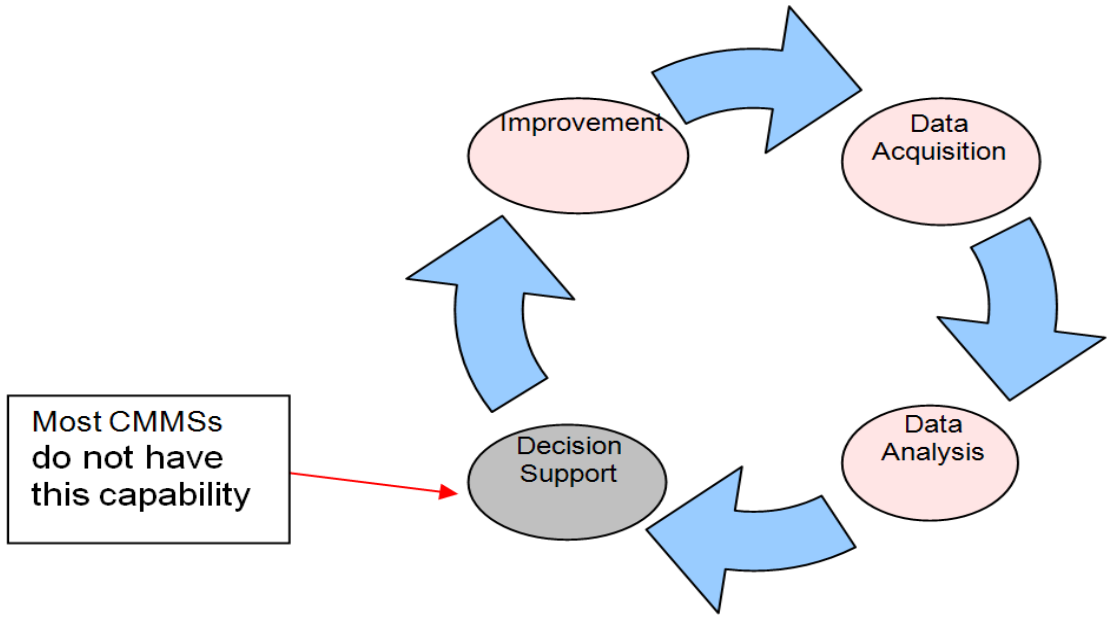


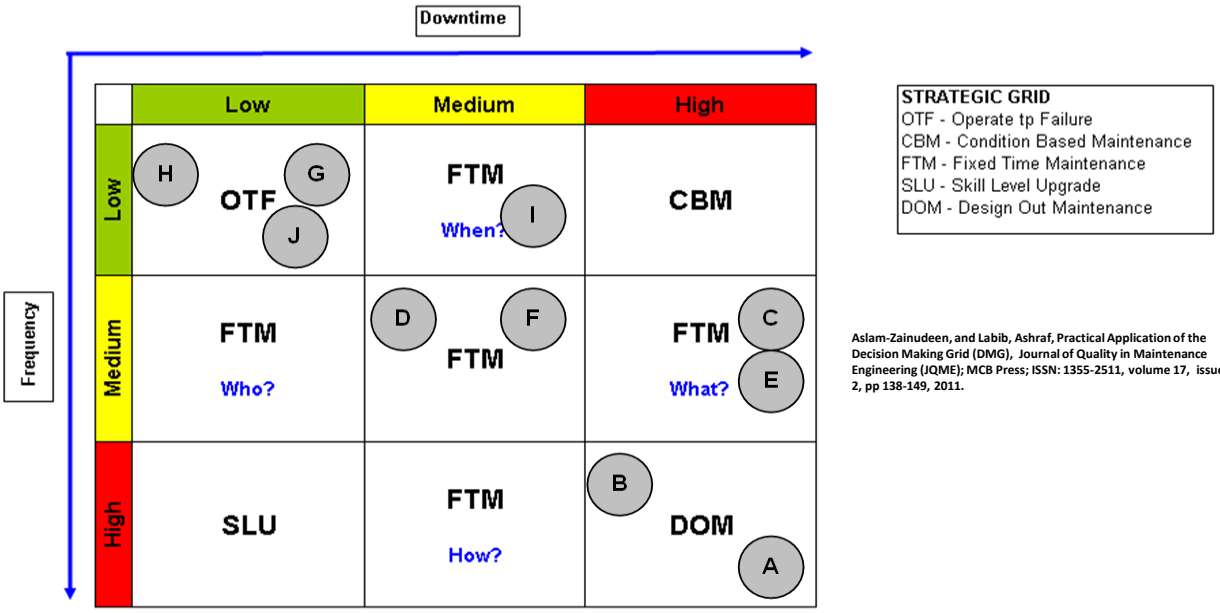
Figure 1: The Effective Asset Management Cycle

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

		Criteria 1 (Frequency)	No. of Failures			Criteria 2 (Downtime)	Delay minutes
High	A	Power	18	High	B	Doors	268
High	B	Doors	13	High	A	Power	225
Medium	C	Safety Systems	5	High	E	Brakes	122
Medium	D	Air Systems	5	High	C	Safety Systems	68
Medium	E	Brakes	4	Medium	F	Current Collection Equipment	51
Medium	F	Current Collection Equipment	4	Medium	D	Air Systems	34
Low	G	Interior Seats, Floor and Trims	3	Medium	I	Train Communication	32
Low	H	Jumpers and Coupling	2	Low	G	Interior Seats, Floor and Trim	28
Low	I	Train Communication	1	Low	H	Jumpers and Coupling	25
Low	J	Underframe	1	Low	J	Underframe	8
		Sum of Top 10	**56**			**Sum of Top 10**	**861**
		Sum of All	**59**			**Sum of All**	**899**
		Percentage	**94%**			**Percentage**	**95%**

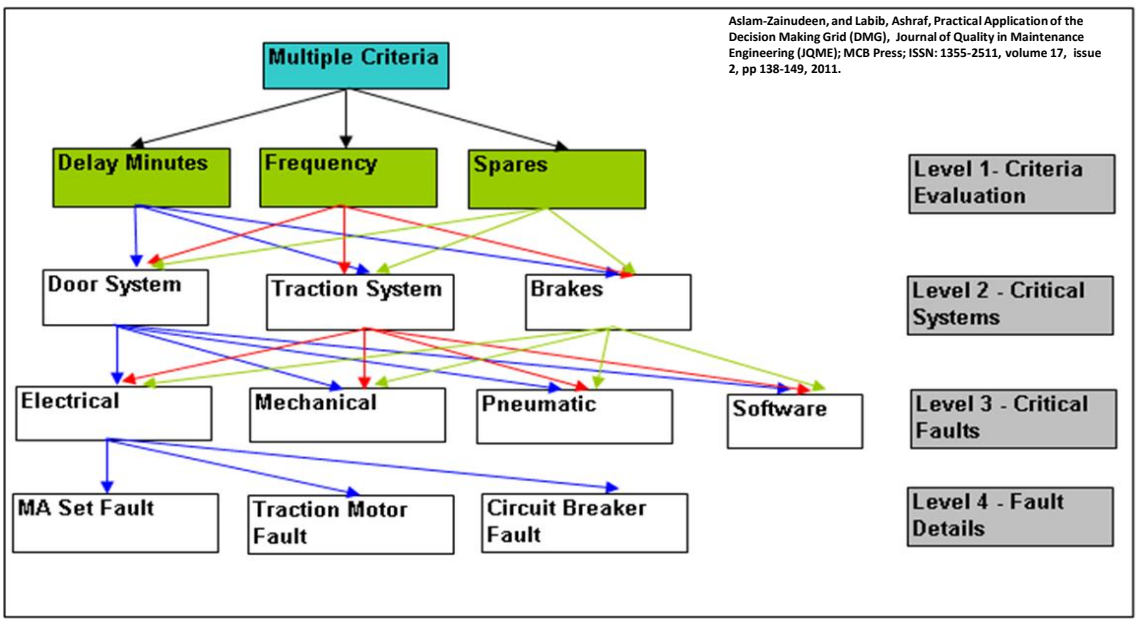
Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Criteria analysis for DMG



Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Figure 4: The Decision Making Grid



Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Figure 6: The Analytic Hierarchy Process for the FCC Class 319s

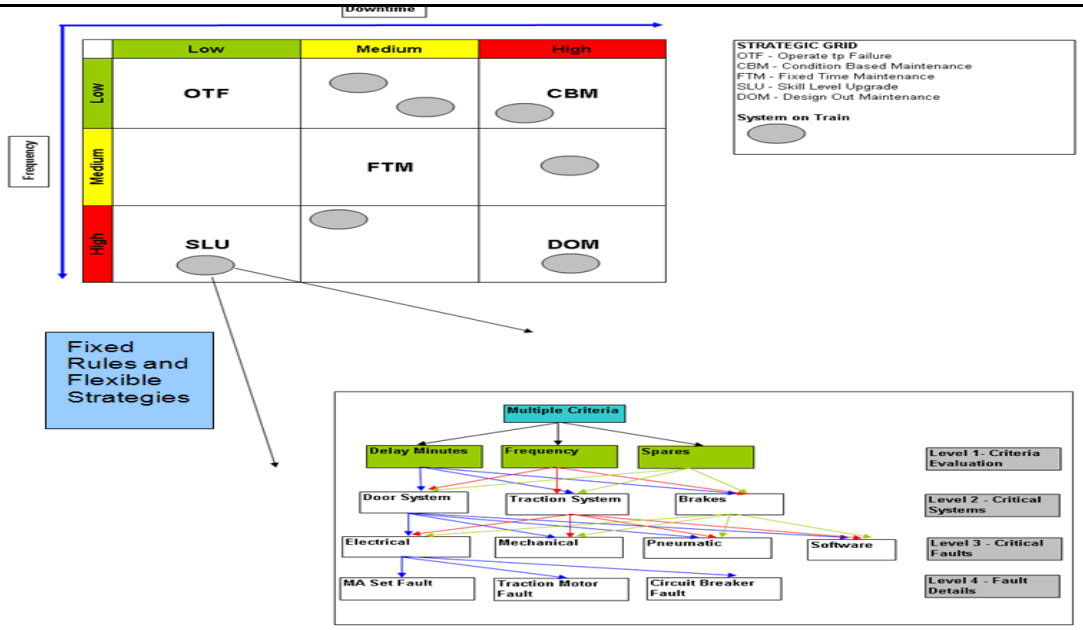


Figure 3: Holonic Maintenance System for First Capital Connect (based on Labib, 2004)

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Introduction

Fundamental questions that need to be asked with regard to existing Computerised Maintenance Management Systems (CMMSs):

- What do users really want from a CMMS?
- Does it support what is happening in the shop-floor? Or, Is it a rather expensive calendar to remind one of when to perform a maintenance schedule?
- Is it really worth spending so much effort, time, and money in buying a system for just being an electronic calendar or a monitoring device?
- Do existing CMMSs really contribute to the bottom line benefits of the company and support in the reduction of breakdowns or are they just a beast to be served by an army of IT specialists?

BUT...

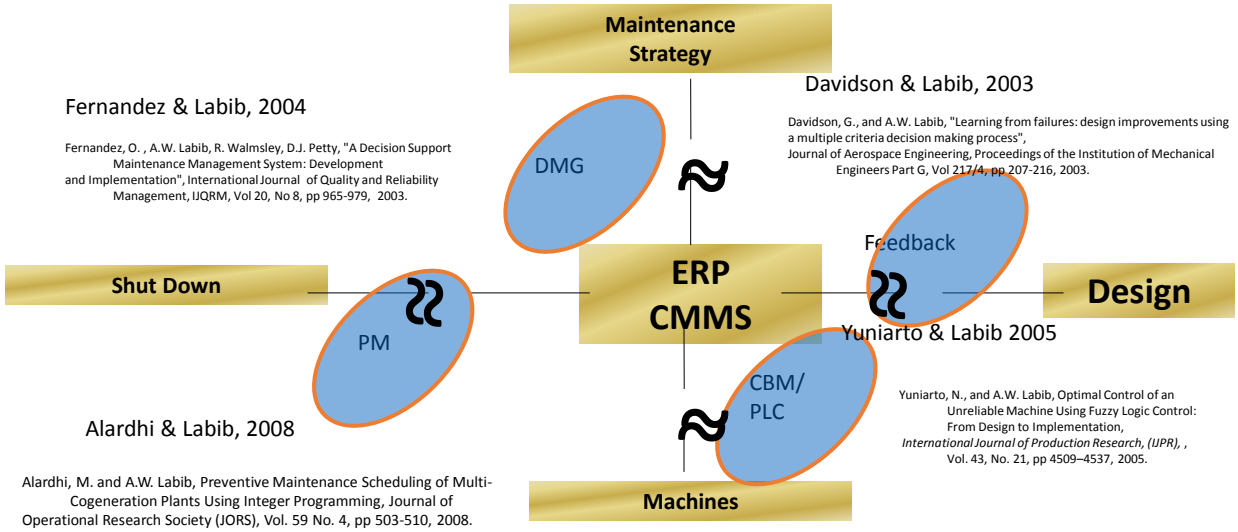
There exists some sort of black hole

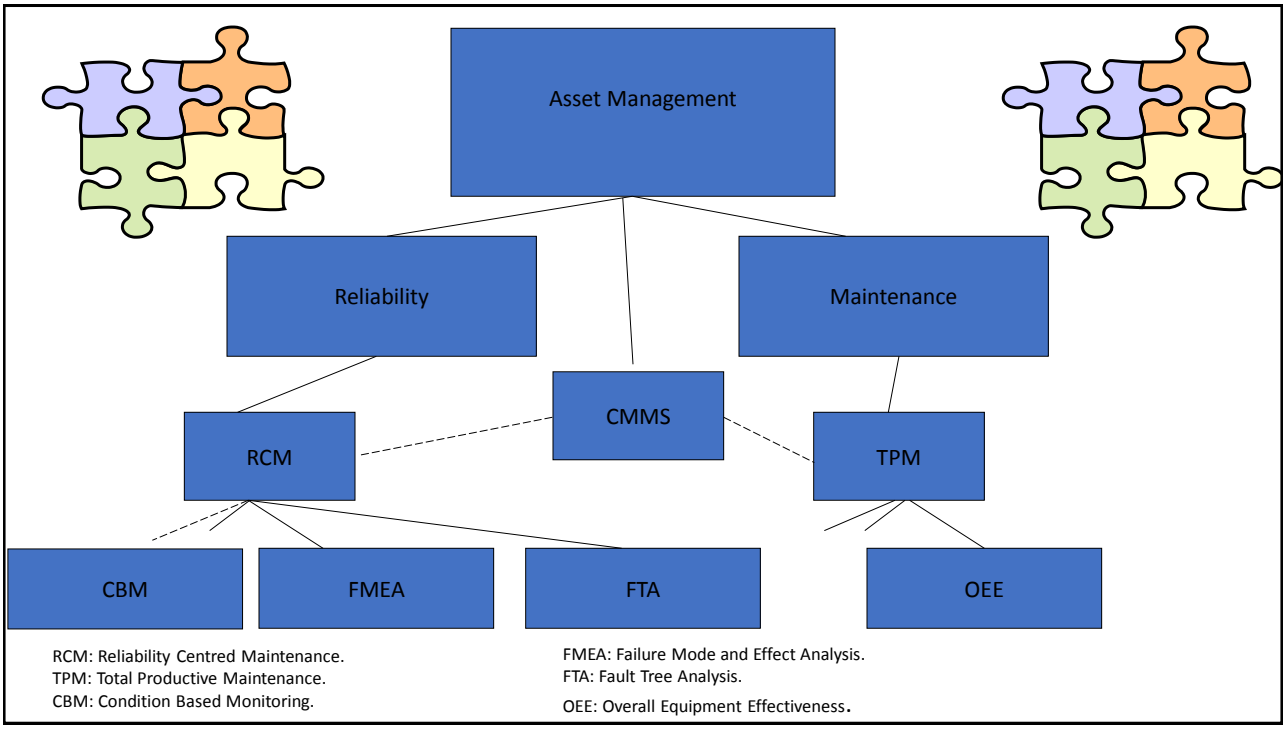
We have proofs…

Evidence of Black Holes

In short, companies tend to spend a vast amount of capital in acquisition of of-the-shelf systems for data collection and their added value to the business is questionable.

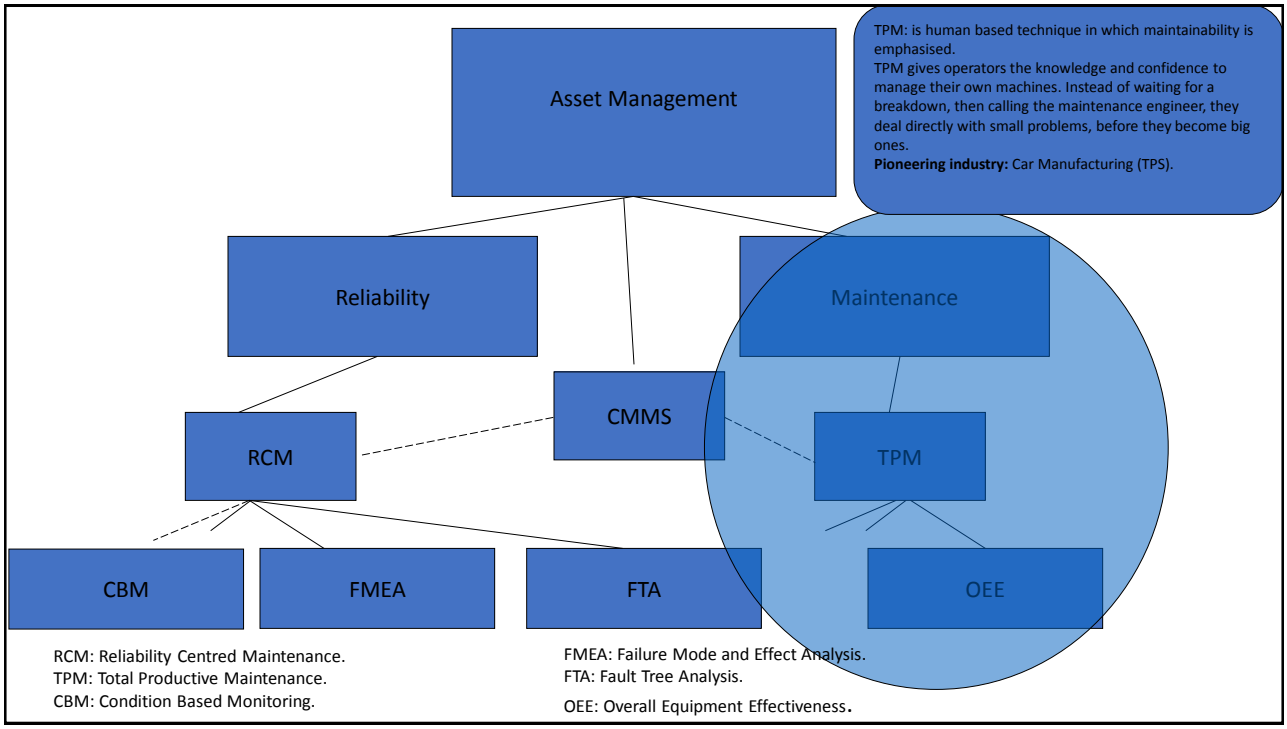
Gaps Model of ERP/CMMSs



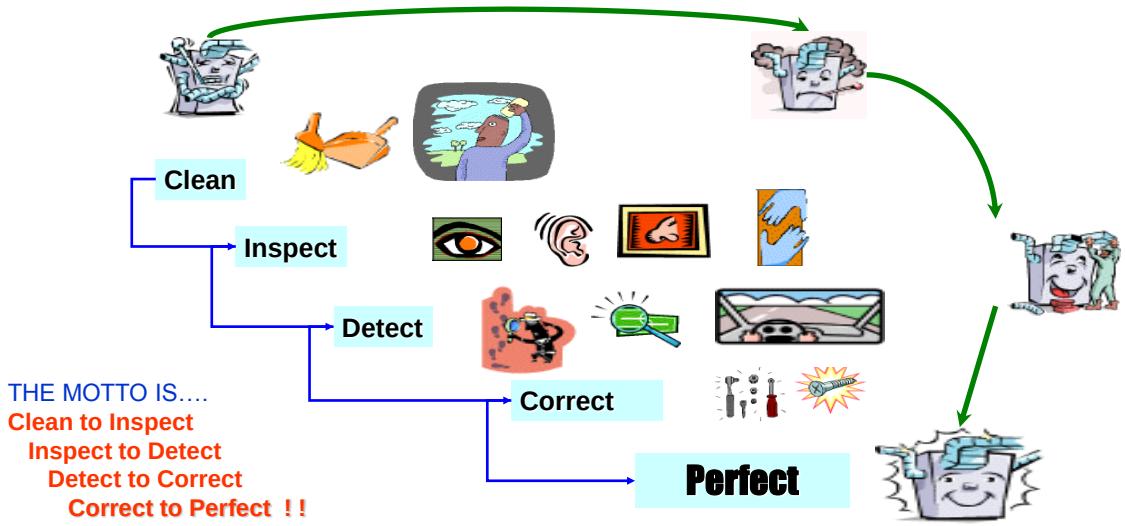


RCM: Reliability Centred Maintenance.
TPM: Total Productive Maintenance.
CBM: Condition Based Monitoring.

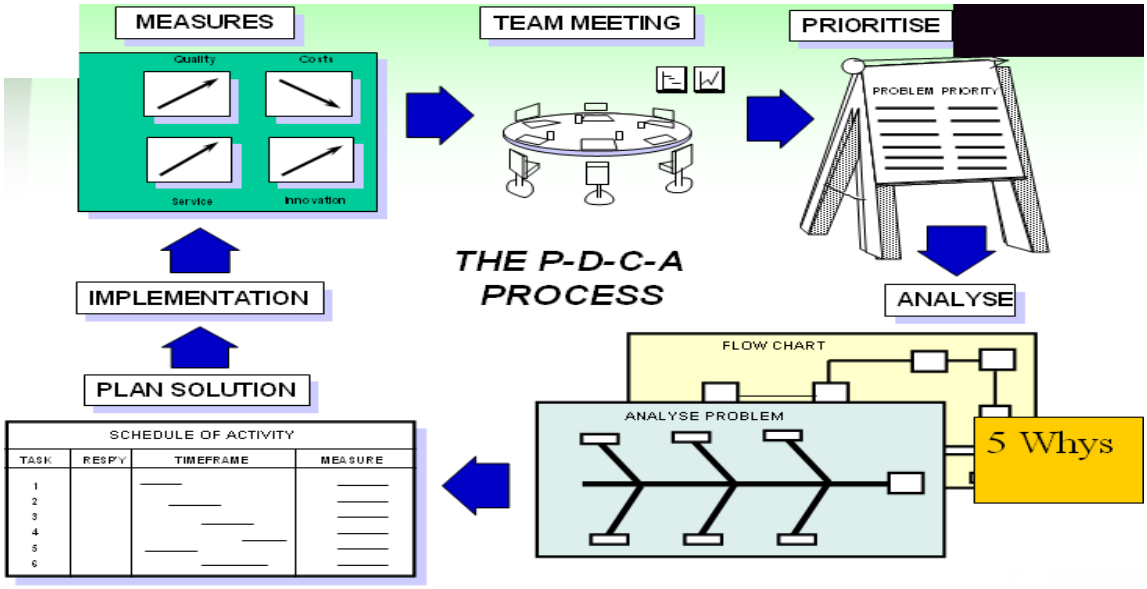
FMEA: Failure Mode and Effect Analysis.
FTA: Fault Tree Analysis.
OEE: Overall Equipment Effectiveness.



Autonomous Maintenance – in a nutshell



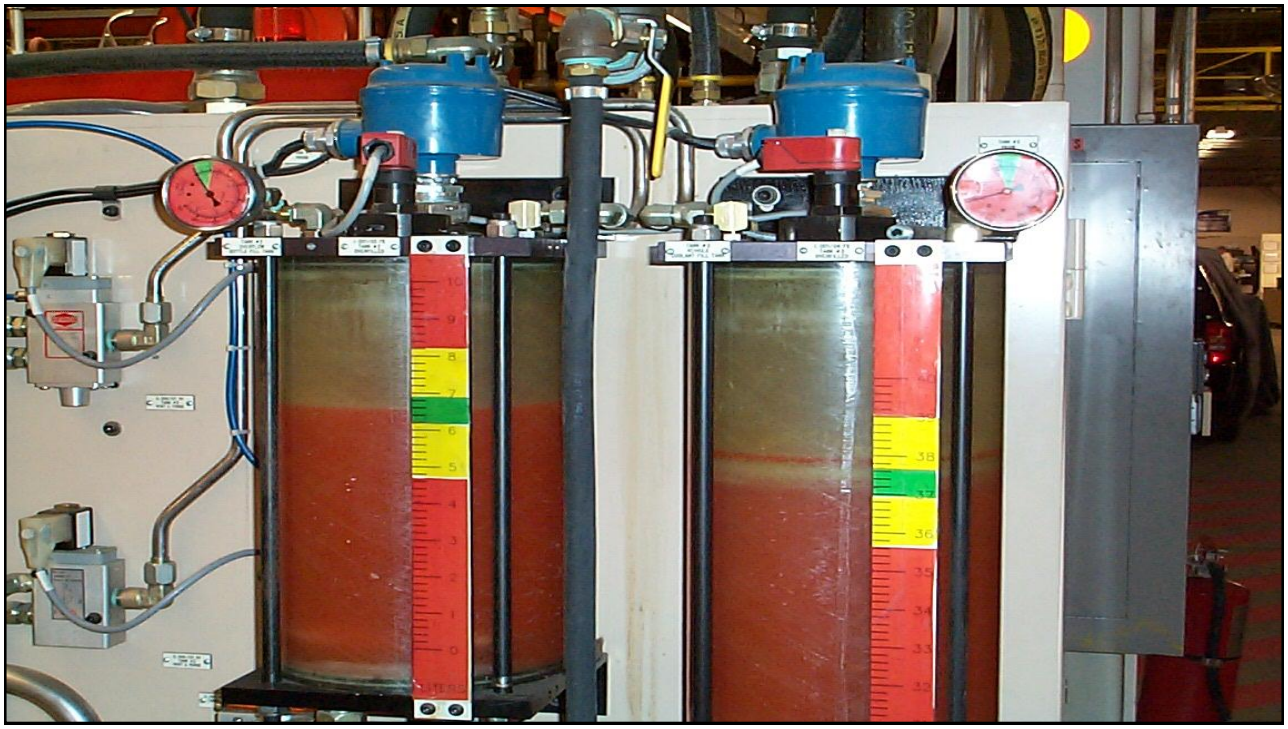
Tools



Making Monitoring Easier

Before **After**

Ensure proper water flow to the bearings of a boiler water supply pump



Making Monitoring Easier

Making Inspection Easier

Before

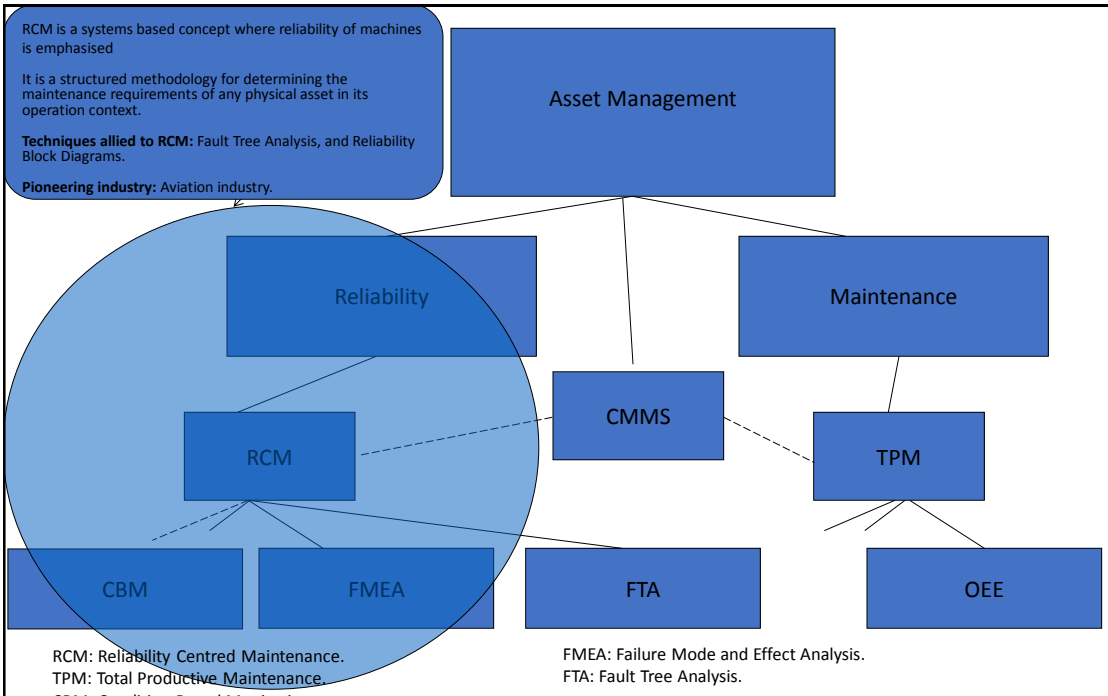
After

RCM is a systems based concept where reliability of machines is emphasised

It is a structured methodology for determining the maintenance requirements of any physical asset in its operation context.

Techniques allied to RCM: Fault Tree Analysis, and Reliability Block Diagrams.

Pioneering industry: Aviation industry.



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FMEA: Failure Mode and Effect Analysis.
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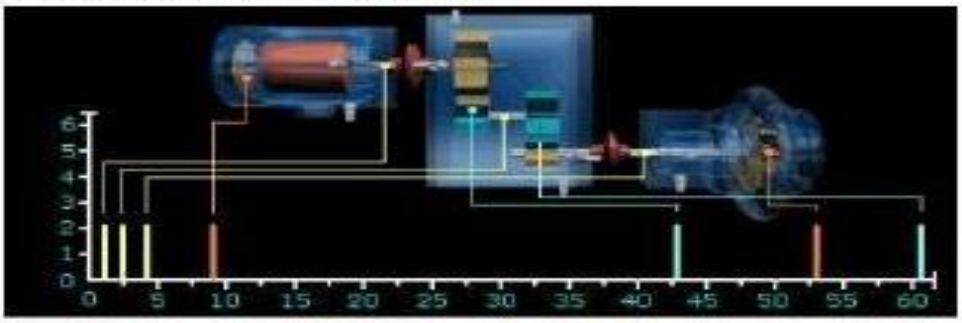
Control the test conditions

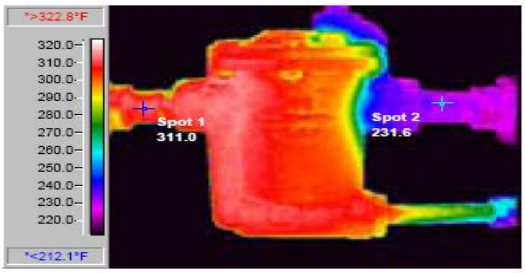
- Vibration changes when the speed and load change.
- The machine must operate in the same state during every test.
- Check the speed and load.

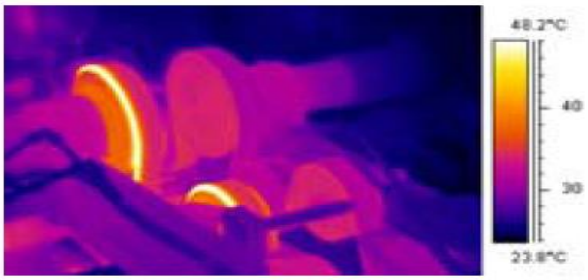
Introducing "forcing frequencies"

- Special calculations are used to indicate where to look in the spectrum – called "forcing frequencies".
- Most vibration analysis programs will perform these calculations.

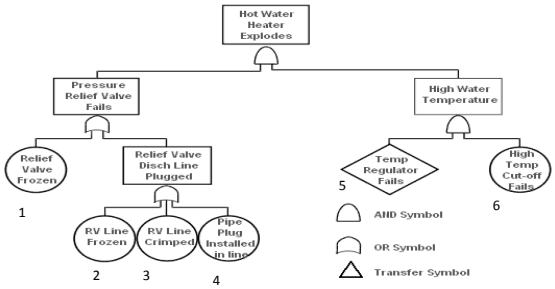


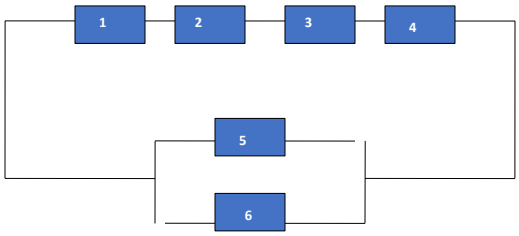
Equipment


*>322.8°F
320.0
310.0
300.0
290.0
280.0
270.0
260.0
250.0
240.0
230.0
220.0
*<212.1°F
Spot 1
311.0
Spot 2
231.6


48.2°C
40
30
23.8°C

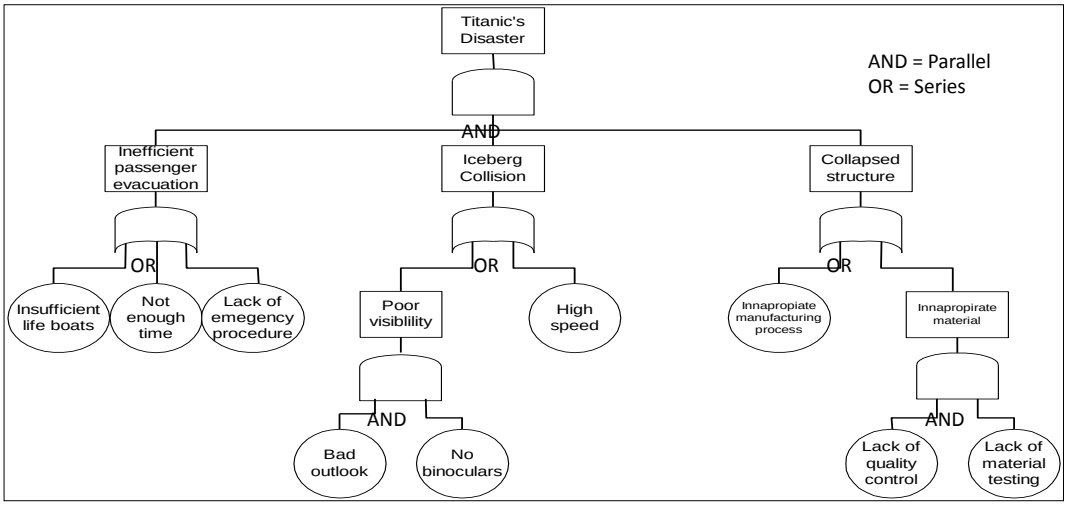
Reliability Centred Maintenance (RCM):
- Fault Tree Analysis (FTA)
- Reliability Block Diagrams (RBD)



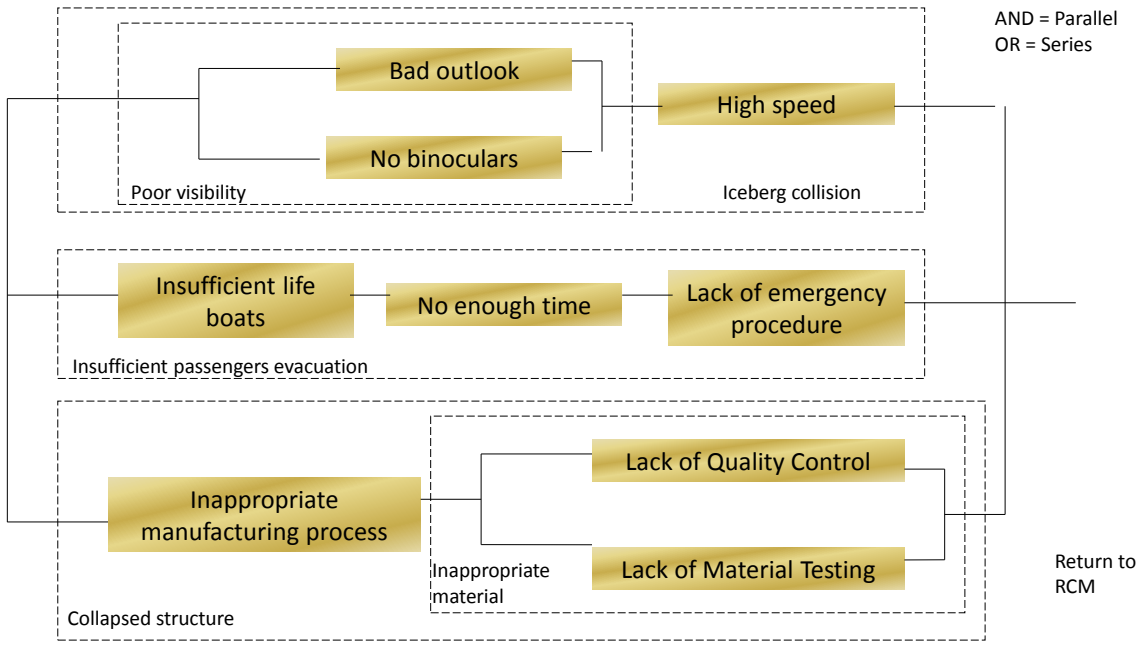


Titanic The Unsinkable Ship That Sank

Fault Tree Analysis (FTA) for the Titanic Disaster



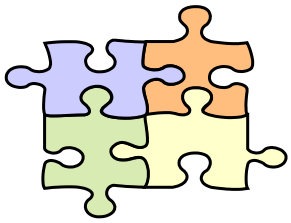
Reliability Block Diagram (RBD) for the Titanic Disaster

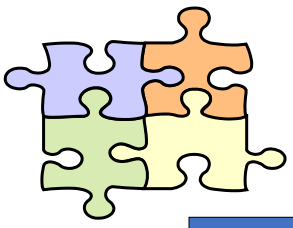


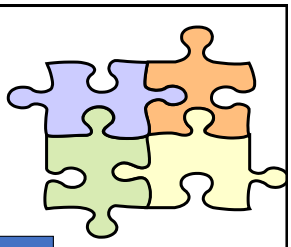
Theoretical Background:

Maintenance & Reliability Policies – Proposed Approach (Model)

- The proposed approach is innovative in that it offers a decision map adaptive to the collected data where it suggest the appropriate use of RCM, TPM, and CBM as well as additional ones.







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FTA: Fault Tree Analysis.
OEE: Overall Equipment Effectiveness.

Proposed Model:

The model identifies 5 levels of maintenance strategies which have an impact on performance.

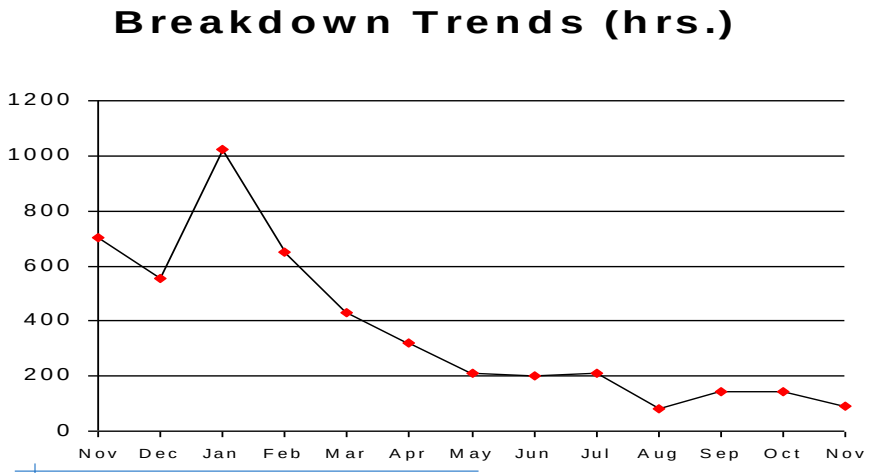
1. OTF: Operate To Failure (or keep the best practice).
2. SLU: Skill Level Upgrade (In general: TPM).
3. CBM: Condition Based Maintenance (In general: RCM).
4. FTM: Fixed Time Maintenance.
   A. Easy FTMs (Who, and When).
   B. Difficult FTMs (What, and How).
5. DOM: Design Out Maintenance.

Proposed Model:
The Decision Making Grid (DMG)

- It acts as a map where the performances of the worst machines are placed based on multiple criteria.
- The objective is to implement appropriate maintenance actions that will lead to the movement of machines towards an improved state with respect to multiple criteria.
- The outputs of the model are:
  - a) classification of maintenance related policies, and
  - b) prioritisation of the proposed actions.

An Industrial Case Study

This case study demonstrates the application of the proposed model and its effect on asset management performance. The application of the model is shown through the experience of a company seeking to achieve World-Class status in asset management. The company has implemented the proposed model which has had the effect of reducing total downtime from an average of 800 hours per month to less than 100 hours per month as shown in Figure.



Company Background and Methodology

In this particular company there are 130 machines, varying from robots, and machine centres, to manually operated assembly tables. Notice that in this case study, only two criteria are used (frequency, and downtime). However, if more criteria are included such as spare parts cost and scrap rate, the model becomes multi dimensional, with low, medium, and high ranges for each identified criterion. The methodology implemented in this case was to follow three steps. These steps are i. Criteria Analysis, ii. Decision Mapping, and iii. Decision Support.

Data Analysis for the DMG

Criteria:	Downtime		Frequency	
	Name	Downtime (hrs)	Name	Frequency (No. off)
	Machine [A]	30	Machine [G]	27
	Machine [B]	20	Machine [C]	16
	Machine [C]	20	Machine [D]	12
	Machine [D]	17	Machine [A]	9
	Machine [E]	16	Machine [I]	8
	Machine [F]	12	Machine [E]	8
	Machine [G]	7	Machine [k]	8
	Machine [H]	6	Machine [F]	4
	Machine [I]	6	Machine [B]	3
	Machine [j]	4	Machine [H]	2
	Sum of Top 10	**138**	**Sum of Top 10**	**97**
	Sum of All	**155**	**Sum of All**	**120**
	Percentage	**89%**	**Percentage**	**81 %**

Criteria Evaluation

A reflective question:

If you were my maintenance manager, what policy action(s) would you instruct me to improve the situation in this report?

- The DO's:
  - Actions should be policy related.
  - Actions should be pragmatic/practical.
- The DO NOT's:
  - No reports from reports (paralysis by analysis).
  - No theoretical slogans ('go and fix machine A', because this what I normally do).

Proposed Model:

The model identifies 5 levels of maintenance strategies which have an impact on performance.

1. OTF: Operate To Failure.
2. SLU: Skill Level Upgrade. In general: TPM.
3. CBM: Condition Based Maintenance. In general: RCM.
4. FTM: Fixed Time Maintenance.
   A. Easy FTMs (Who, and When).
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Proposed Model:

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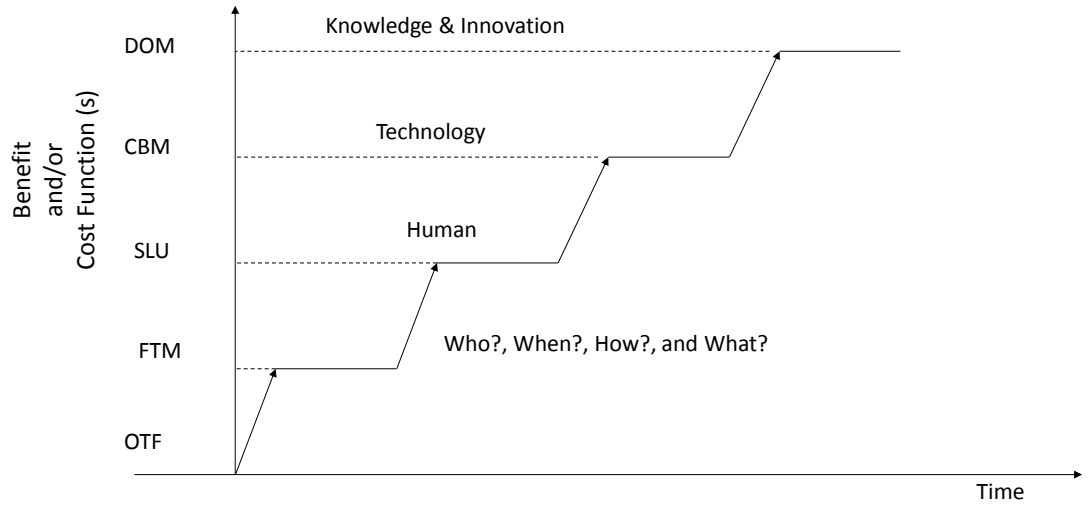
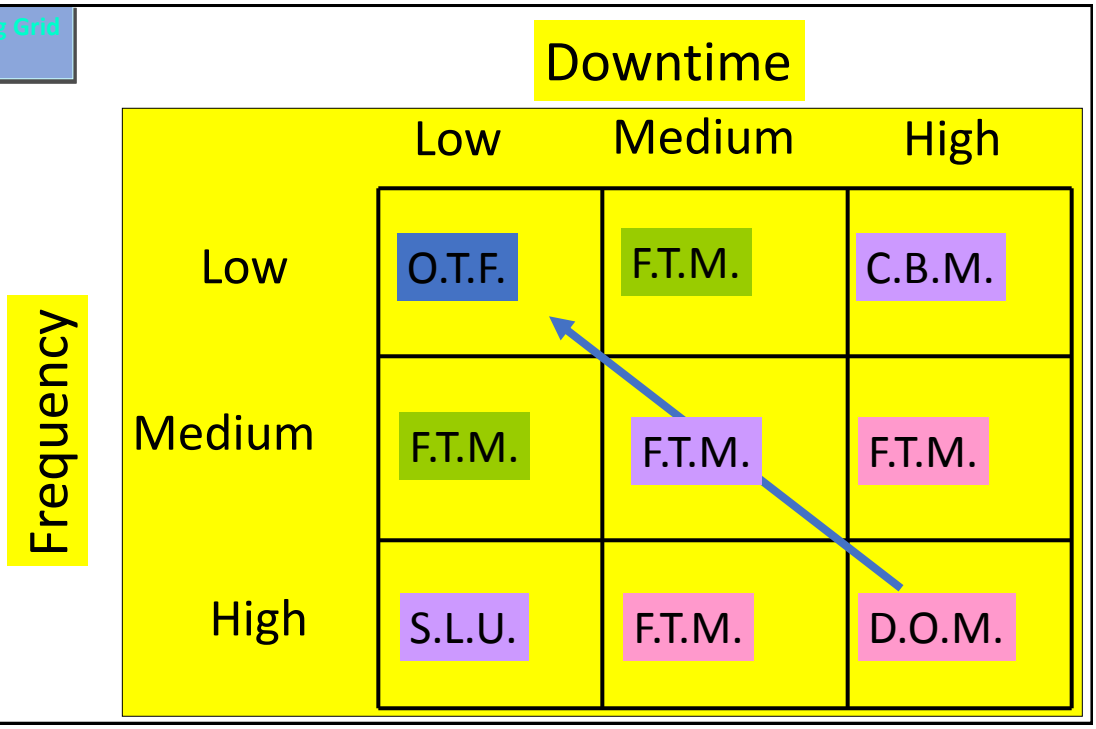


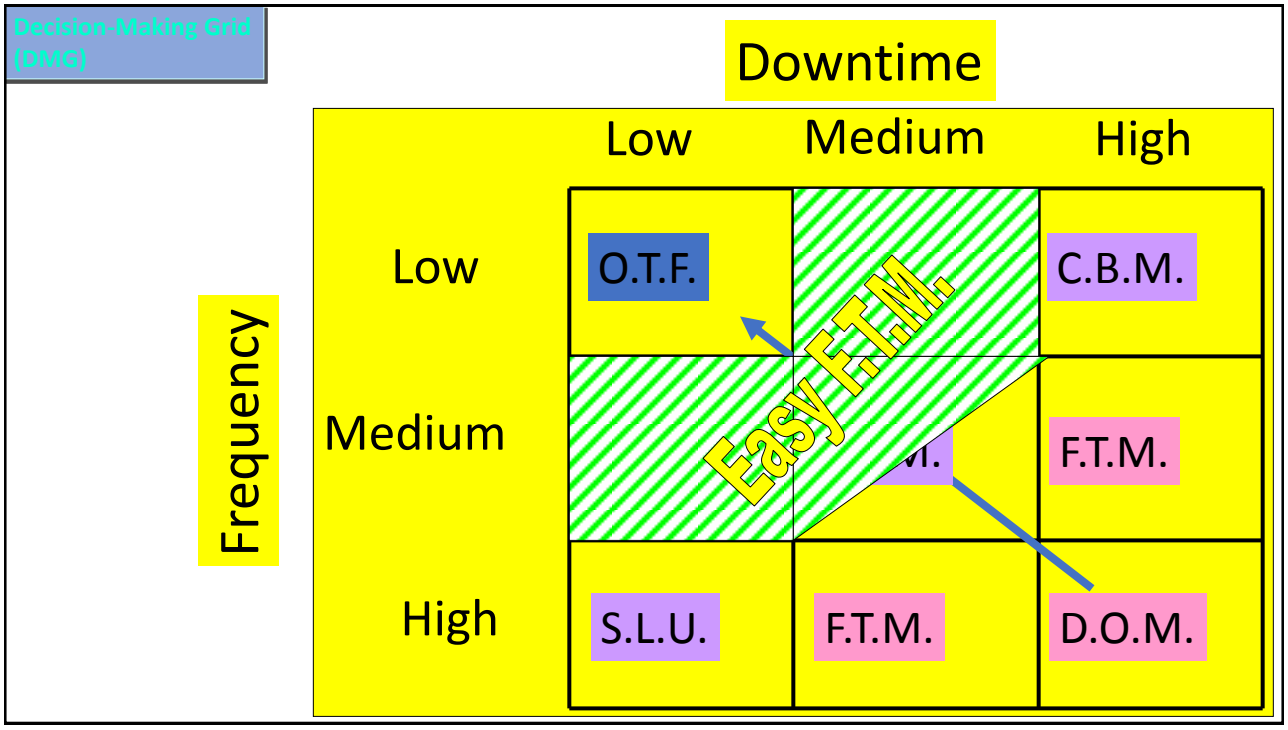
Data Analysis for the DMG

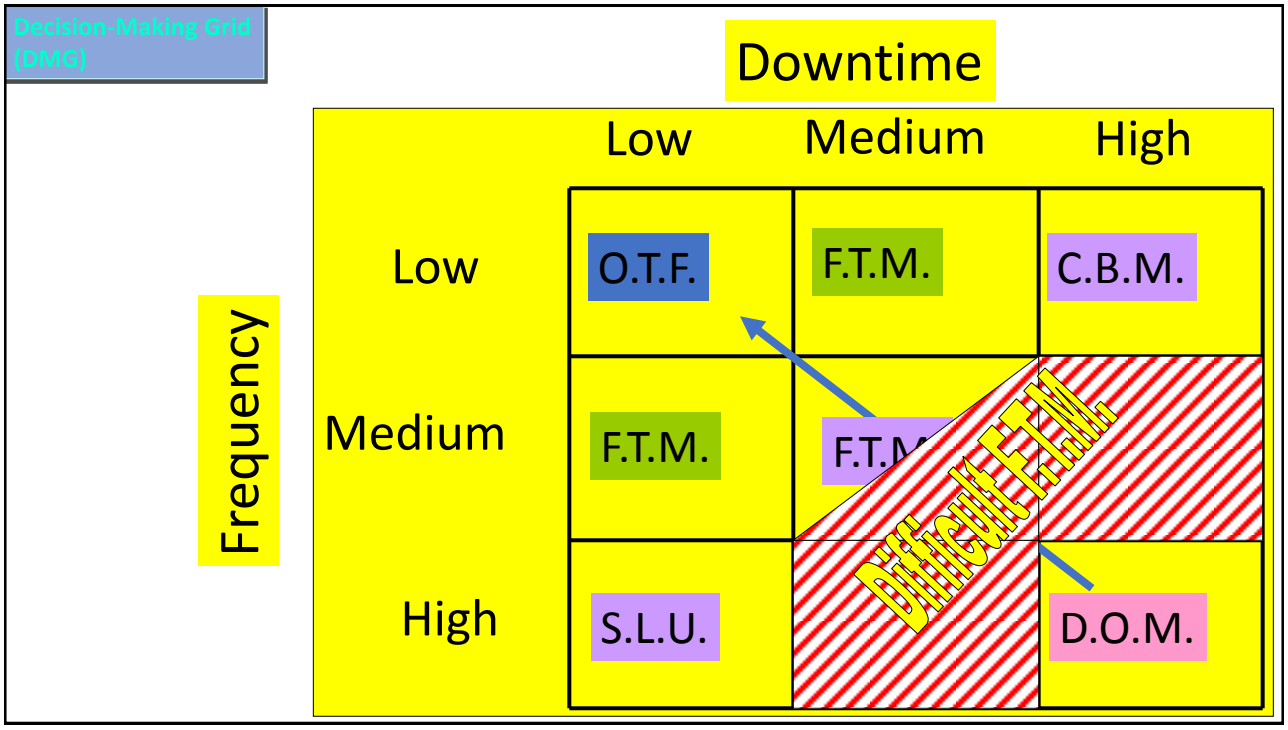
Criteria:	Downtime		Frequency		
	Name	Downtime (hrs)	Name	Frequency (No. off)	
HIGH	Machine [A]	30	Machine [G]	27	HIGH
	Machine [B]	20	Machine [C]	16	
	Machine [C]	20	Machine [D]	12	
MEDIUM	Machine [D]	17	Machine [A]	9	MEDIUM
	Machine [E]	16	Machine [I]	8	
	Machine [F]	12	Machine [E]	8	
LOW	Machine [G]	7	Machine [k]	8	
	Machine [H]	6	Machine [F]	4	LOW
	Machine [I]	6	Machine [B]	3	
	Machine [j]	4	Machine [H]	2	
	Sum of Top 10	**138**	**Sum of Top 10**	**97**	
	Sum of All	**155**	**Sum of All**	**120**	
	Percentage	**89%**	**Percentage**	**81 %**	

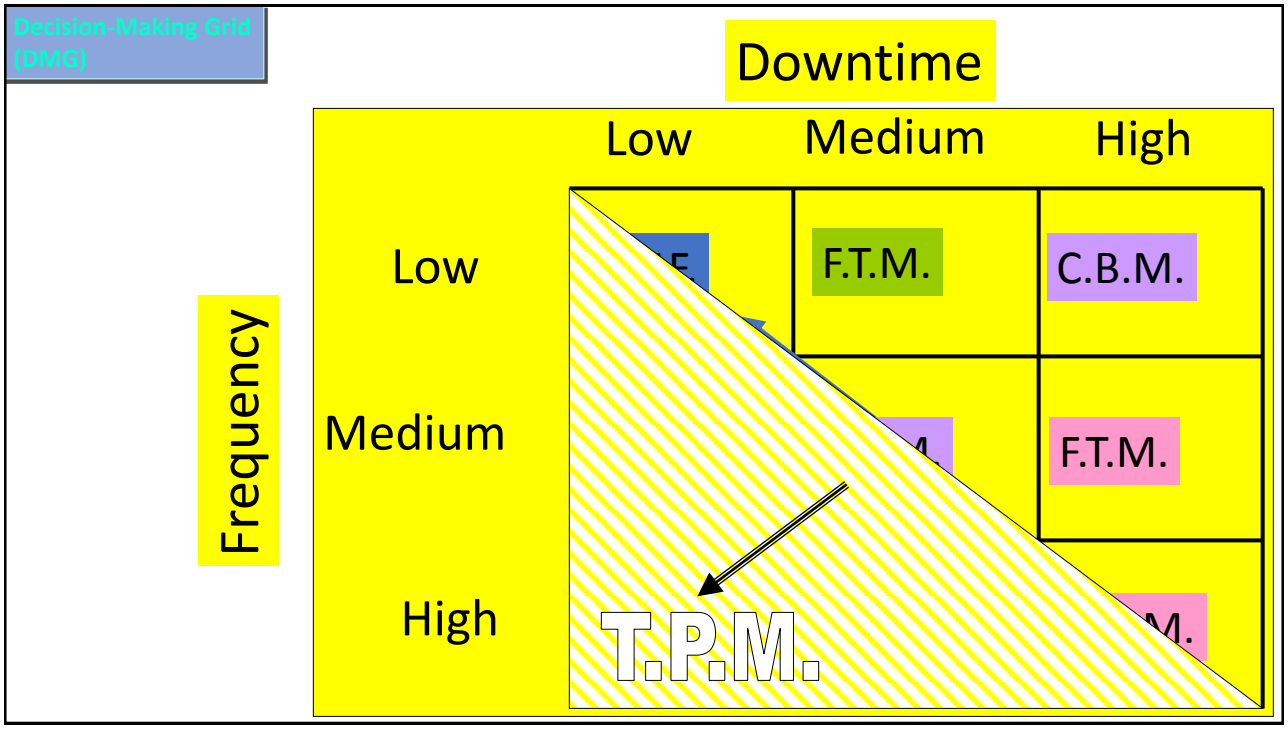
Criteria Evaluation

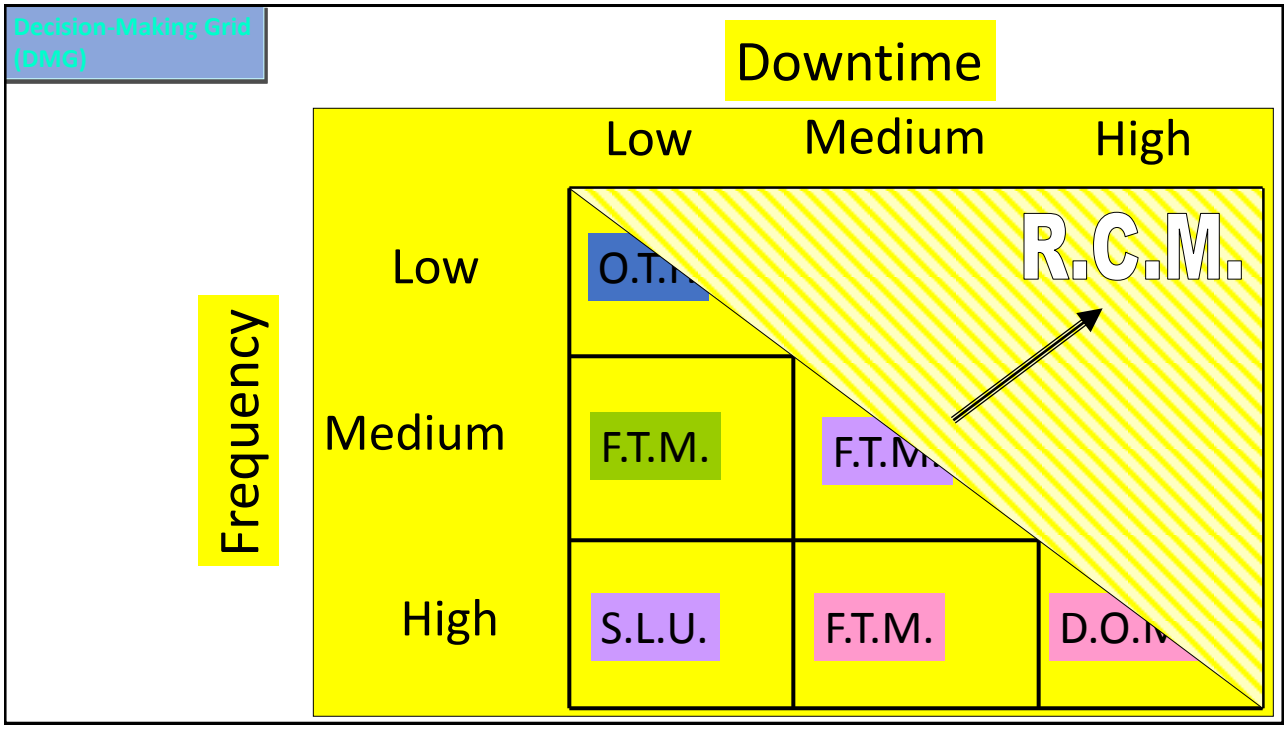
Decision-Making Grid (DMG)




Decision-Making Grid (DMG)
Downtime
Low
Medium
High
Frequency
Low
Medium
High
O.T.F.
C.B.M.
Easy F.T.M.
F.T.M.
S.L.U.
F.T.M.
D.O.M.


Decision-Making Grid (DMG)
Downtime
Low
Medium
High
Frequency
Low
Medium
High
O.T.F.
F.T.M.
C.B.M.
F.T.M.
Difficult F.T.M.
S.L.U.
D.O.M.


Decision-Making Grid (DMG)
Downtime
Low
Medium
High
Frequency
Low
Medium
High
F.T.M.
C.B.M.
F.T.M.
T.P.M.


Decision-Making Grid (DMG)
Downtime
Low
Medium
High
Frequency
Low
Medium
High
R.C.M.
F.T.M.
S.L.U.
F.T.M.

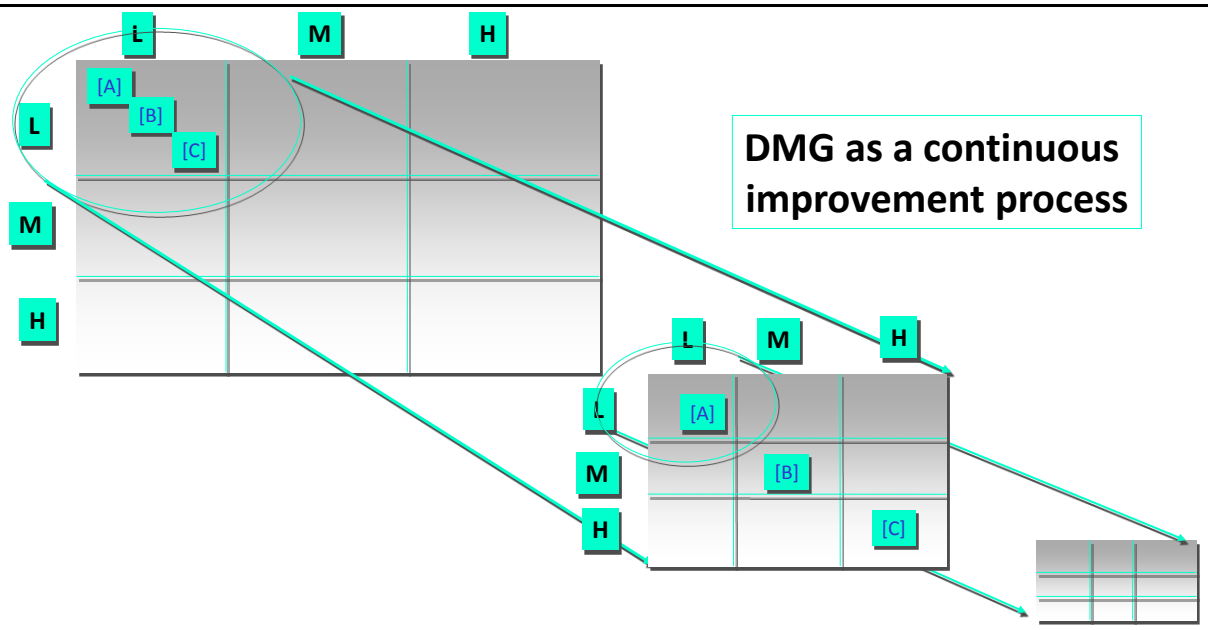
This was Part 1 of the model…….there are 3 parts!

Part 1 is: The DMG strategy selection.

The DMG…

As a…

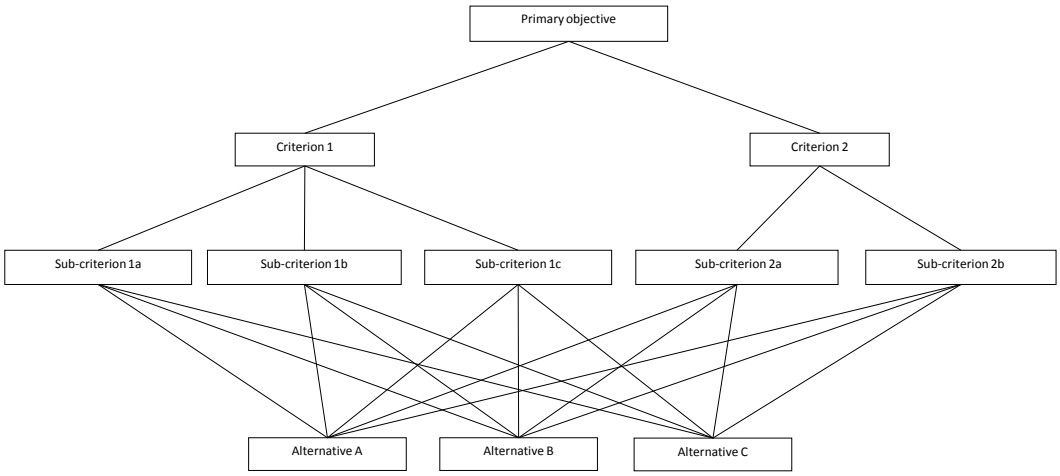
- Continuous Improvement Process.
- Multiple Criteria Analysis.
- Strategic / Operational Concept.
- Generic Methodology.

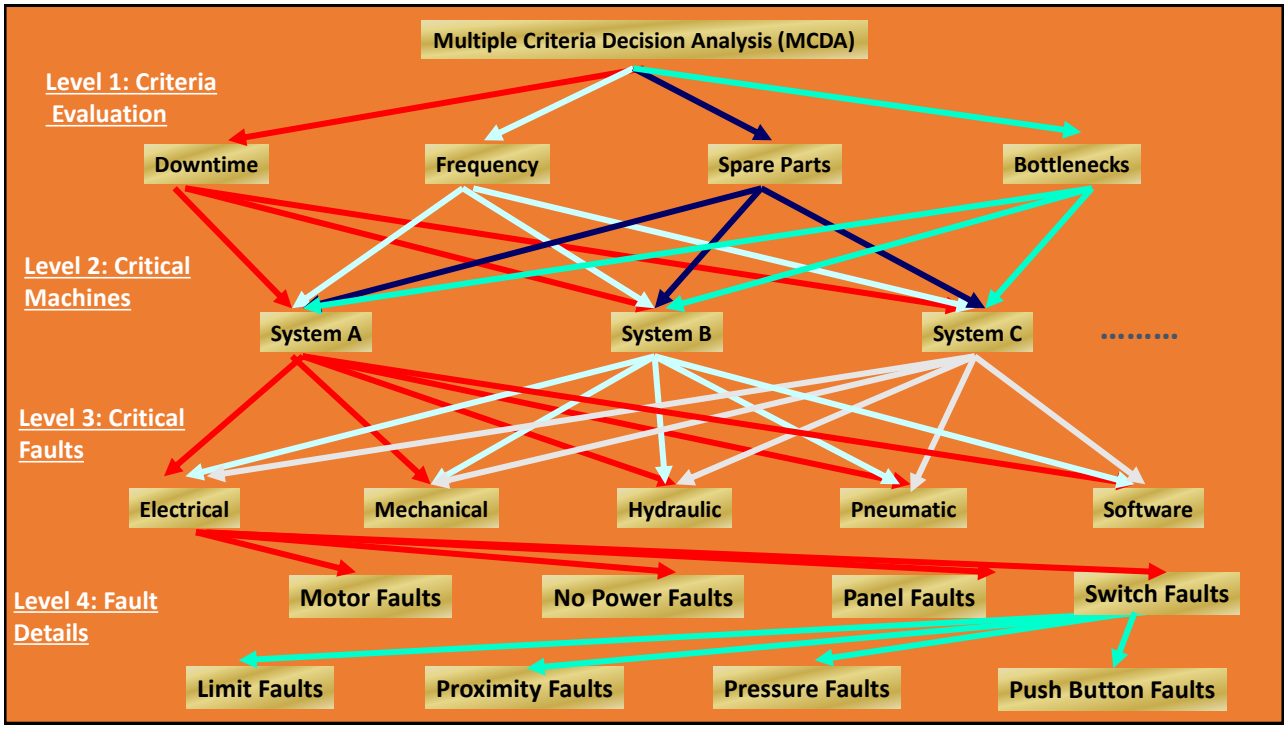


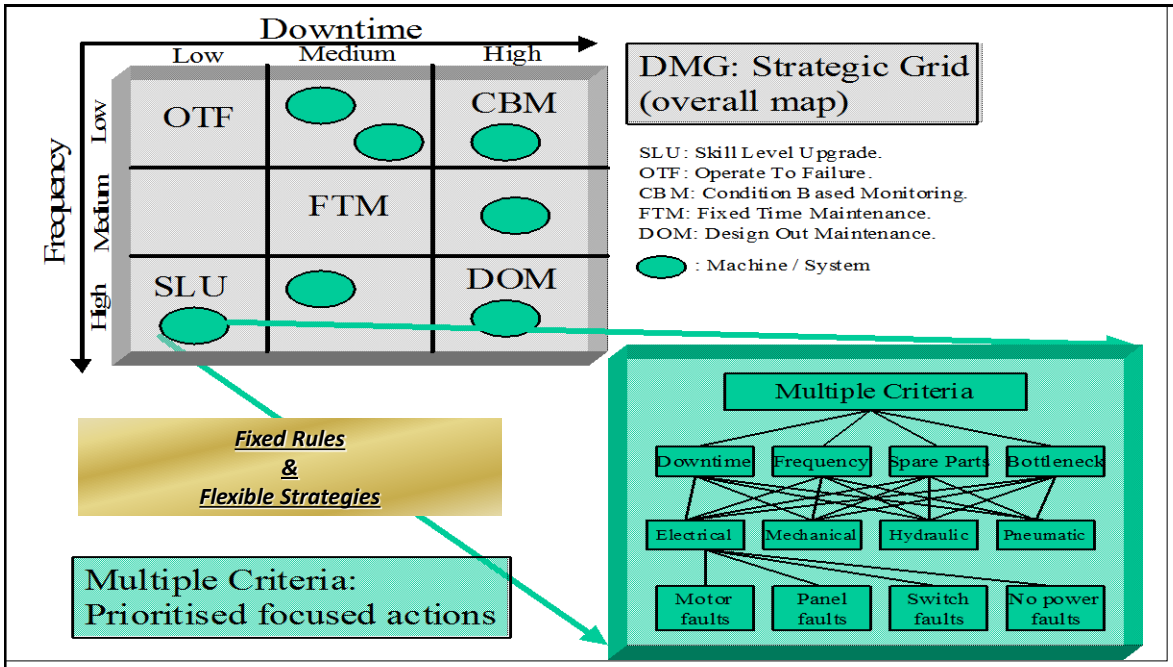
Demonstration of the AHP

Analytic Hierarchy Process

A typical AHP decision hierarchy





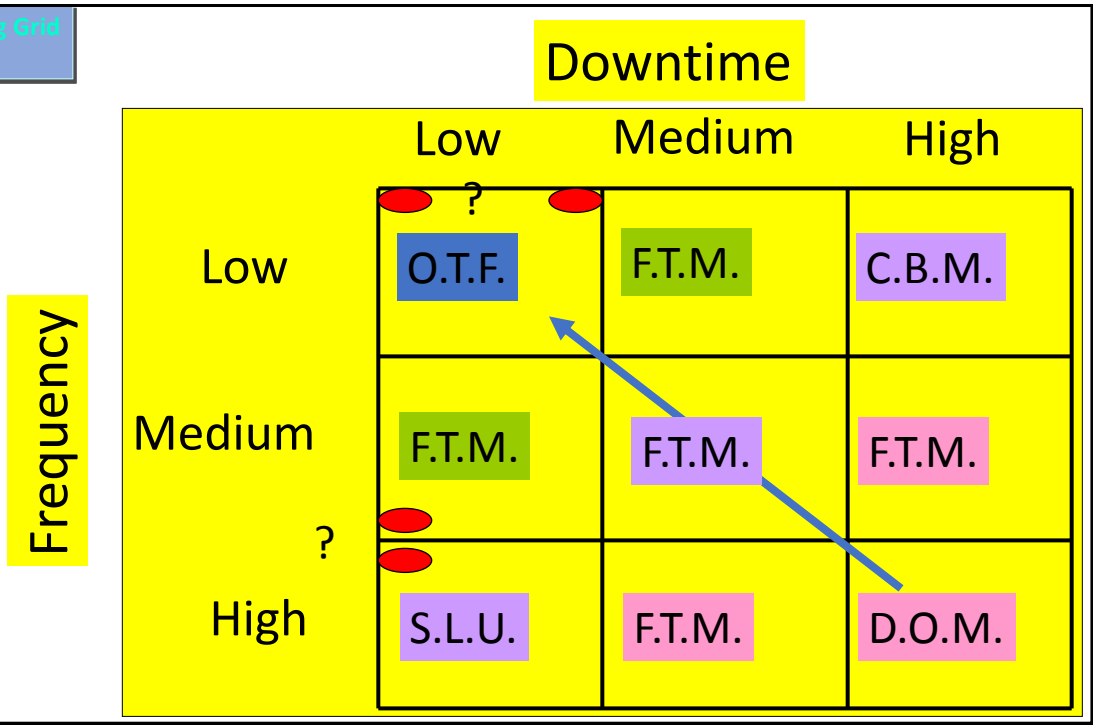


This was Part 2 of the model…….there is still one more part!

Part 1 is: The DMG strategy selection (effectiveness).

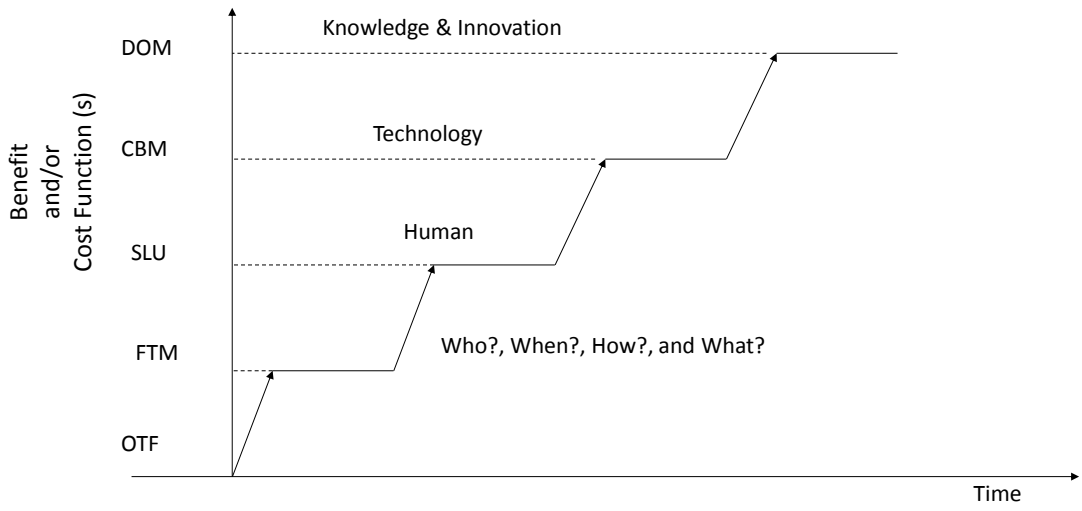
Part 2 is The DMG for focussed actions (efficiency).

Decision-Making Grid (DMG)

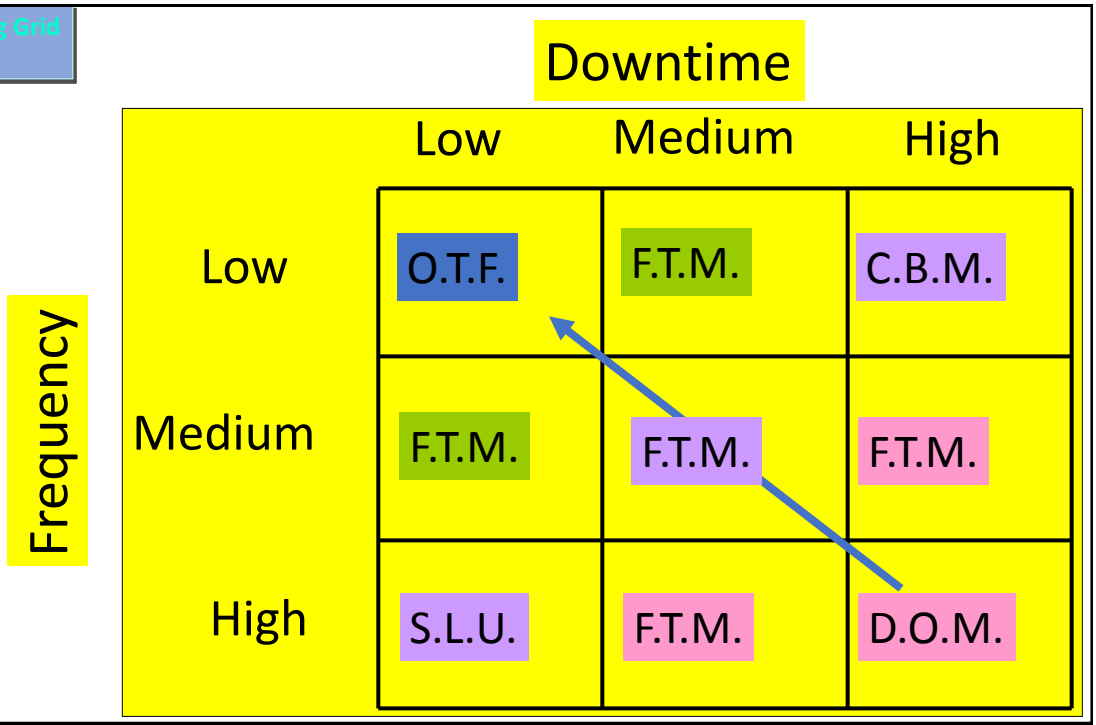


Proposed Model:

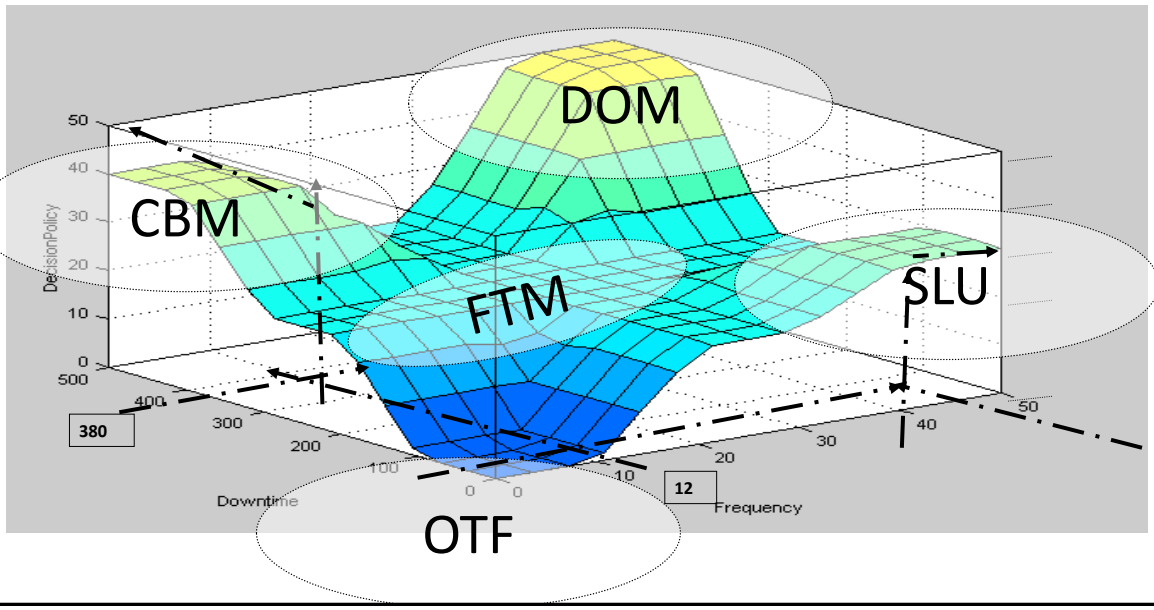
The model identifies 5 levels of maintenance strategies which have an impact on performance.



Decision-Making Grid (DMG)



The Fuzzy Decision Surface



This was Part 3 of the model…….that is it!

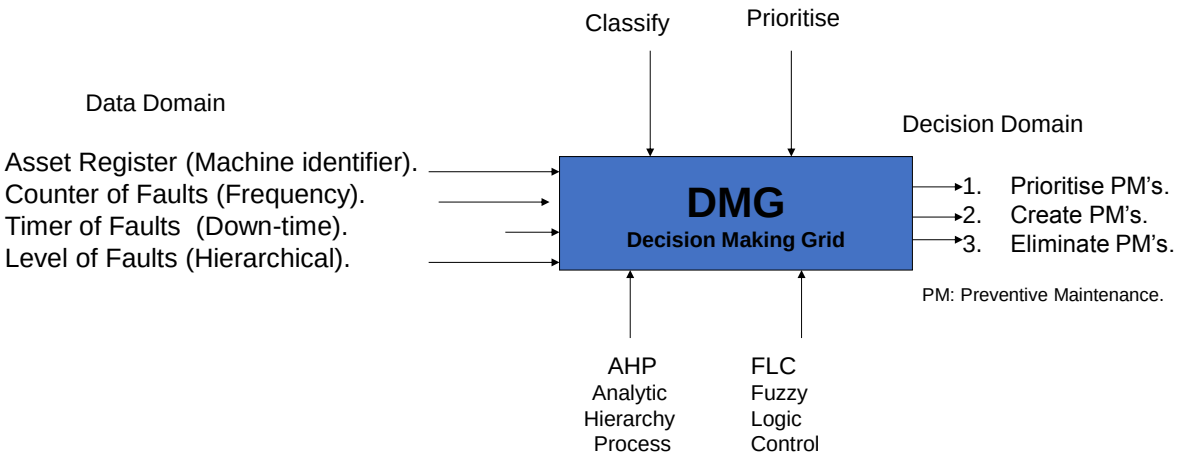
Part 1 is: The DMG strategy selection (effectiveness).

Part 2 is The DMG for focussed actions (efficiency).

Part 3 is the DMG for cost/benefit analysis.

Basic Data Requirements

- Asset Register (Machine identifier).
- Counter of Faults (Frequency).
- Timer of Faults (Down-time).
- Level of Faults (Hierarchical).

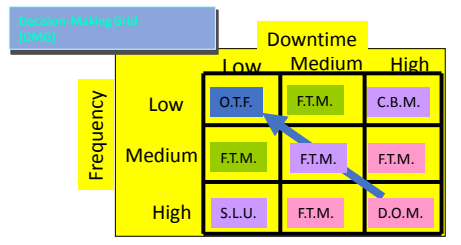


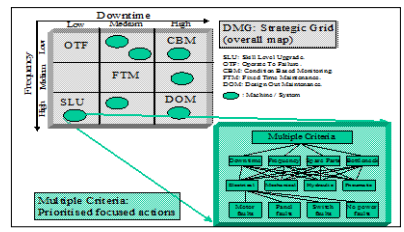
The DMG

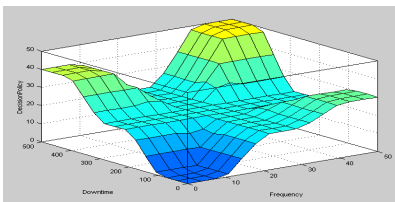
Part 1:The DMG strategy selection (effectiveness).
(Classification of maintenance strategies).

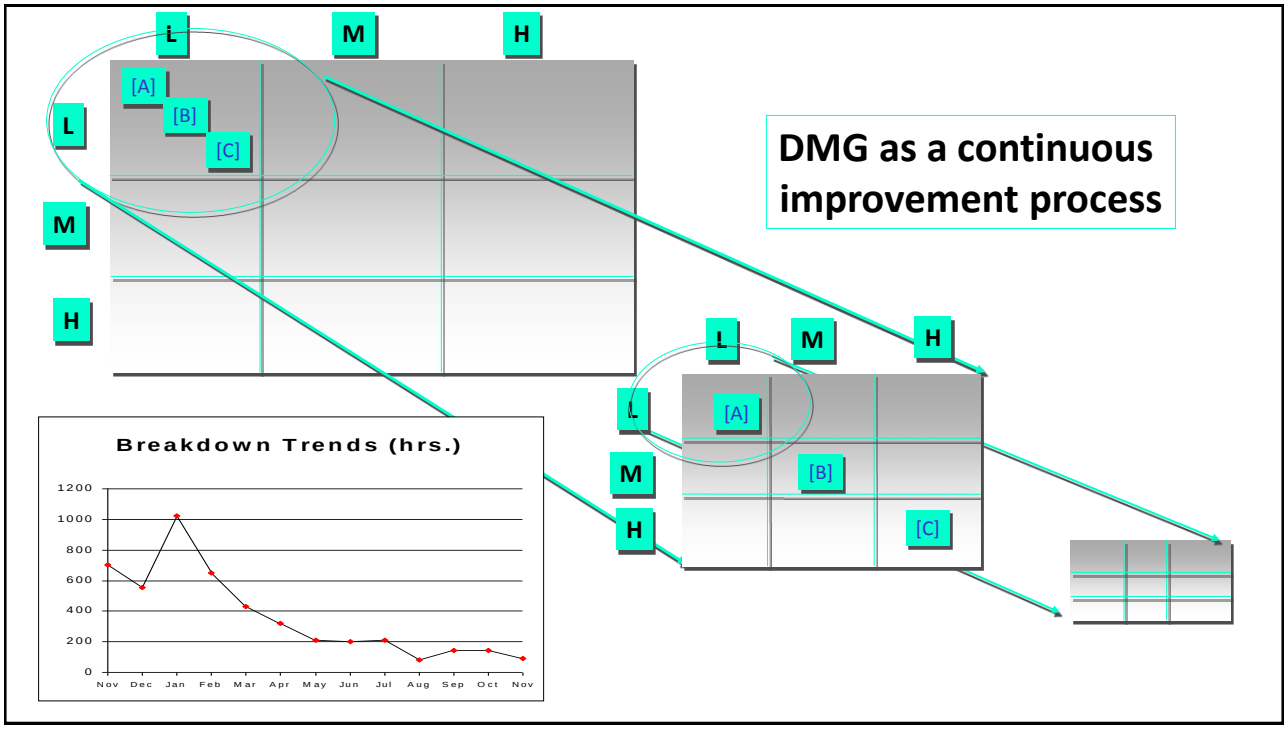
Part 2 :The DMG for focussed actions (efficiency)..
(Using multiple criteria decision making).

Part 3 :The DMG for cost/benefit analysis.
(Using rule based fuzzy logic system).









Characteristics of a model for the way forward

- Why?
  - People are either obsessed with a certain maintenance strategy, or not familiar with some of them.
  - Lots of data but no decisions.

So what we have done is:

- Simple
- Intuitive
- Comprehensive, and
- of Utility

Cases from Industry & European Projects

- **Industry:**
  - Case 1: Qatar Petroleum (QP) - Qatar
  - Case 2: Oman Air B737NG fleet - Oman
  - Case 3: ESB Moneypoint Generating Station – Ireland.
  - Case 4: Ahmadi Distillery Co. – Kuwait.
  - Case 5: PDO - Oman
  - Case 6: TRANSCO – Abu Dhabi, Emirates.
  - Case 7: GE Aviation China – USA/China
  - Case 8: FCC – UK
- **EU Projects:**
  - Train_In_Main.
  - iLearn2Main.
- **Reported publications:**
  - Burhanuddin, *etal*, 2007.
  - Zulkifli *etal*, 2008.
  - Taher, etal, 2009.
  - Shahin, 2011, 2018
  - Ramachandran *etal,* 2012.

قطر للبترول Qatar Petroleum

الطيران العماني OMAN AIR

شركة تنمية نفط عمان Petroleum Development Oman

Case Study – First Capital Connect

Winner of the Outstanding Award (2012) By the Emerald Literati Excellence Network, MCB Press

JQME
17,2

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REVIEWS AND CASE STUDIES

Practical application of the Decision Making Grid (DMG)

Nafisah Aslam-Zainudeen
First Capital Connect, London, UK, and
Ashraf Labib
Portsmouth Business School (PBS), University of Portsmouth, Portsmouth, UK

Abstract

Purpose – The purpose of this paper is to explore the applicability of the Decision Making Grid (DMG) and its usefulness, in practice, in the maintenance of rolling stock in the railway industry. The Class 319 fleet operated by First Capital Connect (FCC) is used to demonstrate the application of the DMG.

Design/methodology/approach – The level of use of the data recorded in the CMMS, in the decision making process for reviewing, and updating the maintenance policy, was established through discussions with senior management at FCC. Available decision support systems were then researched, with emphasis on the DMG concept. The advantages of using the DMG and its application in the real world using data for the Class 319 fleet were then explored and are discussed in this paper.

Findings – This paper discusses the value in applying the DMG concept in the decision-making process for prioritising systems and the work that should be done to ensure the maintenance policy takes into account the performance of the units of rolling stock against the most important criteria for FCC. Through the research carried out, it was established that the existing CMMS already records the data required for the application of the DMG, although in itself, the CMMS does not have any decision support capabilities.

Originality/value – Although a number of different CMMSs are used in the railway industry, few or none of these are capable of providing decision support for maintenance. This paper explores the use of the DMG concept to demonstrate the use of data recorded in the CMMS to develop a more effective maintenance policy and to determine exactly which maintenance activities need to be carried out in order to remedy the worst performing systems in terms of the most important criteria as identified by the business.

Keywords Decision making, Analytic hierarchy process, Decision support systems, Railways, Maintenance, United Kingdom

Paper type Case study

1. Introduction

Computer maintenance management systems (CMMS) are widely used in the maintenance of rolling stock in the railway industry. All of these systems act as effective databases for storing the technical history of all the rolling stock operated by each train operating company (TOC). Some of the more contemporary CMMSs have the capability of producing trends in the data that are recorded, which engineers use to determine what changes need to be made to the maintenance policy. However, most if not all the CMMSs used for the purpose of maintaining rolling stock do not have the capability of providing maintenance engineers or asset managers with decision support – i.e. although the CMMSs are capable of analysing the data that are recorded,

Journal of Quality in Maintenance Engineering
Vol. 17 No. 2, 2011
pp. 138-149

1355-2511
DOI 10.1108/13552511111134574

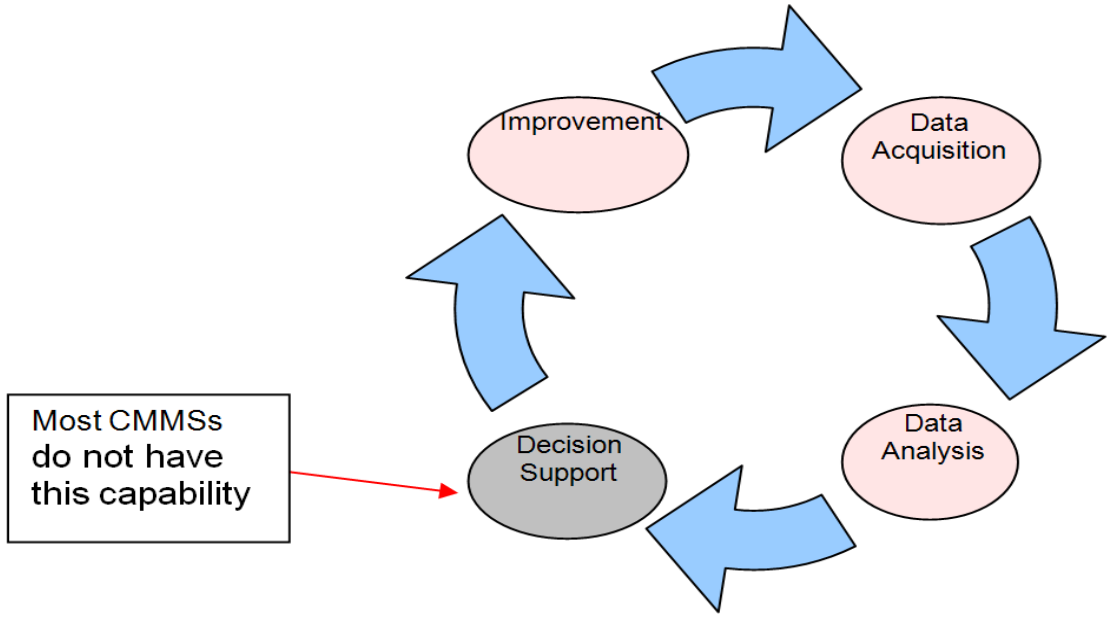


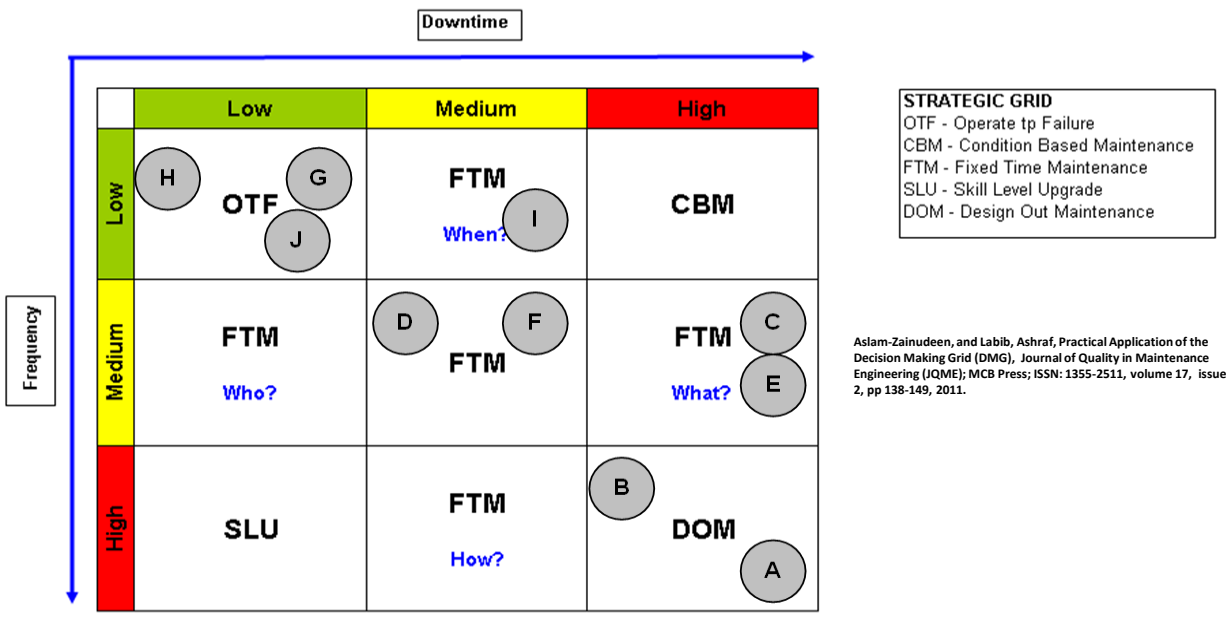
Figure 1: The Effective Asset Management Cycle

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

		Criteria 1 (Frequency)	No. of Failures			Criteria 2 (Downtime)	Delay minutes
High	A	Power	18	High	B	Doors	268
High	B	Doors	13	High	A	Power	225
Medium	C	Safety Systems	5	High	E	Brakes	122
Medium	D	Air Systems	5	High	C	Safety Systems	68
Medium	E	Brakes	4	Medium	F	Current Collection Equipment	51
Medium	F	Current Collection Equipment	4	Medium	D	Air Systems	34
Low	G	Interior Seats, Floor and Trims	3	Medium	I	Train Communication	32
Low	H	Jumpers and Coupling	2	Low	G	Interior Seats, Floor and Trim	28
Low	I	Train Communication	1	Low	H	Jumpers and Coupling	25
Low	J	Underframe	1	Low	J	Underframe	8
		Sum of Top 10	**56**			**Sum of Top 10**	**861**
		Sum of All	**59**			**Sum of All**	**899**
		Percentage	**94%**			**Percentage**	**95%**

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Criteria analysis for DMG



Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Figure 4: The Decision Making Grid

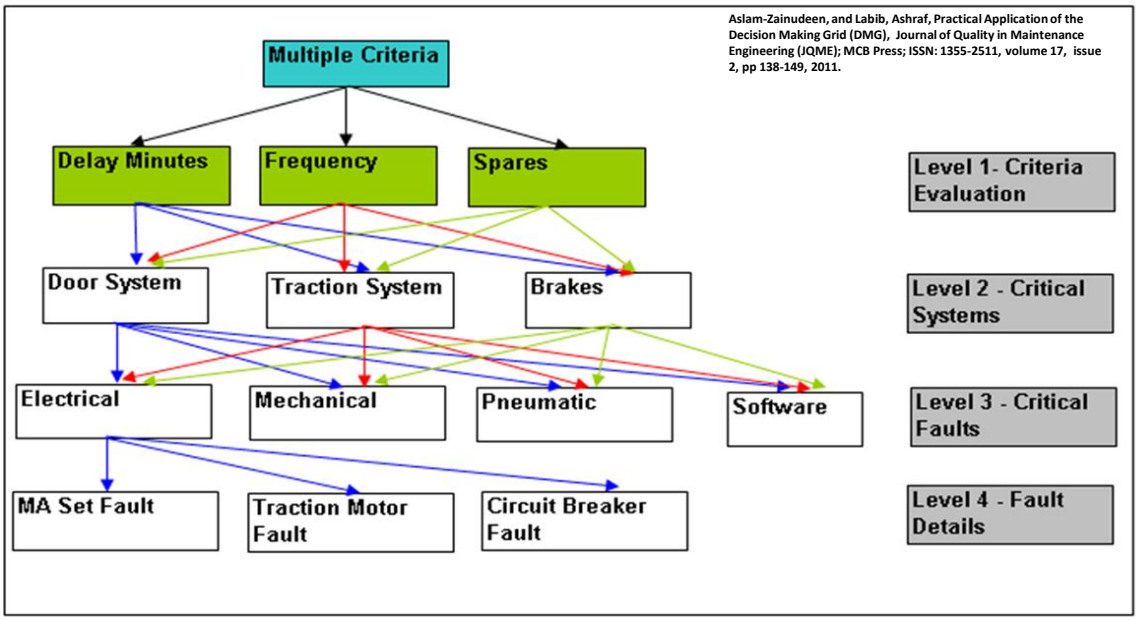


Figure 6: The Analytic Hierarchy Process for the FCC Class 319s

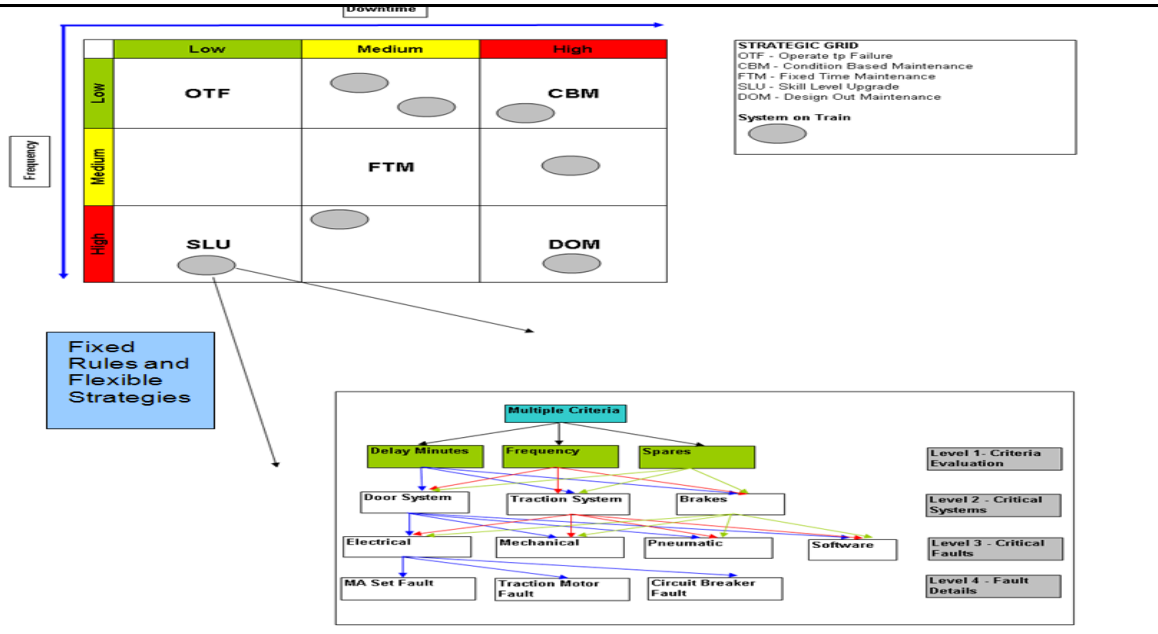


Figure 3: Holonic Maintenance System for First Capital Connect (based on Labib, 2004)

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Conclusion:

It is concluded that the application of the DMG would assist FCC engineers in making decisions about what types of maintenance should be done and would also allow maintenance to be adapted to suit the changing real world performance of the fleets.

The advantages of ensuring maintenance work is prioritised in this manner would have the following advantages to FCC as a business:

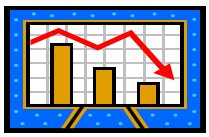
1. Lower downtime of the units.
2. Reduced maintenance costs because of focus on the most effective work that can be done.
3. Reduced impact on passenger services and therefore an improved corporate image in the eyes of the customer.
4. Increased profits through the increased availability of units for revenue earning service.
5. Increased reliability of the units because the worst performing systems are prioritised and the work carried out is adapted to deal with the root causes of the failures of these worst performing systems.
6. Reduced operating costs due to the reduction of failures in service.
7. Enables continuous improvement within FCC because after the first set of worst performing systems are improved, work on the next set of worst performing systems can be started.

Due to the similarities in the CMMSs used in other TOCs in the railway industry, it is also concluded that the application of the DMG would be worth considering in these TOCs in order to enable the realisation of the previously described benefits.

Aslam-Zainudeen, and Labib, Ashraf, Practical Application of the Decision Making Grid (DMG), Journal of Quality in Maintenance Engineering (JQME); MCB Press; ISSN: 1355-2511, volume 17, issue 2, pp 138-149, 2011.

Conclusion - The Revenue of a Company can be Improved by:

- Higher prices on products or reduction of raw material cost.
- Reduction of production – and maintenance costs.
- Increased productivity.
- High quality products.



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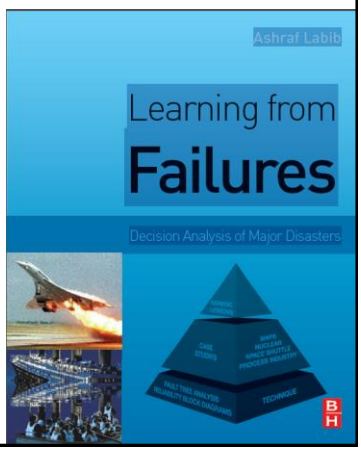

Thank You.....Any Questions?

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