FORMING AND APPLICATION OF MAINTENANCE MANAGEMENT UNITS IN PRIVATE AND GOVERNMENT ESTABLISHMENTS

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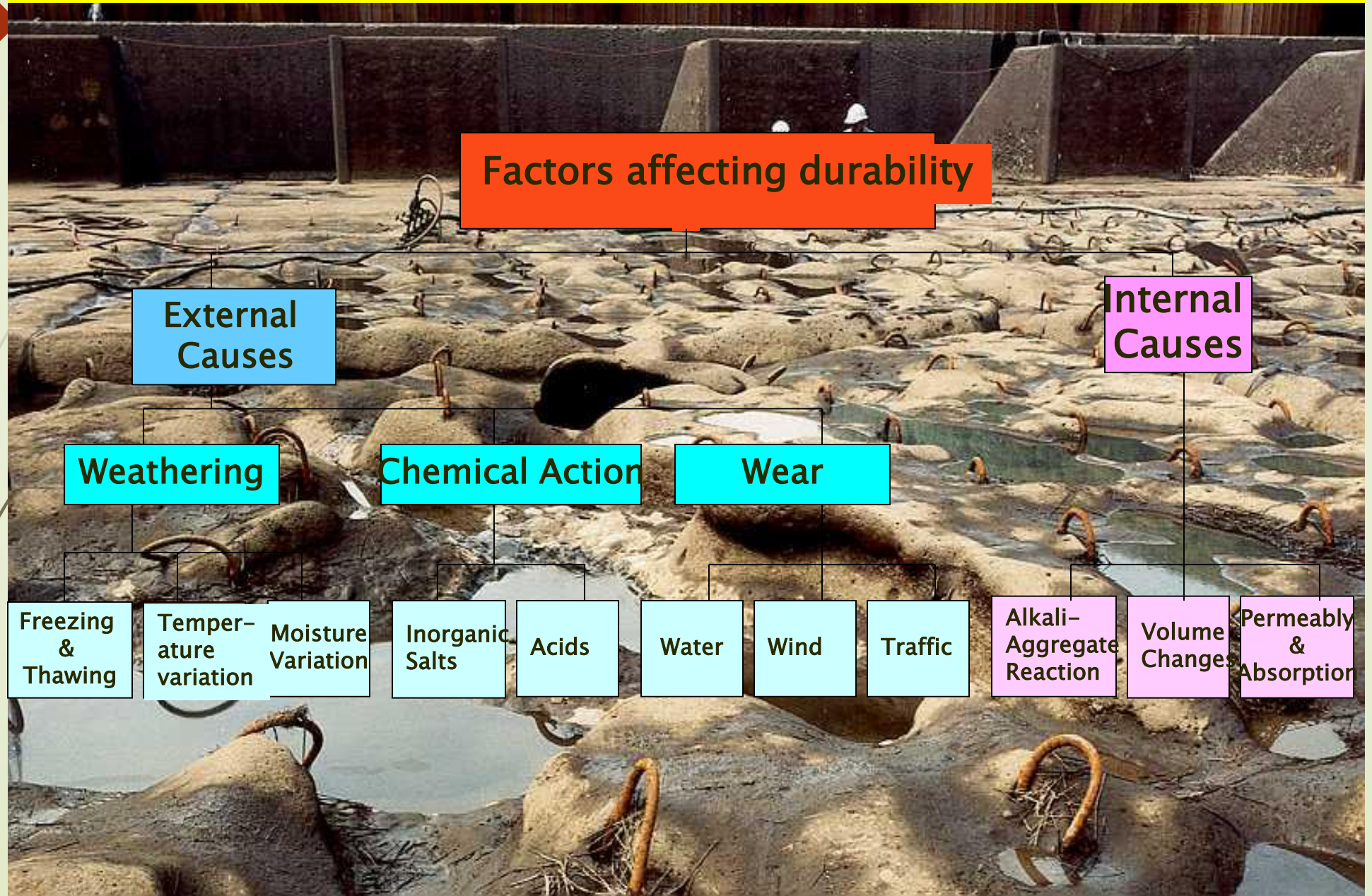
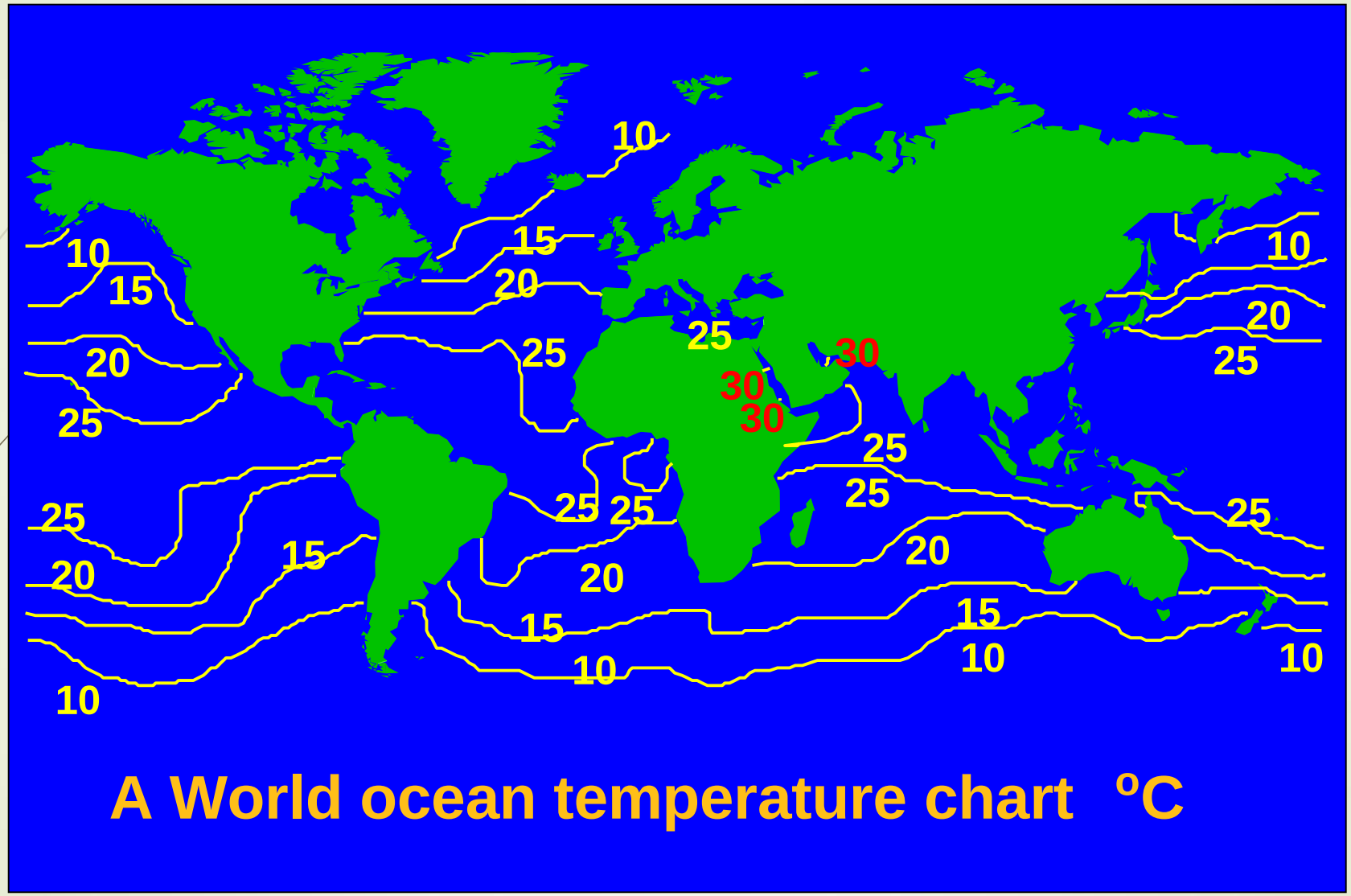
PART ONE

THE PROBLEM

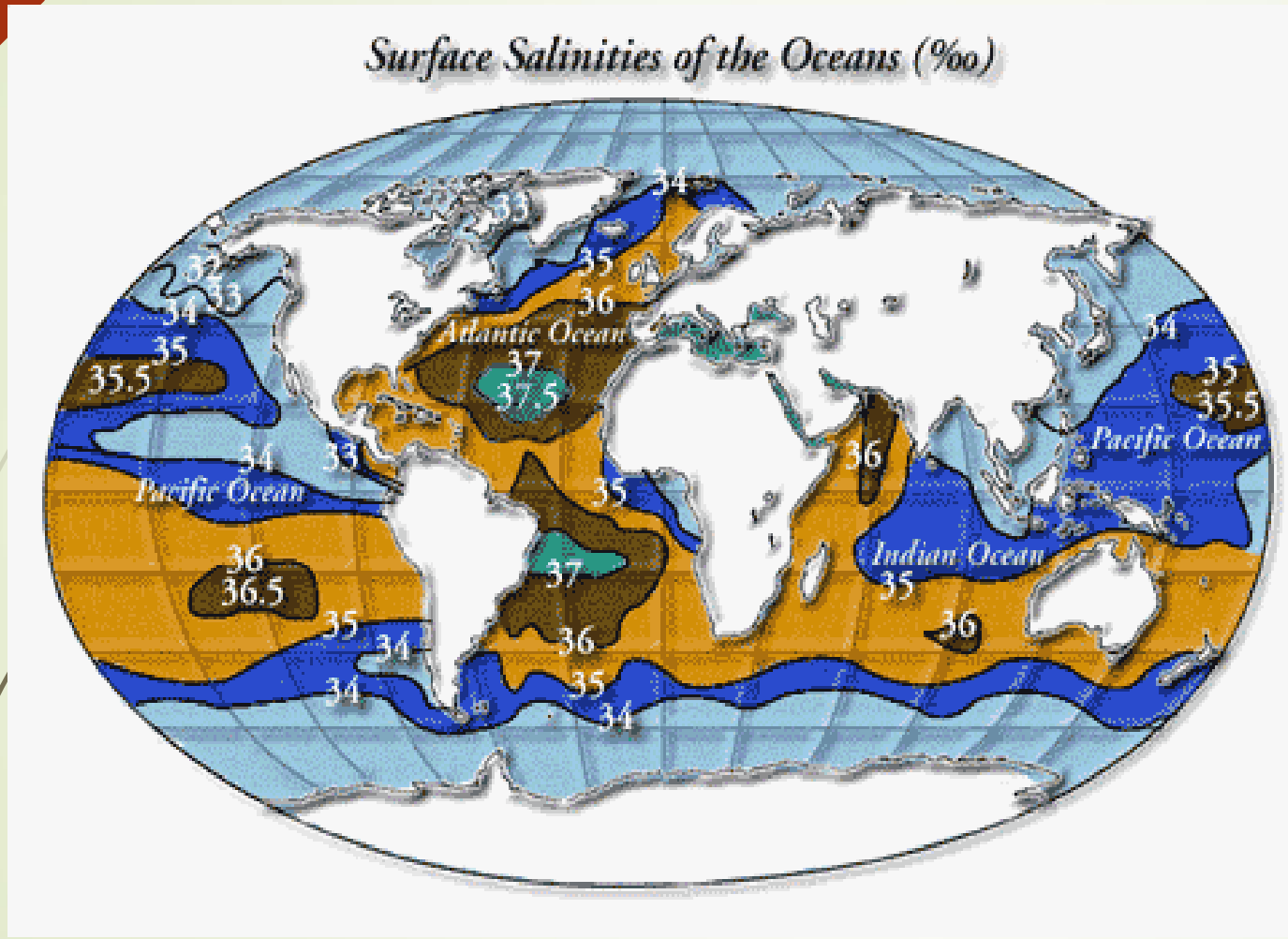
DETERIORATION AND CORROSION

Durability and Deterioration




10
15
20
25
30
A World ocean temperature chart °C

Corrosion - salinity



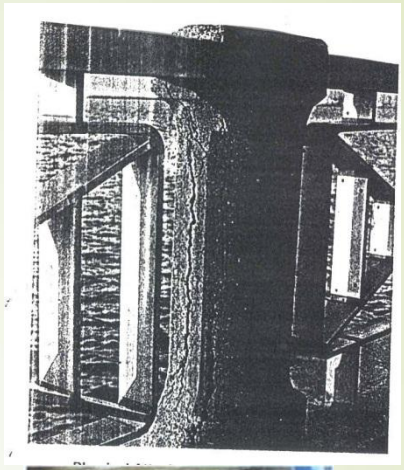
East Mediterranean
39 – 41ppt

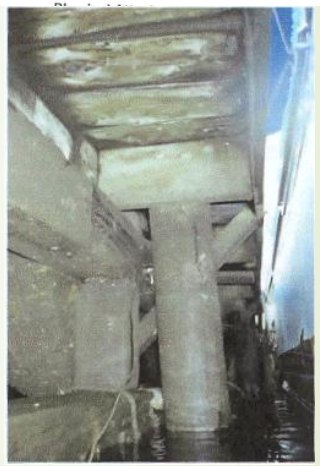
Arabian Gulf
40 – 50 ppt

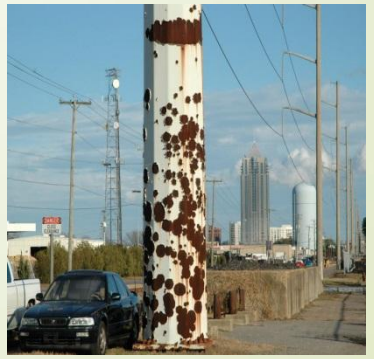
Sulfate ion concentration

Sulfate ion concentration

THE COST OF MAINTENANCE





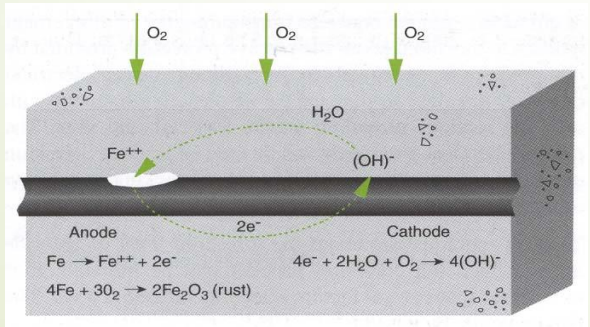


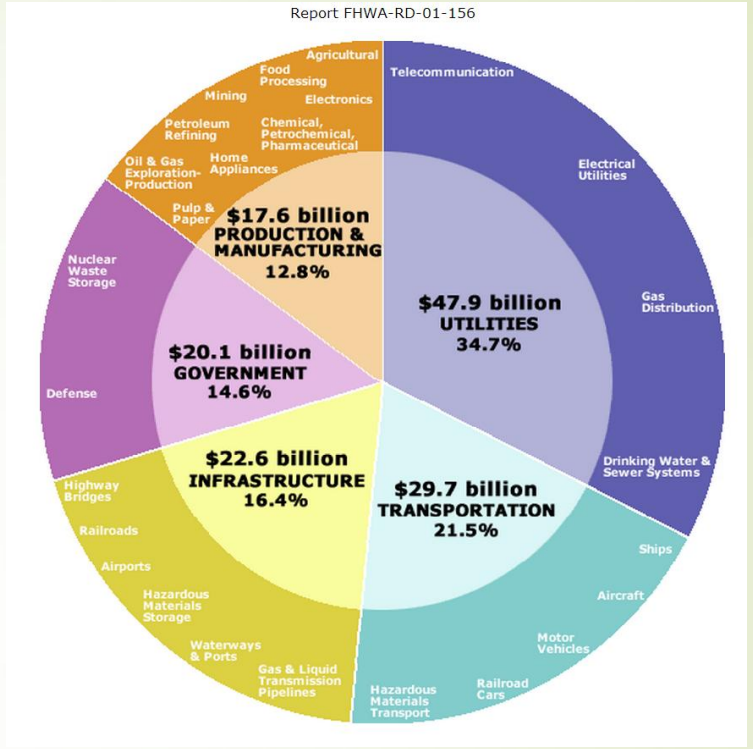
•Although accurate figures are hard to come by, it is estimated that the world spend about US $5.0 Trillion in construction .

•Within Europe it has been estimated that the value of the infrastructure built environment represents around 50% of the national wealth of most countries. Around 50% of the expenditure in the construction industry in Europe is spent on repair, maintenance and remediation.

Cost of Corrosion

- According to the NACE study, the cost of corrosion in the U.S. can be estimated to be equal to $1 Trillion. Recent report by Visiongain calculates that the global oil and gas corrosion prevention market was worth $18.72 billion in 2012.
- The annual cost of corrosion worldwide is estimated at USD $ 2.2 trillion which is about 3% of the world's GDP.





Country	Estimated Cost of Corrosion (US$ billion)				
	2007	2008	2009	2010	2011
Kingdom of Bahrain	0.91	1.04	1.04	1.15	1.25
State of Kuwait	5.82	7.70	5.15	6.03	6.50
Sultanate of Oman	2.16	3.12	2.76	3.12	3.33
State of Qatar	4.20	5.76	5.11	6.36	7.78
Kingdom of Saudi Arabia	19.70	24.18	19.55	22.65	24.84
United Arab Emirates	10.33	11.60	12.47	13.53	14.26

DIAGNOSIS AND EVALUATION

Investigation- Preliminary Survey

It is a walk around structure & consists of:

Familiarization with type and extent of deterioration

- Collecting samples of loose concrete or lumps that can be easily pulled out
- Plan access to hidden areas
- Set safety requirements
- Equipment required: notebook, camera, measuring tape, hammer, binoculars, original drawings, papers marked with grid for sketching

Investigation- Preliminary Inspection

Its objective is to develop an initial of the most likely causes of deterioration. It mainly consists of inspecting :

- Cracks: location, type, orientation, width and Length, (To make cracks more visible, spray concrete with water and avoid noon hours)
- Deterioration (spalling, pop-outs, discoloration)
- Leaks, damp patches or lime-scale
- Reinforcement corrosion
- Previous repairs
- Location and condition of joints
- Condition of any Bearings

Sample of Preliminary inspection Form

Structure ..... Part of structure ..... Date of inspection	Rating					
	0 None	1 Very slight	2 Slight	3 Moderate	4 Severe	5 Very severe
Defects						
Cracking	☐	☐	☐	☐	☐	☐
Plastic shrinkage/settlement	☐	☐	☐	☐	☐	☐
Thermal contraction	☐	☐	☐	☐	☐	☐
Structural	☐	☐	☐	☐	☐	☐
Crazing	☐	☐	☐	☐	☐	☐
Rust staining	☐	☐	☐	☐	☐	☐
Water leakage	☐	☐	☐	☐	☐	☐
Pop-outs	☐	☐	☐	☐	☐	☐
Spalling	☐	☐	☐	☐	☐	☐
Loss of surface	☐	☐	☐	☐	☐	☐
Abrasion	☐	☐	☐	☐	☐	☐
Chemical attack	☐	☐	☐	☐	☐	☐
Efflorescence	☐	☐	☐	☐	☐	☐
Others (specify below)	☐	☐	☐	☐	☐	☐
Existing repairs (if any)						
Delamination/debonding	☐	☐	☐	☐	☐	☐
Cracking	☐	☐	☐	☐	☐	☐
Others (specify below)	☐	☐	☐	☐	☐	☐
Supplementary documentation	**Details** (including reference numbers etc)					
Sketches	.....					
Photographs	.....					
Others (specify below)	.....					

Additional comments (general condition of structure, local effects that may influence performance, such as damp areas).

Investigation

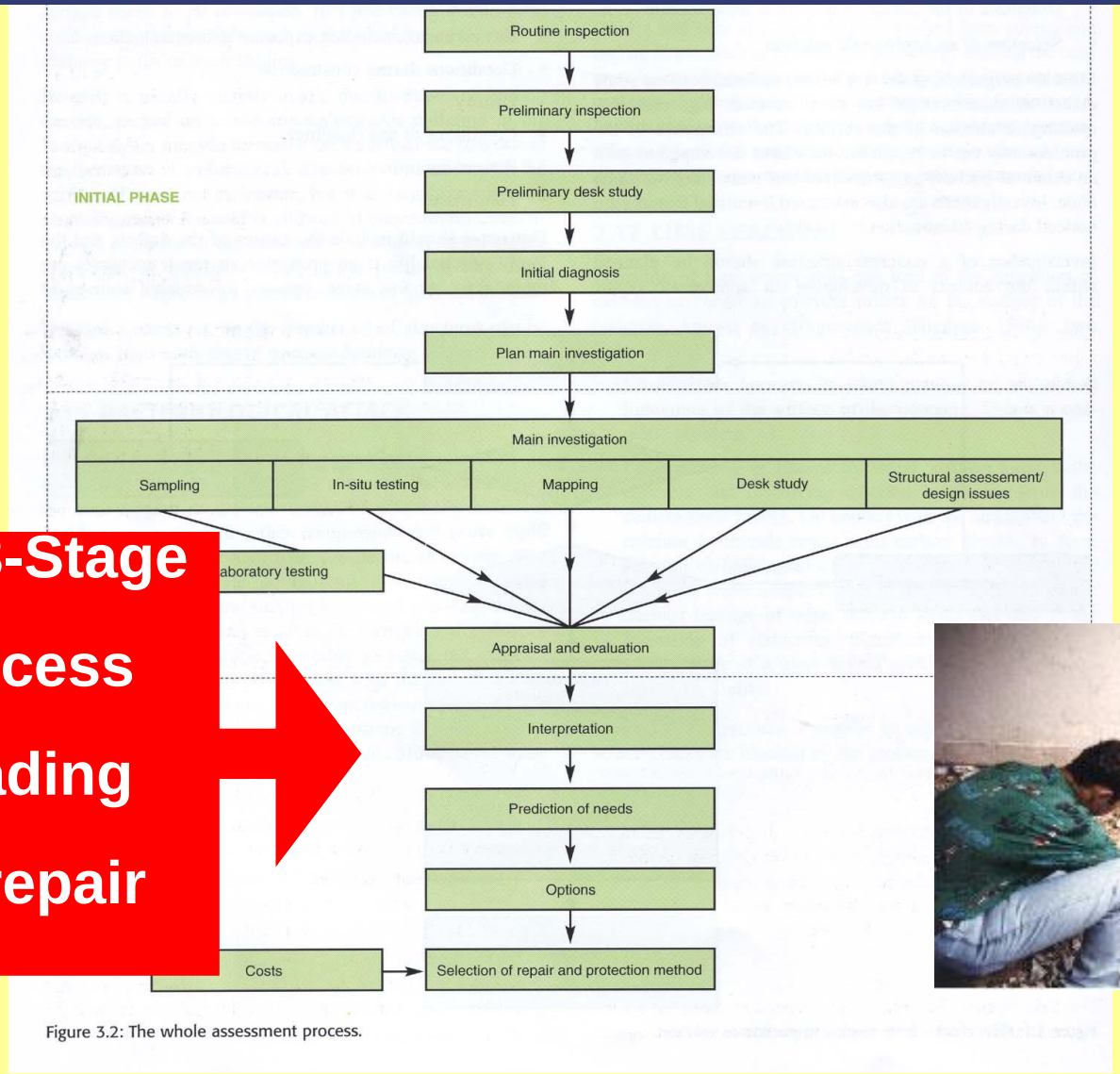
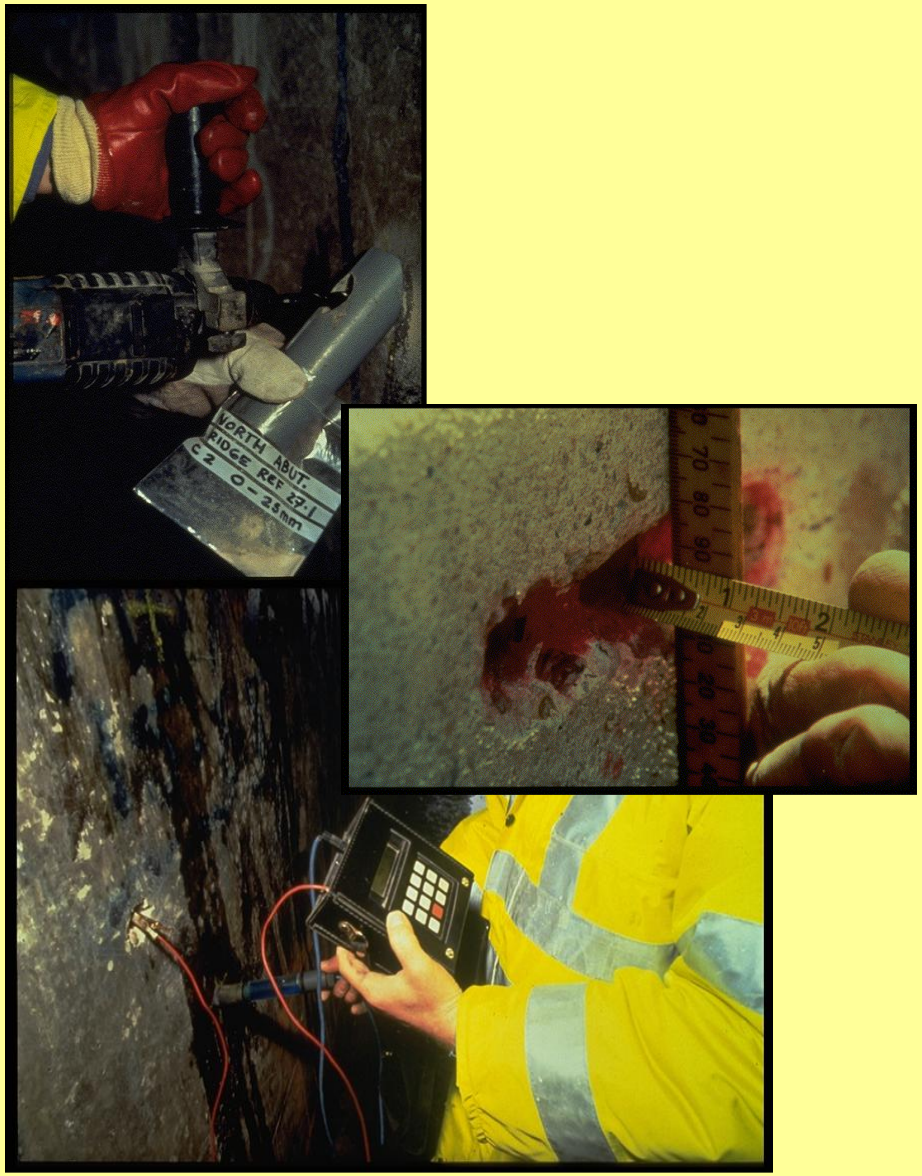


Figure 3.2: The whole assessment process.

The 3-Stage Process Leading to repair

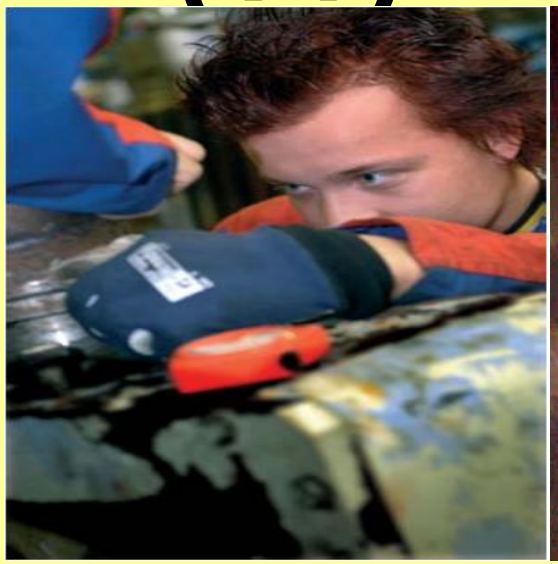
Diagnostic techniques



- visual assessment
- Delamination - hammer/chain
- covermeter - presence of reinforcement
- chloride analysis
- phenolphthalein test for carbonation
- half cell measurements to ASTM C876
- resistivity
- corrosion rate (linear polarisation)
- permeability
- ultrasonics
- petrography
- radar

Visual INSPECTION Testing (VT)

Visual Inspection is the most common and readily available inspection. It is the process of eye fixations on a test specimen. Many times the inspector is trained to look for certain clues that might indicate defects or flaws. Most ndt inspections start with a visual inspection.



Plastic settlement
A-Over reinforcement
B- Arching
C- Change of depth

Crazing
J- Against formwork
K - Floated concrete

I - Long-term drying shrinkage

K - Floated concrete

Plastic shrinkage
D-Diagonal
E- Random
F- over reinforcment

C- Change of depth

N - Alkali silica reaction

B- Arching

Early thermal contraction
G- External restraint
H- Internal restraint

Corrosion of Reinf.
L - Natural
M- Calcium chloride

D- Diagonal

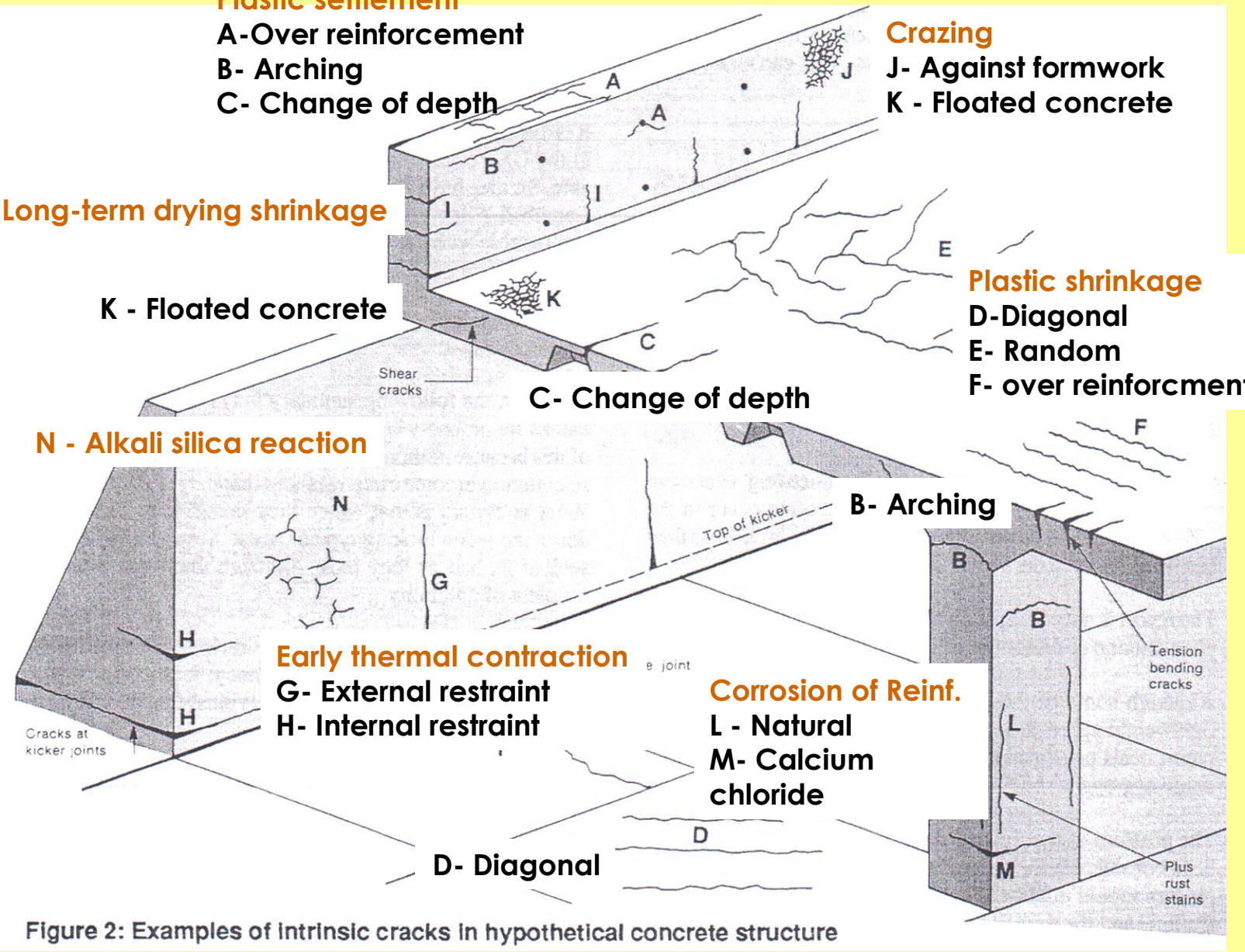


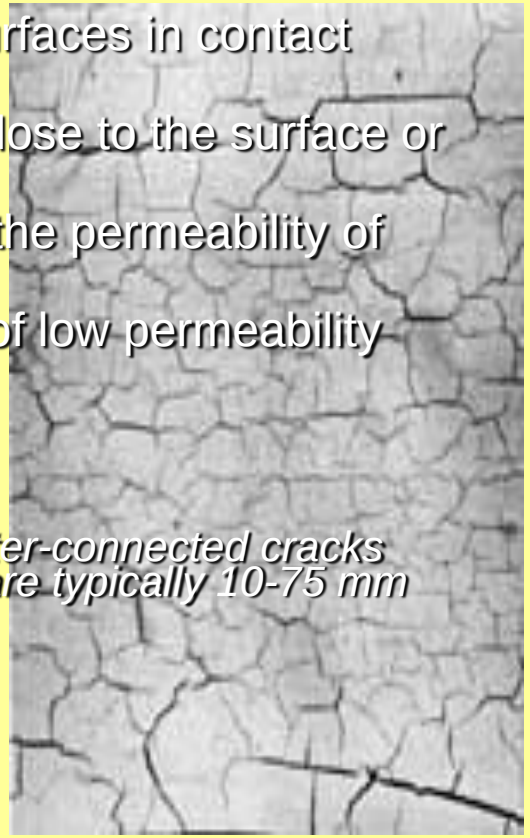
Figure 2: Examples of intrinsic cracks in hypothetical concrete structure

Crazing

- Crazing can occur both on exposed surfaces and on surfaces in contact with form work.
- It occurs either where there is a change in properties close to the surface or where there is a steep moisture content gradient.
- The type of formwork is also important, as it can affect the permeability of the formed concrete surface.
- Steel and plastic form work faces that are smooth and of low permeability appear to increase the incidence of crazing.

- ***Characteristic defects***

Crazing is a close pattern of narrow (say 0.1 mm wide) shallow inter-connected cracks usually forming closed polygonal loops. The polygonal areas are typically 10-75 mm across and the cracks are usually only a few millimetres deep.



Transverse

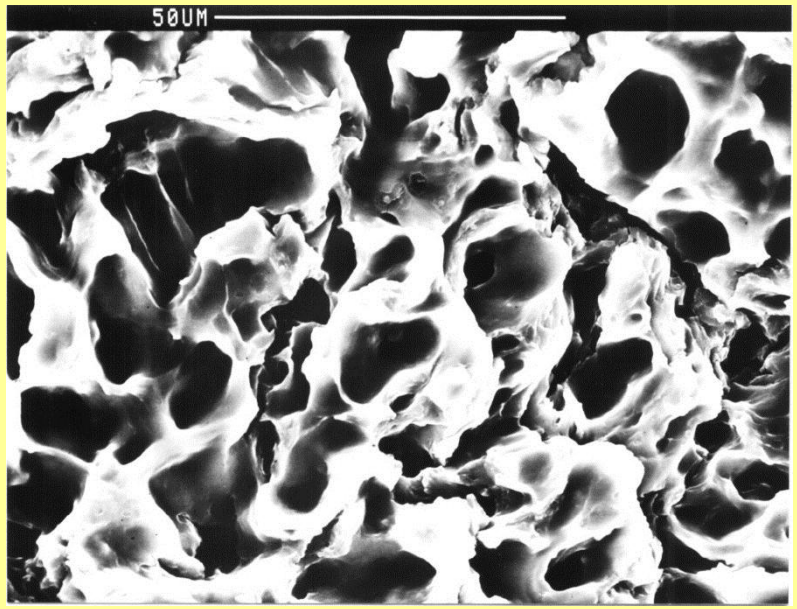
Cracks that develop at right angles to the long direction of the member.

Deterioration

1) Physical manifestation of failure of material (e.g., cracking, delamination, flaking, pitting, scaling, spalling, straining) caused by environmental or internal autogenous influences on hardened concrete as well as other materials;
2) Decomposition of material during either testing or exposure to service.
Disintegration - Reduction into small fragments and subsequently into particles.

Cavitation

Pitting of concrete caused by implosion, i.e., the collapse of vapor bubbles in flowing water which form in areas of low pressure and collapse as they enter areas of higher pressure.



Corrosion

destruction of metal by chemical, electrochemical, or electrolytic reaction with its environment.

Delamination

A separation along a plane parallel to a surface as in the separation of a coating from a substrate or the layers of a coating from each other, or in the case of a concrete slab, a horizontal splitting, cracking or separation of a slab in a plane roughly parallel to, and generally near, the upper surface; found frequently in bridge decks and other types of elevated reinforced-concrete slabs and may be caused by the corrosion of reinforcing steel; also found in slabs on grade caused by development, during the finishing operation, of a plane of weakness below the densified surface; or caused by freezing and thawing, similar to spalling, scaling, or peeling except that delamination affects large areas and can often be detected by tappin

Dusting

The development of a powdered material at the surface of hardened concrete.

Efflorescence

A deposit of salts, usually white, formed on a surface, the substance having emerged in solution from within either concrete or masonry and subsequently been precipitated by evaporation.

Plastic Cracks

Cracking that occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.

Pitting

Development of relatively small cavities in a surface; in concrete, localized disintegration, such as a popout; in steel, localized corrosion evident as minute cavities on the surface.

Peeling

A process in which thin flakes of mortar are broken away from a concrete surface, such as by deterioration or by adherence of surface mortar to forms as forms are removed.

Popout

The breaking away of small portions of a concrete surface due to localized internal pressure which leaves a shallow, typical conical, depression.

Scaling

Local flaking or peeling away of the near-surface portion of hardened concrete or mortar; also of a layer from metal.

Spall

A fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the large mass.

Bugholes

Small regular or irregular cavit usually not exceeding 25 mm in diameter, resulting from trapment of air bubbles in the surface of formed concr during placement and consolidation.

Cold Joint

A joint or discontinuity resulting from a delay in placement of sufficient time to preclude a union the material in two successive lifts.

Honeycomb

Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.

Stalactite

A downward-pointing deposit form as an accretion of mineral matter produced by evaporation dripping water from the surface of concrete, commoi shaped like an icicle.

TESTING OF STRUCTURES

CLASSIFICATION OF VARIOUS TEST METHODS

Destructive tests.

These conventional methods enable the strength of the concrete to be measured by way of cores or cubes cut from the concrete. However, this is not possible in all cases and especially not for slender members.

Non-destructive tests.

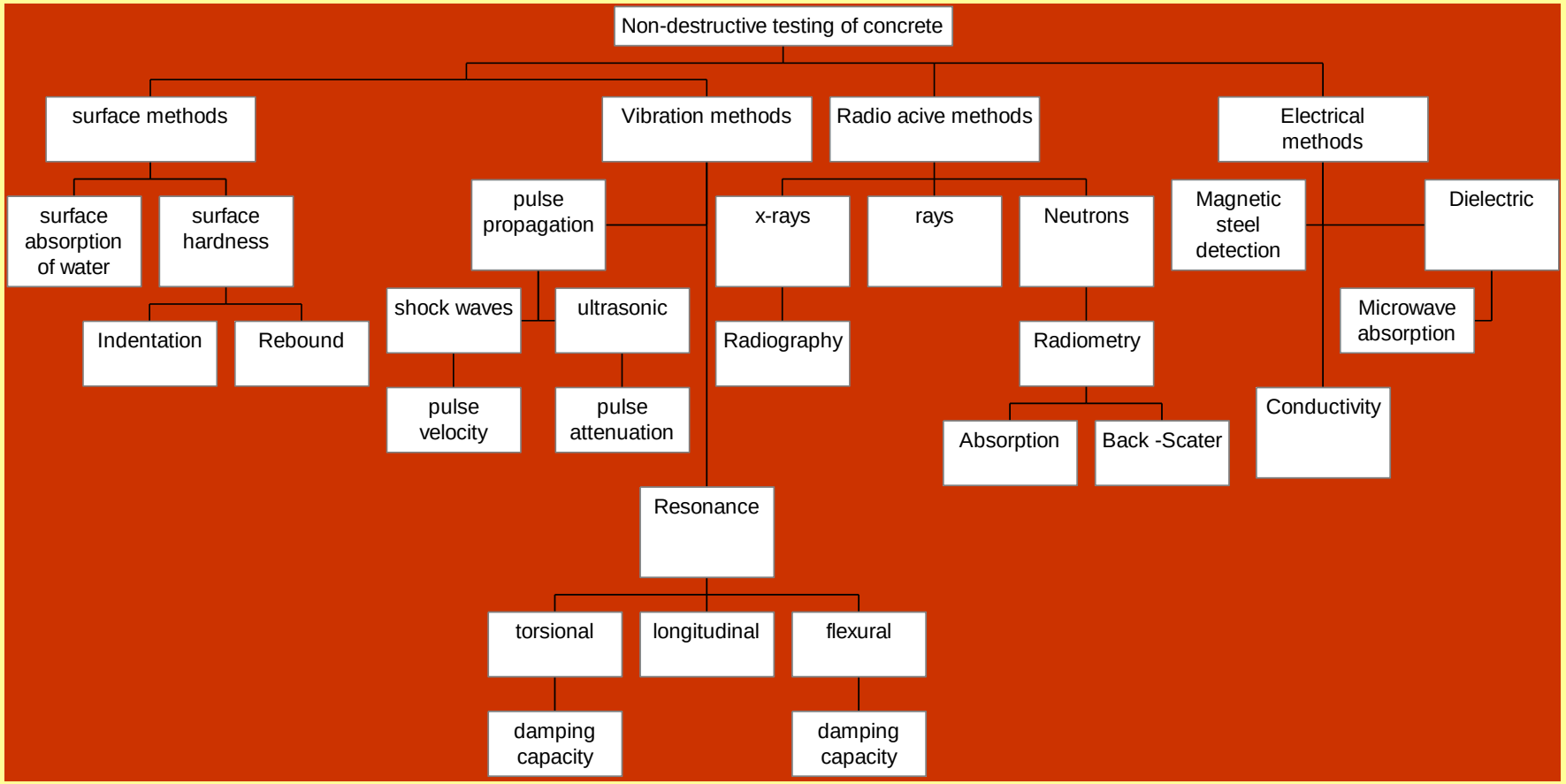
By definition, the strength properties are not measured directly so some other properties are measured and the strength estimated by calibration.

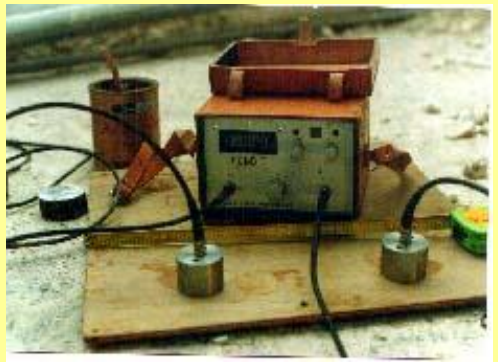
Naturally, these methods have the great advantage that concrete is not damaged

Partially destructive tests.

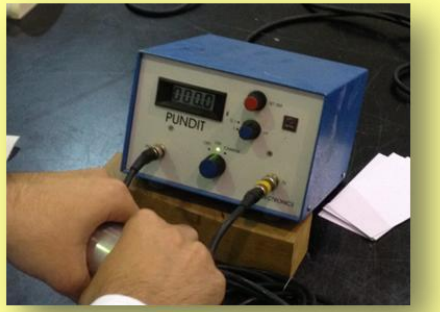
In these tests, the concrete is tested to failure but the destructive resulting is very localized and member under test is not weakened to any significant extent

A Range of Techniques used for the Non-Destructive Testing of Concrete

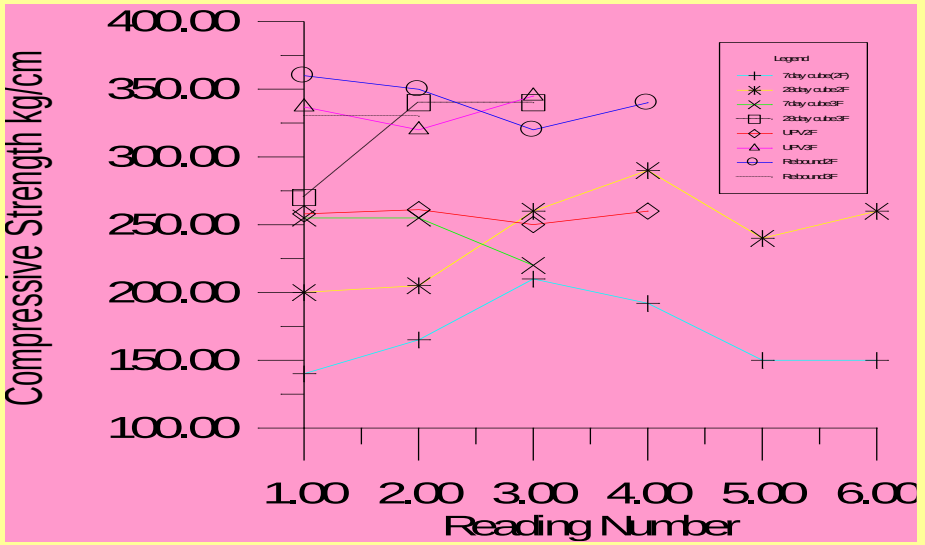


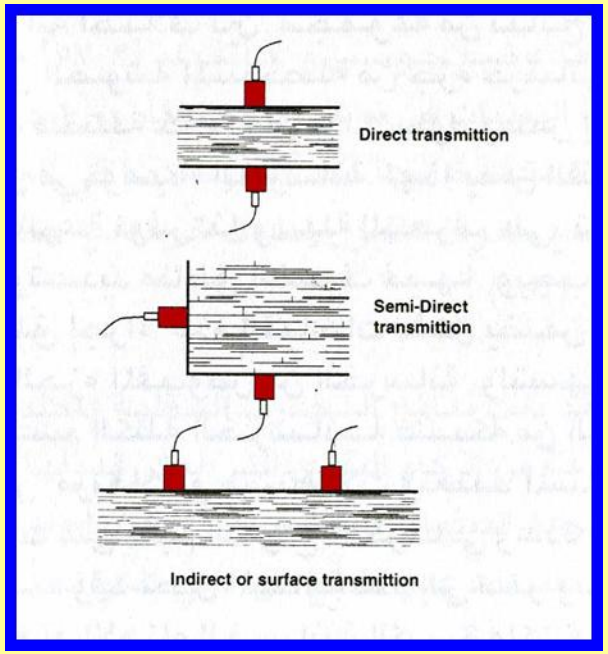


Ultrasonic Pulse Velocity



- It is important to note that when the relationship between pulse velocity and strength is determined by calibration tests the best predictions of compressive strength can be achieved.

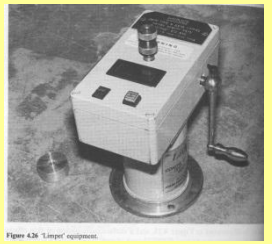


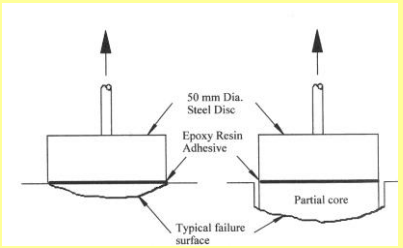


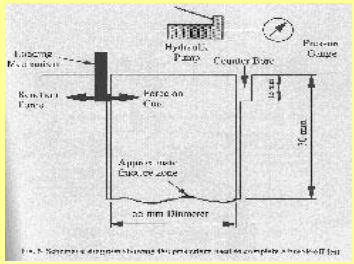
The factors influencing calibrations are so many that even under ideal conditions with a specific calibration it is unlikely that 95% confidence limits of better than +-20% can be achieved for an absolute strength prediction for in-place concrete

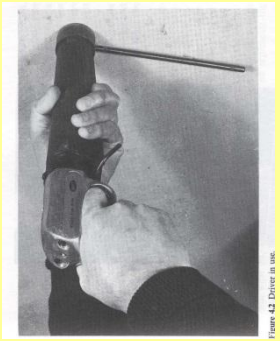
TESTING OF CONCRETE

METHOD	STANDARDS		PRINCIPLE FEATURES
	ASTM	BS 1881	
Rebound hammer	C805		Existing concrete,best used comparatively
Pull out	C900	207	Existing concrete , high variability
Pull off		207	Existing concrete surface or partially cored
Break off	C1150	207	New construction or Exsisting concrete





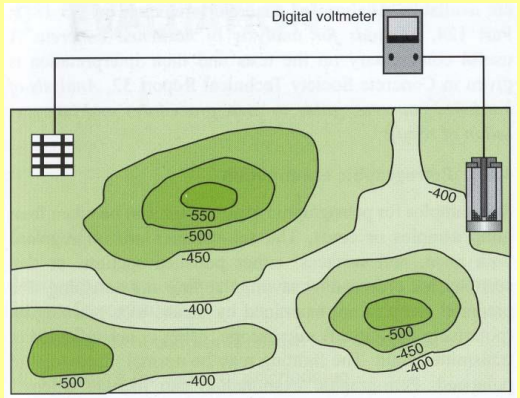


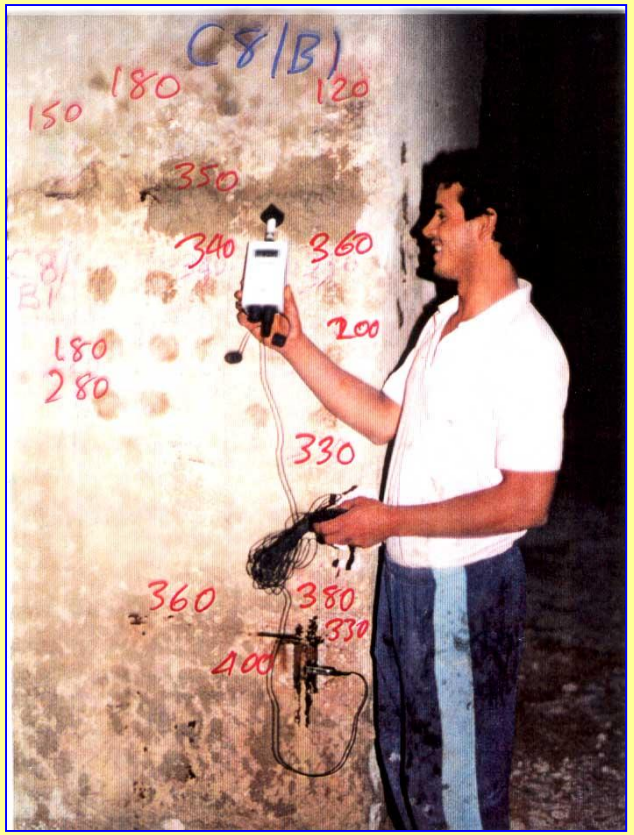


IN-SITU Testing

•**Half Cell potential: It measures the electrical potential on the surface of steel to qualitatively estimate the its likelihood of corrosion.**

Potential P (mV)	Risk of corrosion
P > -200 mV	5 %
-350< P< -200	50 %
P< -350	95 %





MAINTENANCE AND ITS TYPES

Introduction

Maintenance defined per BS 3811: 1984(1) as:

- ***The combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.***

➢ **From this definition two key components can be identified:**

Actions that relate to the physical execution of maintenance work, and its initiation, financing and organisation .

The notion of an acceptable condition, which implies an understanding of the requirements for the effective usage of the building and its parts and consideration of building performance.

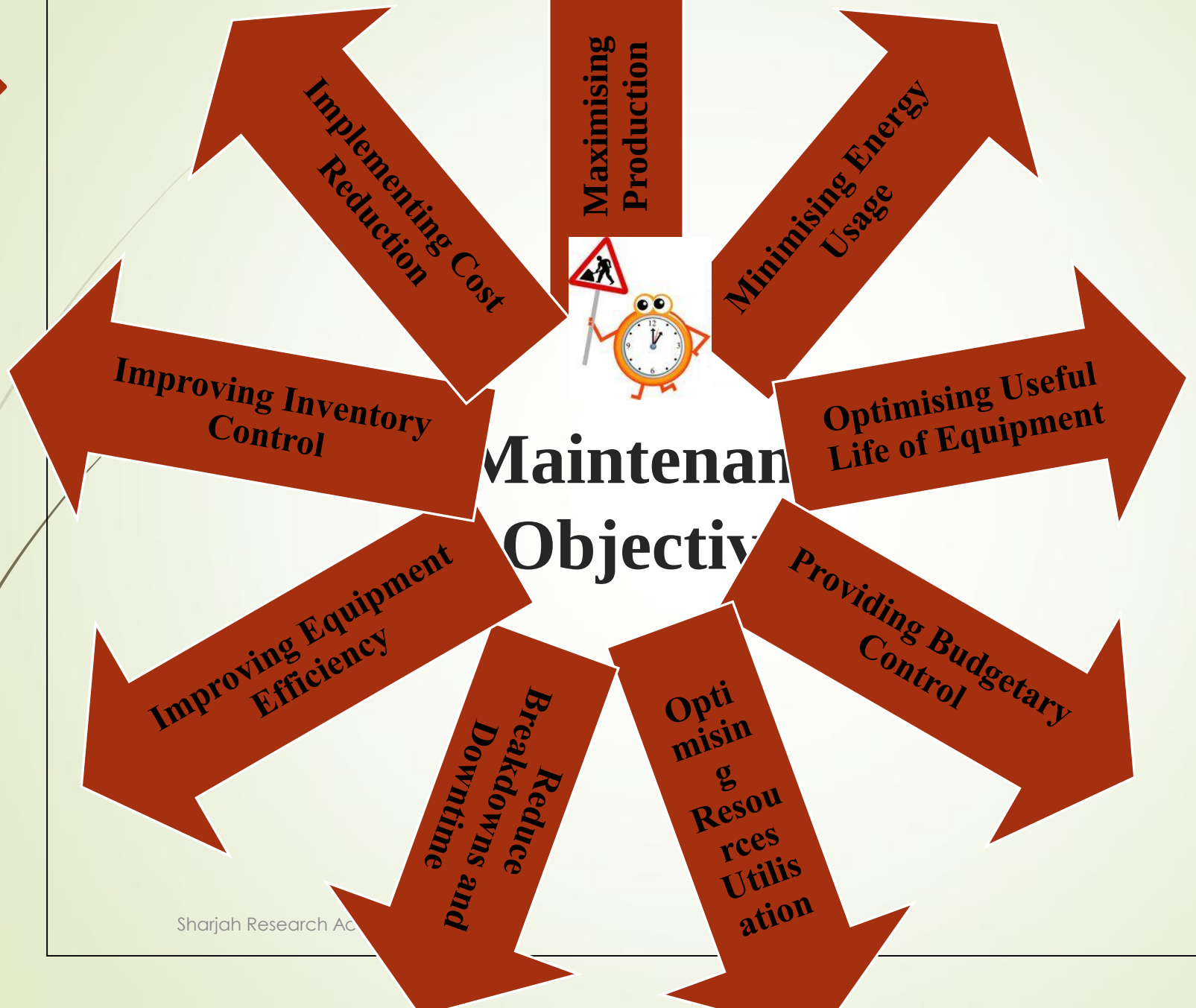
Maintenance Activities

In any MAINTENANCE operation there will be almost an element of IMPROVEMENT, if only through the replacement of a damaged component, so they are inseparable. However, establishments find it easier to attract funds and grands for major improvements maintenance attracts minimal attention and funding.

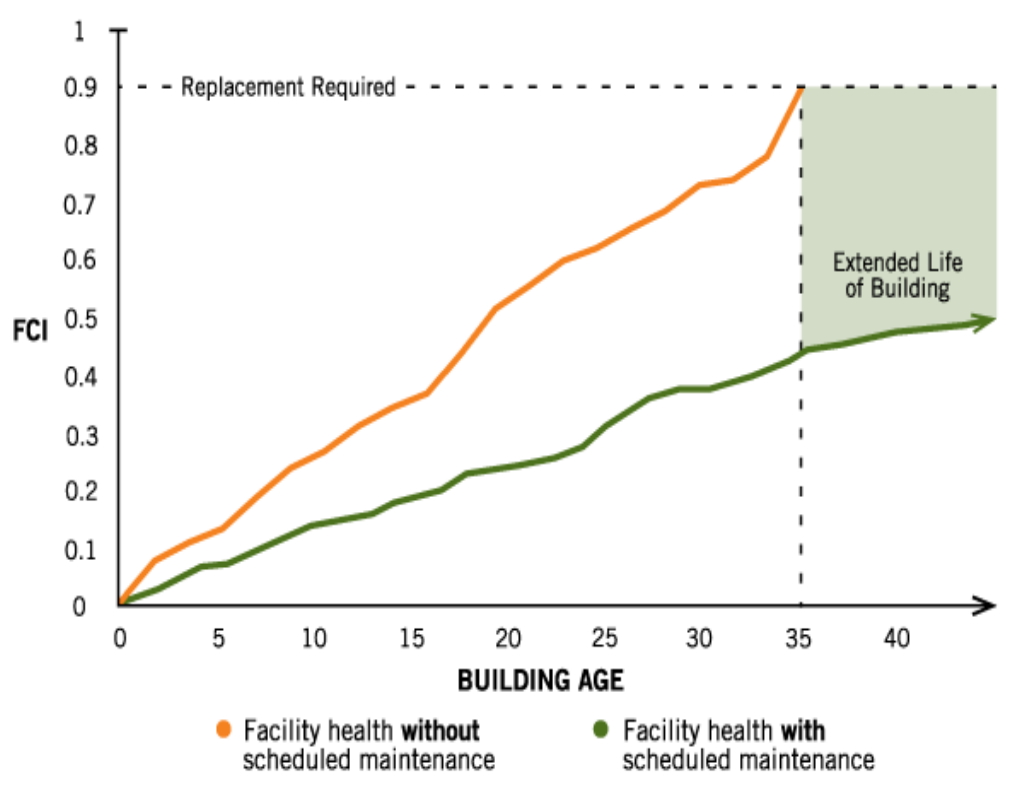
But both are very different and distinguishable from CONVERSION, REHABILITATION AND REFURBISHMENT, which have the clear objectives of adapting or increasing the utilization of the building, rather than maintaining it at the current level.

Thus building maintenance needs to be seen as a part of a larger property management function and viewed in the context of the emerging discipline of facilities management (FM).

It has been estimated that the annual cost of building maintenance,conversion,rehabilation and refurbishment in the UK is currently in the region of £10 Billion,


Maximising Production
Minimising Energy Usage
Optimising Useful Life of Equipment
Providing Budgetary Control
Optimising Resources Utilisation
Reduce Breakdowns and Downtime
Improving Equipment Efficiency
Improving Inventory Control
Implementing Cost Reduction
Maintenan
Objectiv

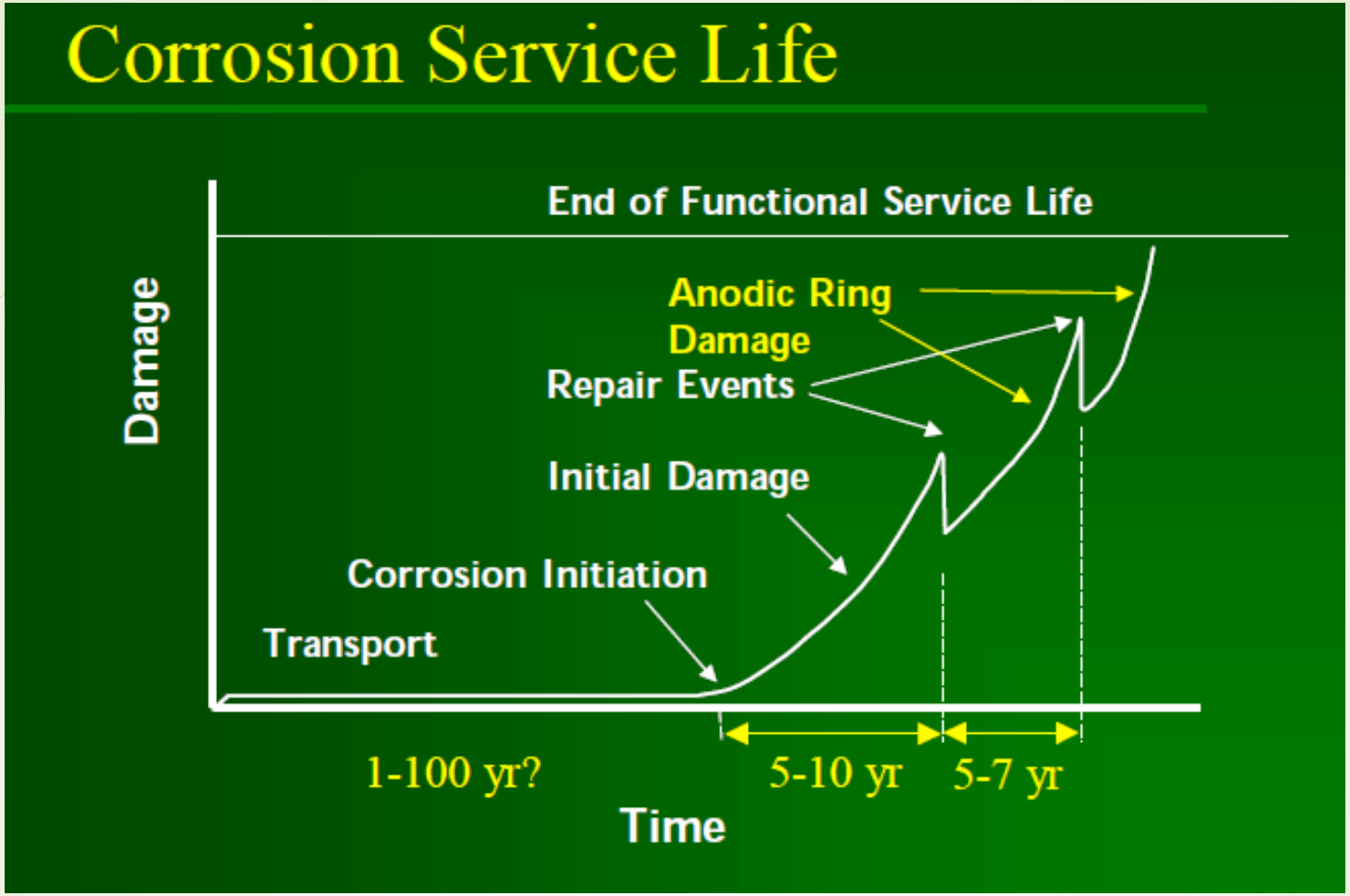
Extended Life of Building



- A Facilities Condition Index (FCI) of zero reflects a building that has no deferred maintenance, while an FCI of **one** would require full building replacement.

Source: BCIT Facilities and Campus Development

Corrosion Service Life

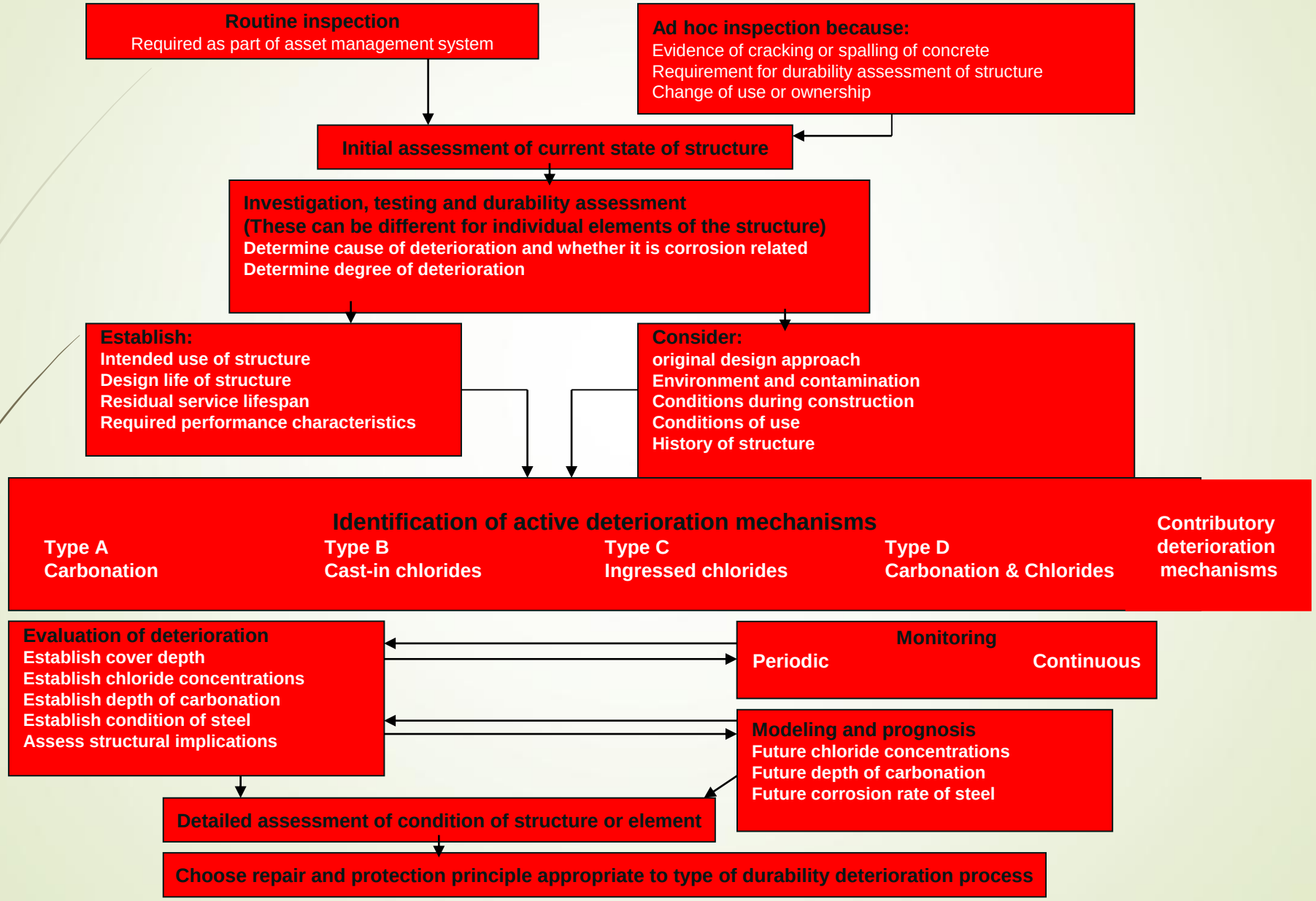


De Sitter's Law of Fives

A major repair can be expected to cost roughly five times what routine maintenance would have cost. An all-out replacement will cost five times what major repair would have cost.

DET

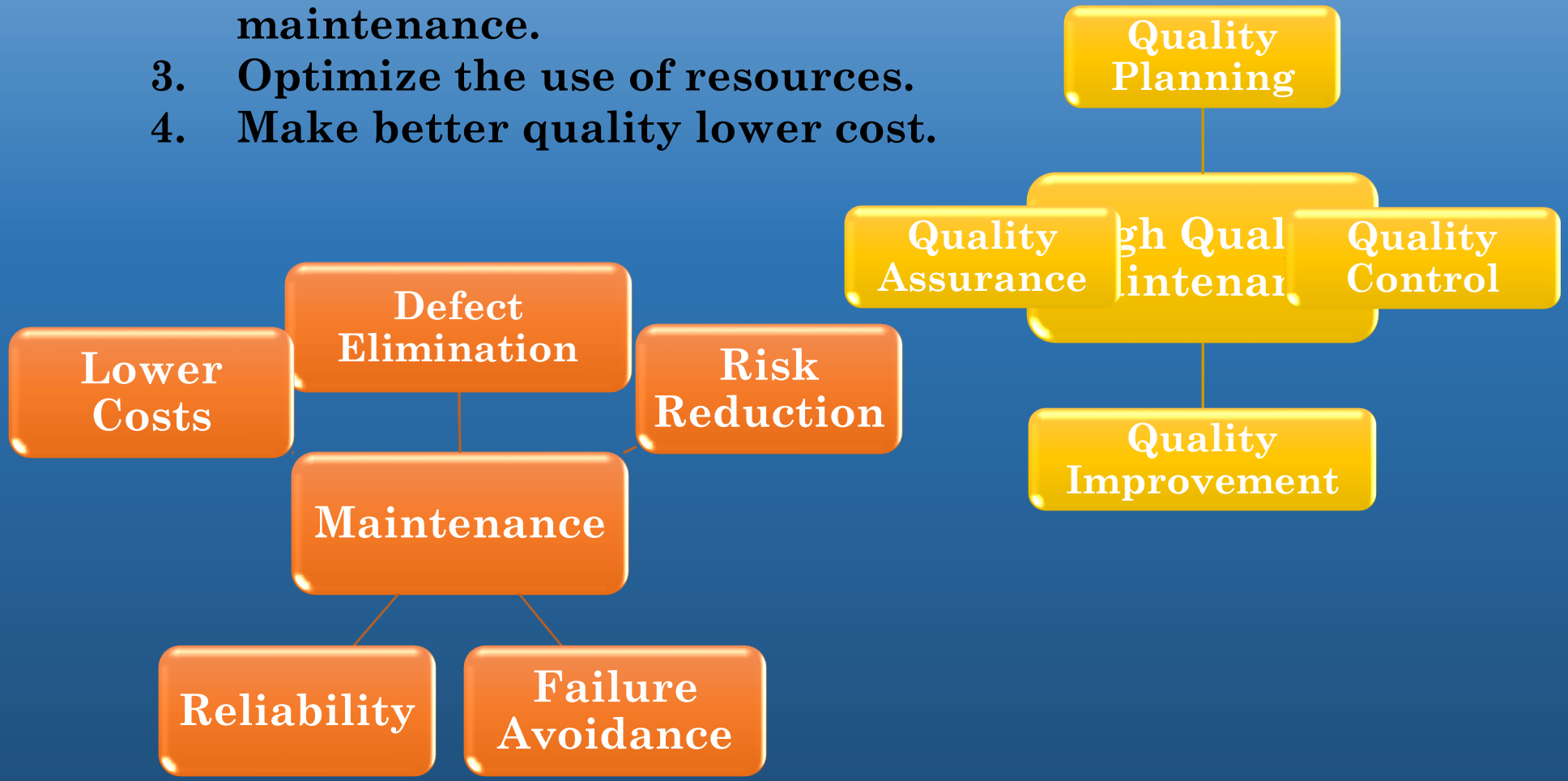
A summary of a decision making process for investigating and assessing



Importance Of Maintenance

Improve the Maintenance Systems to :

1. **Prevent failures.**
2. **Reduce the need to do maintenance.**
3. **Optimize the use of resources.**
4. **Make better quality lower cost.**



Importance of Maintenance

- Investing in roads maintenance at the right time saves future costs for example if the asset deteriorate the costs to restore their original conditions increases.
- The impacts of inadequate maintenance can be felt immediately on the safety of the road and on vehicle performance. If left unchecked, minor maintenance problems tend to become more serious and more expensive to repair.
- The South African National Road Agency Ltd. (SANRAL) estimates that repair costs can rise to six times maintenance costs after three years of neglect and to 18 times after five years of neglect. However, finding the necessary funding for maintenance can be difficult.

Life cycle Management and Maintenance

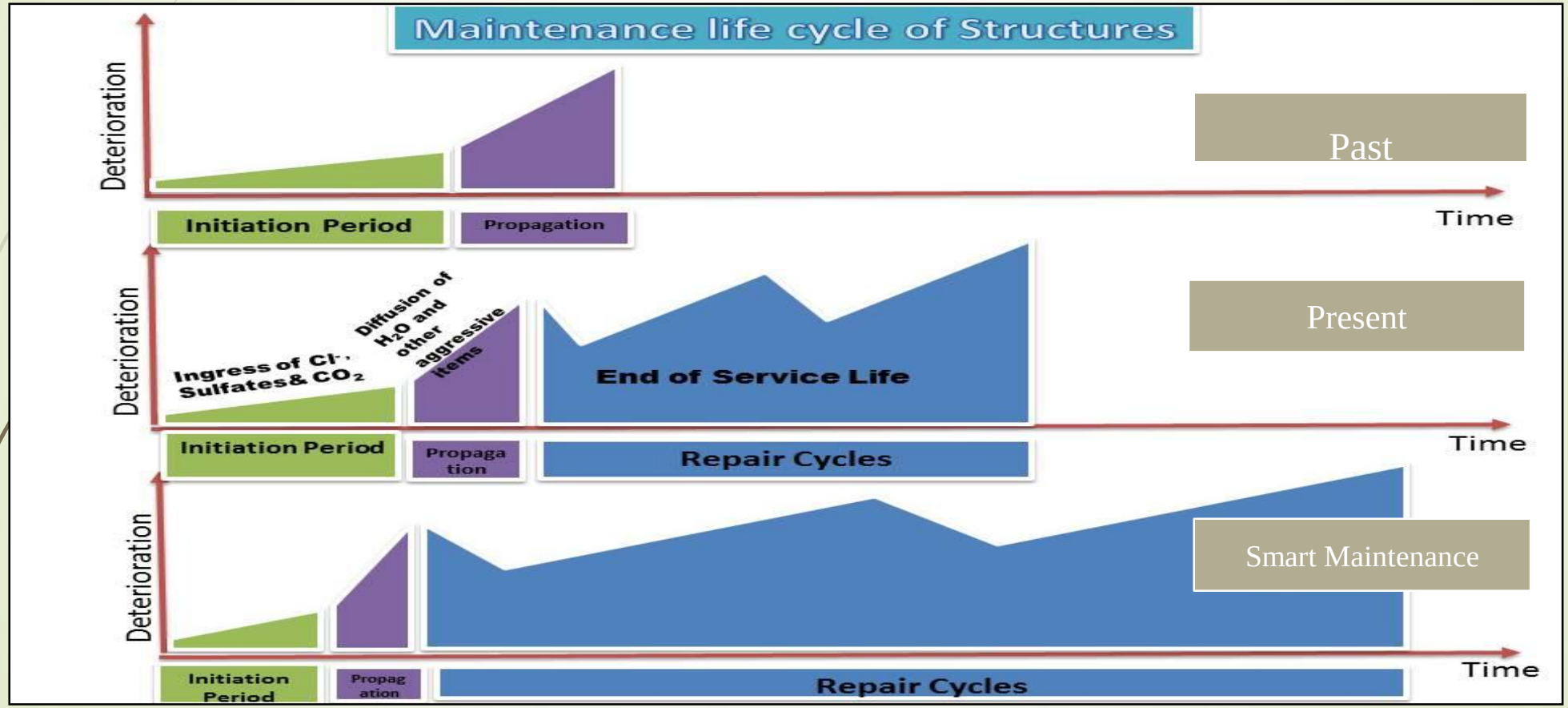


Figure 3: Maintenance Life cycle of Structures

Maintenance History

1. In the period of pre-World War II, people thought of maintenance as an added cost to the plant which did not increase the value of finished product.

Therefore, the maintenance at that era was restricted to fixing the unit when it breaks because it was the cheapest alternative

Maintenance History

2. During and after World War II at the time when the advances of engineering and scientific technology developed, people developed other types of maintenance, which were much cheaper such as preventive maintenance.

In addition, people in this era classified maintenance as a function of the production system.

Maintenance History

3. Nowadays, increased awareness of such issues as environment safety, quality of product and services makes maintenance one of the most important functions that contribute to the success of the industry.

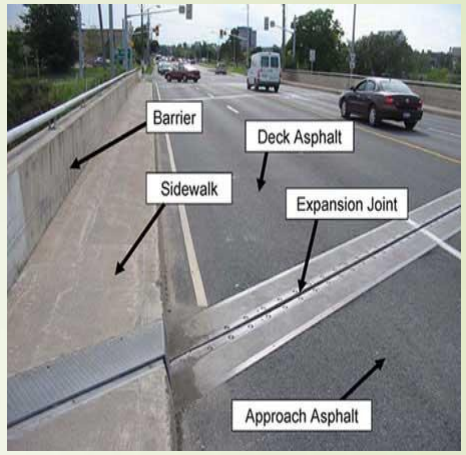
World-class companies are in
continuous need of a very well organised
maintenance programme to compete world-wide.

Types of Maintenance

- Run to Failure Maintenance (RTF)
- Preventive Maintenance (PM)
- Corrective Maintenance (CM)
- Improvement Maintenance (IM)
- Predictive Maintenance (PDM)

- Maintenance
  - Planned maintenance (proactive)
    - Predictive maintenance
      - Statistical - based
      - Condition - based
    - Preventive maintenance
      - Window
      - Running
      - Routine
      - Opportunity
    - Improvement maintenance
      - Engineering services
      - Design - out
      - Shutdown improvement
    - Corrective maintenance
      - Deferred
      - Remedial
      - Shutdown corrective
  - Unplanned maintenance (reactive)
    - Emergency
    - Breakdown

SHUTDOWN MAINTENANCE



Run to Failure Maintenance (RTF)

- It is the required repair, replacement, or restore action performed on a facility after the occurrence of failure to bring this facility to at least its minimum acceptable condition. It is the firstborn type of maintenance. It is subdivided into two types:

1. ***Emergency maintenance:*** it is carried out as fast as possible, to bring a failed facility to a safe and operationally-efficient condition.
2. ***Breakdown maintenance:*** it is performed after the occurrence of an advanced considered failure for which advanced provision has been made in the form of repair method, spares, materials, labour and equipment.

Preventive Maintenance (PM)

- It is a set of activities that are performed on plant equipment, machinery, and systems before the occurrence of a failure to prevent or eliminate any degradation in their operating conditions.
- British Standard 3811:1993 Glossary of terms defined preventive maintenance as:
  - *The maintenance carried out at pre-determined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning and the effects limited.*
- The advantage of applying preventive maintenance activities is to satisfy most of maintenance objectives.

Corrective Maintenance (CM)

- In this type, actions such as repair, replacement, or restore will be carried out after the occurrence of a failure in order to eliminate the source of this failure or reduce the frequency of its occurrence.

In the British Standard 3811:1993 Glossary of terms, corrective maintenance is defined as:

> the maintenance carried out after recognition and intended to put an item into a state in which it can perform a required function.

Improvement Maintenance (IM)

- It aims at reducing or eliminating entirely the need for maintenance.
- This type of maintenance is subdivided into three types as follows:

1. Design-out maintenance which is a set of activities that are used to eliminate the cause of maintenance, simplify maintenance tasks, or raise machine performance from the maintenance point of view by redesigning those machines and facilities which are vulnerable to frequent occurrence of failure and their long term repair or replacement cost is very expensive.

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- Wiener, N. (1982) *Cybernetics*. MIT.

Predictive Maintenance (PDM)

- Predictive maintenance is a set of activities that detect changes in the physical condition of equipment (signs of failure) in order to carry out the appropriate maintenance work for maximising the service life of equipment without increasing the risk of failure.

- It is classified into two kinds according to the methods of detecting the signs of failure:
  - *Condition-based predictive maintenance*
  - *Statistical-based predictive maintenance*

Predictive Maintenance (PDM)

- *Condition-based predictive maintenance* **depends on** continuous or periodic condition monitoring equipment to detect the signs of failure.

- *Statistical-based predictive maintenance* **depends on** statistical data from the meticulous recording of the stoppages of the in-plant items and components in order to develop models for predicting failures.

Advanced Repair Methods

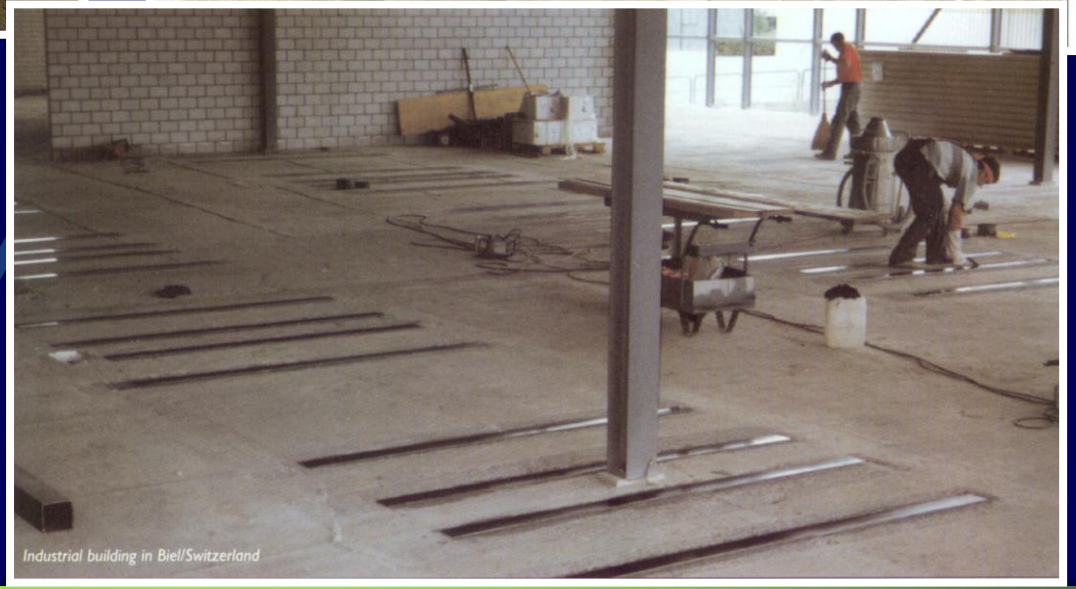
Strength Assessment Strategies and Rehabilitation of Bridges using Advanced Composite Materials

CARBON FIBER SHEETS

- Strengthening is used to:
  - Resist Higher Loads
  - Restore Strength of Deteriorated Members
  - Increase Ductility
- Traditional Methods
  - Externally Bonded Steel Plates
  - External Post Tensioning
  - Steel or Concrete Jackets

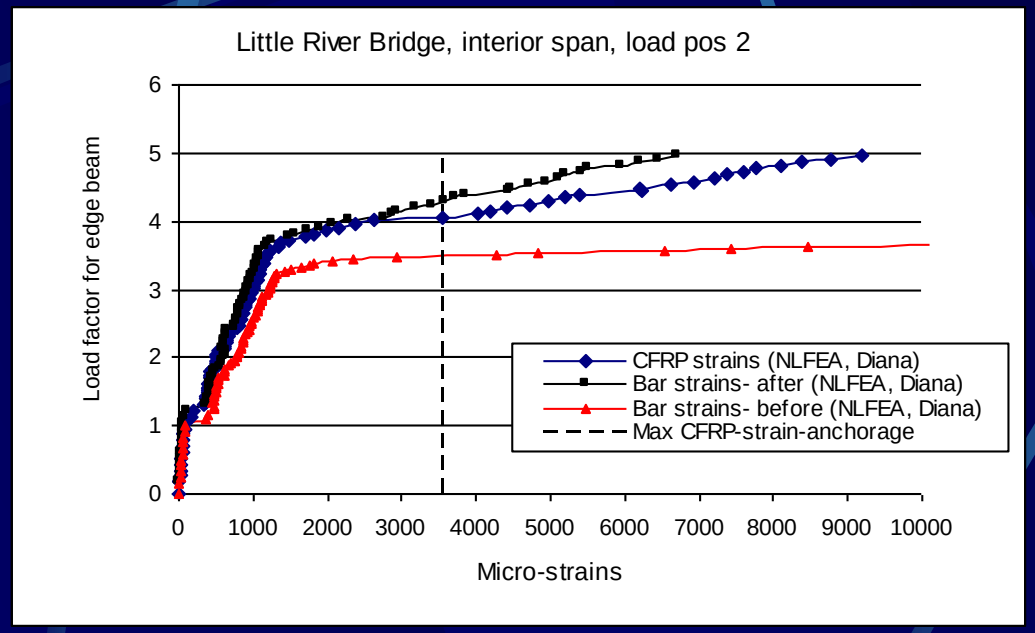
Ref. Riadh Al Muhaidi

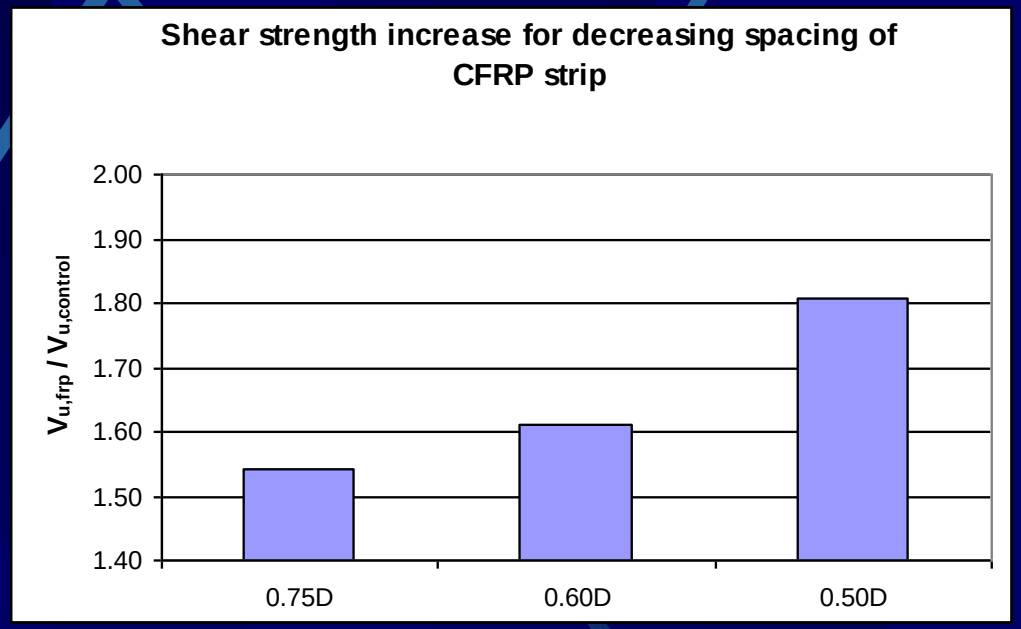
Flexure → Slabs



MONASH University

Analysis of load testing results
Little River Bridge





MONASH University

PART TWO

MAINTENANCE AND ORGANISATIONS

Introduction

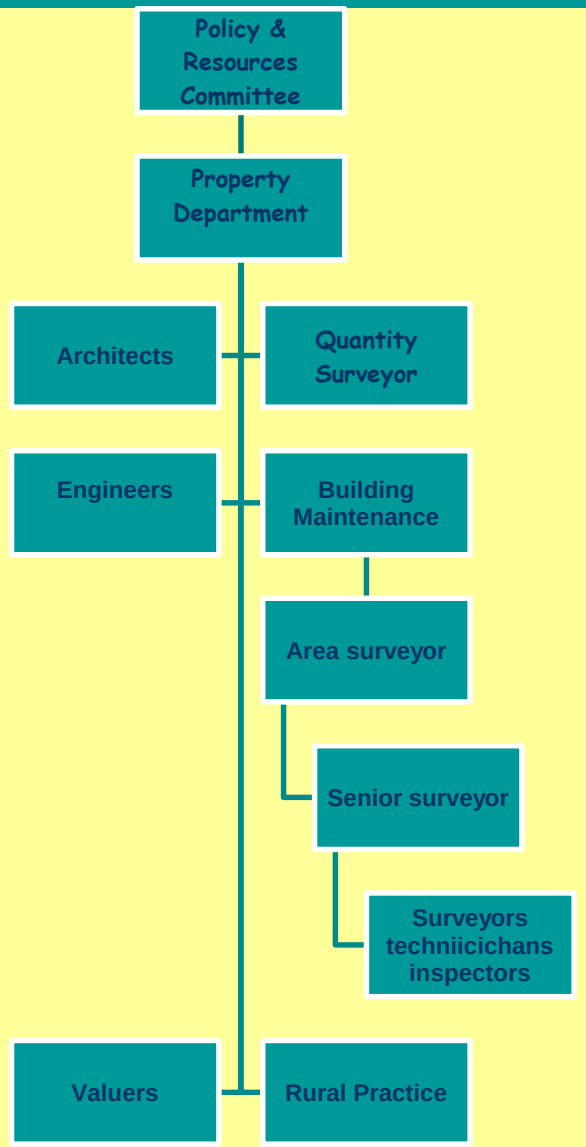
The Committee on Building Maintenance recommended the adoption of the following definition of maintenance:

*'… *work undertaken in order to keep, restore or improve every facility, i.e., every part of the building, its services and surrounds to a currently acceptable standard and to sustain the utility and* ***VALUE*** *of the facility.'*

- Within the private sector, there are different opinions between parties on opposing sides of a tenancy agreement. These perceptions may range from a 'cosmetic' view to an in-depth evaluation of building performance needs
- Within the public sector, it is apparent that social and political forces will have some bearing, and it may be extremely difficult to justify a given stance in the same terms that might be exercised in the private sector.

Maintenance Management System

Maintenance is a combination of any actions carried out to retain an item in ,or restore it to an acceptable condition



Execution of the work

- A policy will need to be formulated to indicate how maintenance work is to be executed. This will involve consideration of such factors as:
- Who executes the work o When is it executed o How is it executed
- How is it supervised and controlled
- Its relationship with other activities in the organisation

The Maintenance Department

A Policy will need to be formulated to indicate how maintenance work is to be executed. This will involve consideration of such factors as:

- ✓ ***who executes the work***
- ✓ ***When is it executed***
- ✓ ***How is it supervised and controlled***
- ✓ ***Its relationship with other activities in the organization***

The position of the maintenance department within the organization, and its relationships with other departments and functions, may be single biggest indicator of the degree of importance attached to maintenance by senior management.

Position of the maintenance department within the organisation

- The position of the maintenance department within the organisation, and its relationships with other departments and functions, may be the single biggest indicator of the degree of importance attached to maintenance by senior management.
- A carefully integrated maintenance department indicates a positive policy stance, where building maintenance has been considered as an important part of the organisational objectives.

  - ✓ This is related to overall corporate objectives. Also, in too many instances the reverse position will be the case, which reflects the low priority given to property maintenance by many organisations.

The Building Maintenance Organization

- ***Scope of the maintenance department***

- Maintenance department is used to describe the person or persons responsible for the planning, control and execution of maintenance operations. This may include independent bodies, as consultants and contractors. And the relationships with these bodies and the rest of the organisation must be carefully taken into account. The nature of these interfaces will influence operational methods and management systems.
- In general, each of the following phases must be considered in structuring maintenance departments:
  - Generation of maintenance work
  - Execution of the work
  - Control of operations
  - Provision of feedback
  - Financial control
  - Evaluation of performance

The Building Maintenance Organization

- The department set up to deal with maintenance needs must address two major concerns:
  1. It must provide an appropriate service within the guidelines established by proper consideration of corporate objectives.
  2. It must be capable of judging its own effectiveness by monitoring and controlling its performance.

- The need to satisfy these two issues underlines the importance of the interface of maintenance with the rest of the organisation. For example, a typical housing association defines a set of performance indicators, amongst which are the following:
  - Accountability
  - Response to repairs
  - An indication of the times properties are unoccupied

Functions of a Maintenance Department

Advisory Function

- This can be seen as a key area of interface, involving liaison with owners, and consultation with senior management, to advise on such matters as:

- **The development of the design for new buildings, their design and procurement**
- **The production of as-built drawings arid maintenance manuals**
- **The performance requirements of new buildings in general**
- **The provision of specialist advice, and other services related to the areas of adaptation, refurbishment and extensions/modifications**
- **Determination of standards, and the setting of performance indicators in relation to the primary needs of the organisation**
- **Providing on-going information on building condition**
- **On-going information relating to maintenance costs**
- **Advising senior management on the organisational needs of maintenance**

Organisation of Maintenance Departments

- The relationship between a maintenance department and the rest of the corporate body can be extremely variable, it is possible to identify common elements or operations that will exist in the departments themselves. These include:

  I. Identification of maintenance work, both planned and emergency, which can be called work input

  II. Instructions for the work have to be transmitted to the work team o Execution, supervision, approval and valuation of the work o Authorisation and making payment o A contractual framework o An accounting context

  III. A feedback system, the sophistication of which is variable

Organisation of Maintenance Departments

- These can be represented in the maintenance system, which is based on Wiener's view of an organisation as an adaptive system, entirely dependent on measurement and correction through information feedback.

- Maintenance organisations can be broadly encapsulated into two types of organisation:
  A. Centralised
  B. Decentralised

Organisation of Maintenance Departments

- There are differences in these models, relating to operational aspects. This will vary, through a range of factors directly related to operational matters:
  a. The nature of the building stock
  b. Volume, timing and diversity of the workload
  c. The complexity of the stock in technical terms
  d. Geographical and topographical factors
  e. Restrictions on the timing of work
  f. Whether work is to be executed by contract or direct labour
  g. The level of expertise of the work force, and the extent to which non-operational tasks, such as routine inspections, are delegated to the people on the job
  h. How maintenance is defined in the organisation, such as the degree of involvement of the maintenance department in minor capital works

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- Corrosion Management

CASE STUDIES

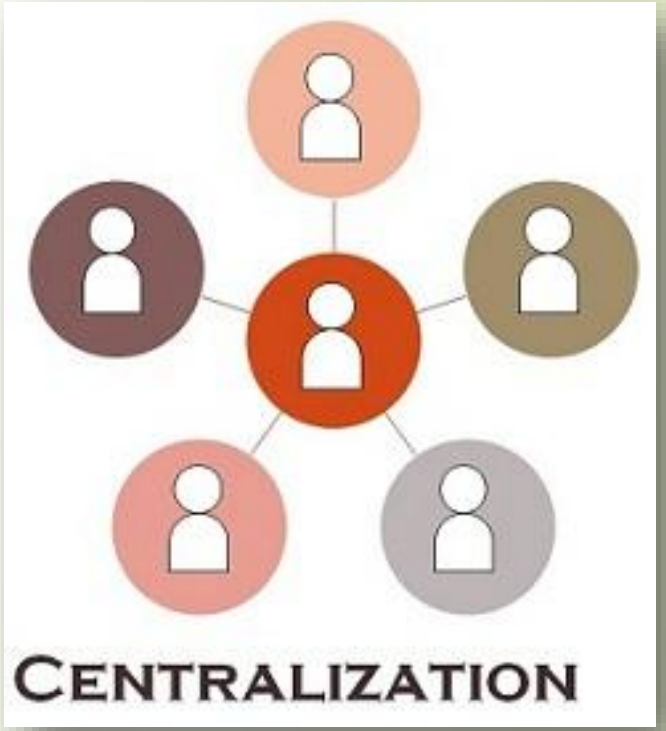
Centralization vs Decentralization

- Organizations' philosophy, maintenance, load, size and skill, will lead the decision of the origination to choose, whether to be Centralized, Decentralized or Hybrid (between both).

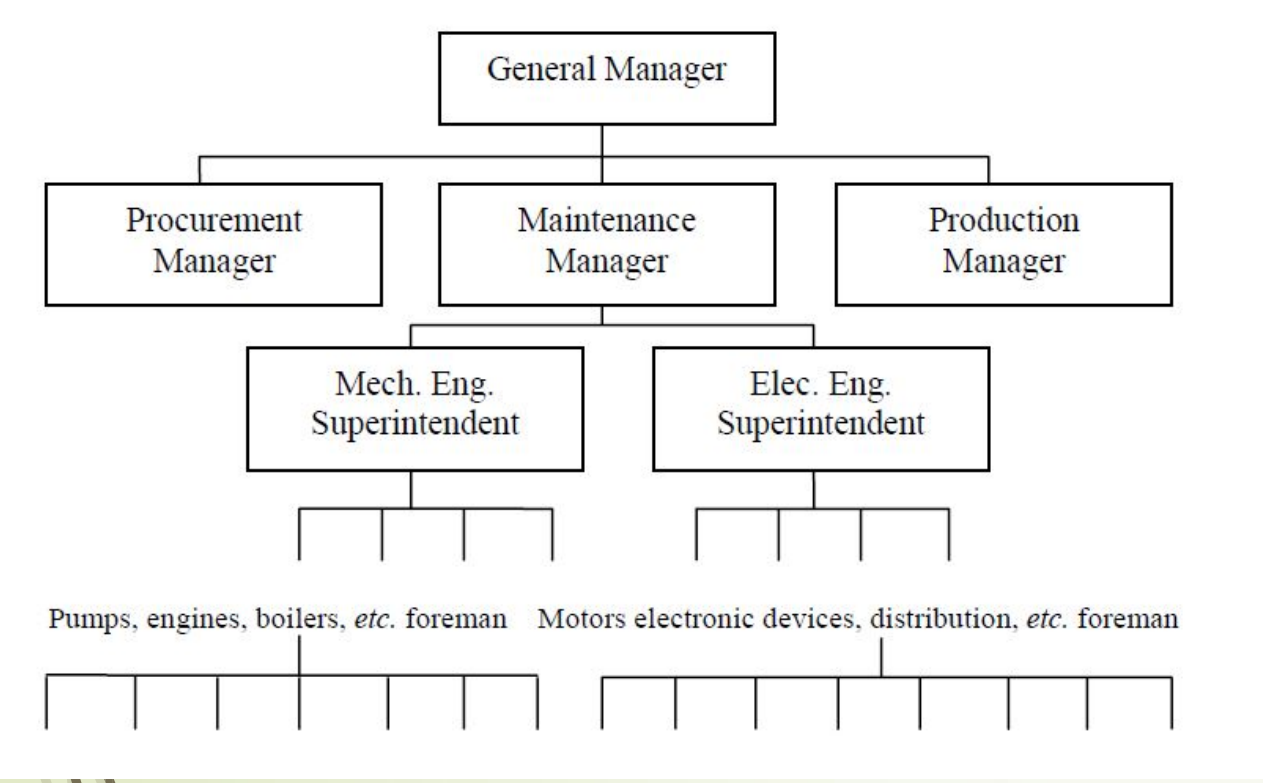
Source: http://keydifferences.com/wp-content/uploads/2015/05/Centralization-Vs-Decentralization.jpg

Centralization

Advantages	Disadvantages
Provides more flexibility and improves utilization of resources such: highly skilled crafts and special equipment and therefore results in higher efficiency	Less specialization on complex hardware is achieved since different persons work on the same hardware
Allows more efficient line supervision;	Supervision of crafts becomes more difficult and as such less maintenance control is achieved
Line supervision is usually more effective since one individual is responsible for all maintenance.	Less utilization of crafts since more time is required for getting to and from jobs
Permits the purchasing of modern equipment.	More costs of transportation are incurred due to remoteness of some of the maintenance work.
usually permits more effective on-the-job training.	More cost in connection with transportation is necessitated in view of remoteness of some of the maintenance work.



Example (Centralized)



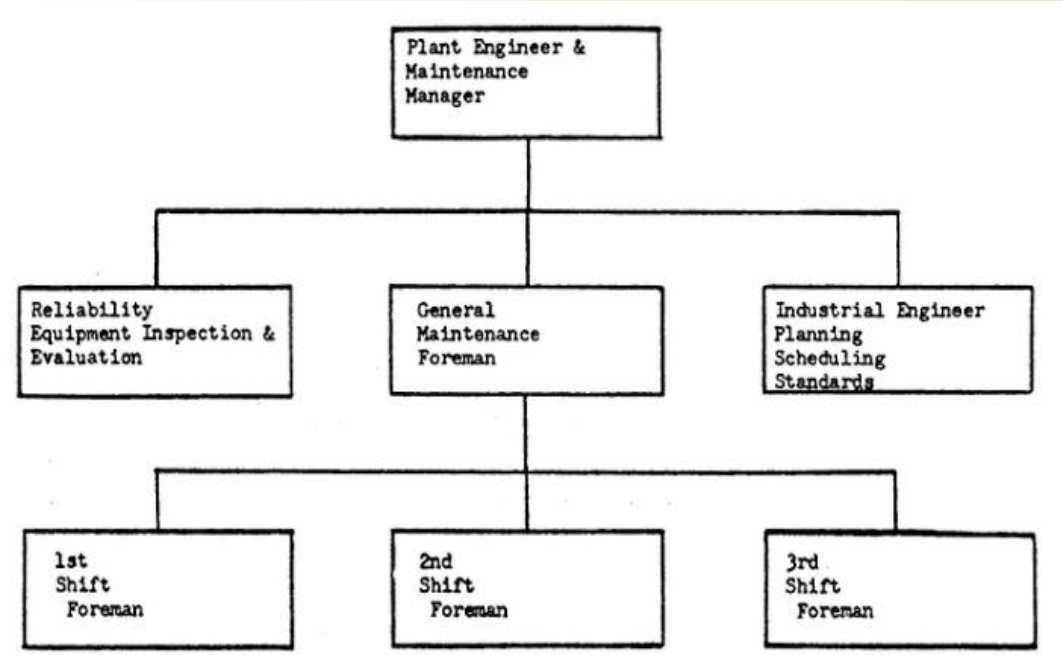


Figure 1.4 Maintenance organization chart utilizing centralized maintenance typical of small and medium-sized plants.

(Benjamin W. Niebel (1994))

Decentralization

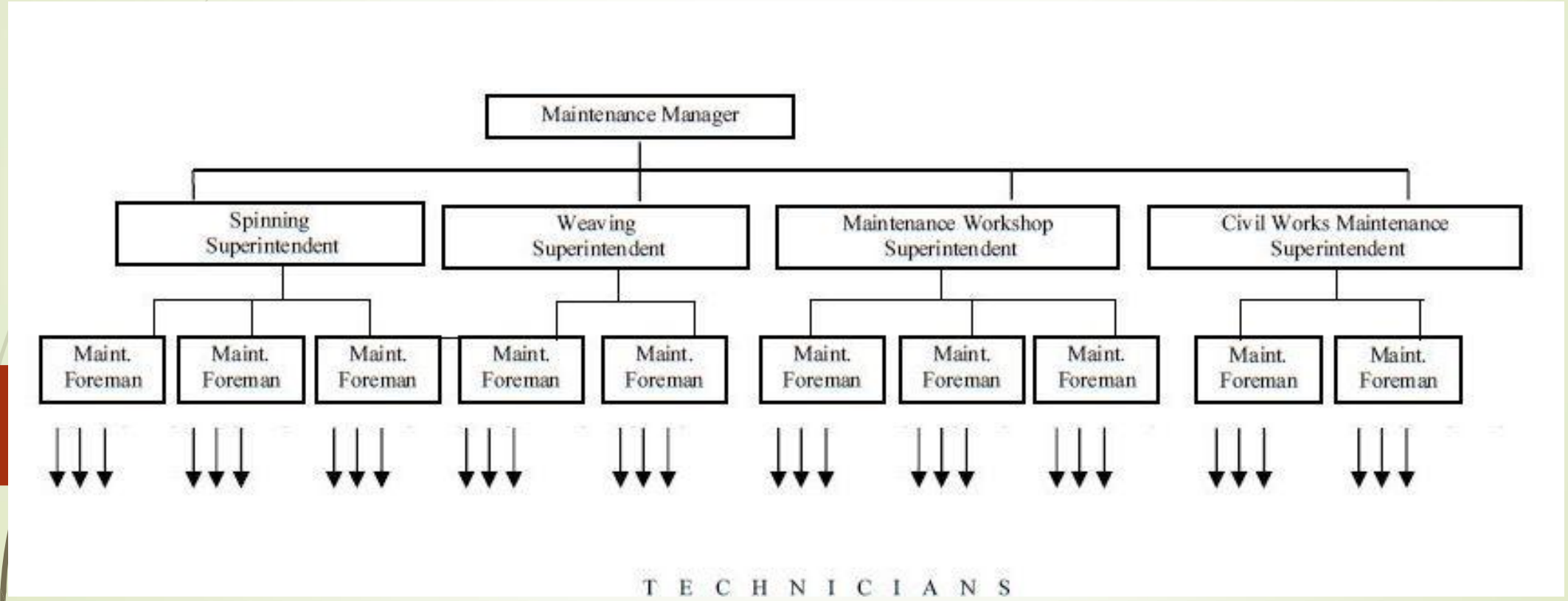
Advantages	Disadvantages
supervision is usually closer and workmen become more familiar with complex sophisticated facilities in view of the same specialists being reassigned to service the same equipment	This tends to reduce the flexibility of the maintenance system as a whole.
There is room for innovation and individual thought processes that could benefit the company as a whole or even one simple task	The range of skills available becomes reduced
reduced travel time in getting to and from the job	only in large plant or scaled companies
and the spirit of cooperation that exists between production and maintenance workers when working together in the same generalized area.	loses its principal advantage when production workers assume a greater responsibility for preventive maintenance
Employees of this type of environment favor change and like the fast paced environment that allows them to have input and feedback.	Manpower utilization is usually less efficient than in a centralized maintenance.

Source: http://keydifferences.com/wp-content/uploads/2015/05/Centralization-Vs-Decentralization.jpg

https://blog.ordoro.com/2012/07/19/centralized-organization/

(Benjamin W. Niebel (1994))

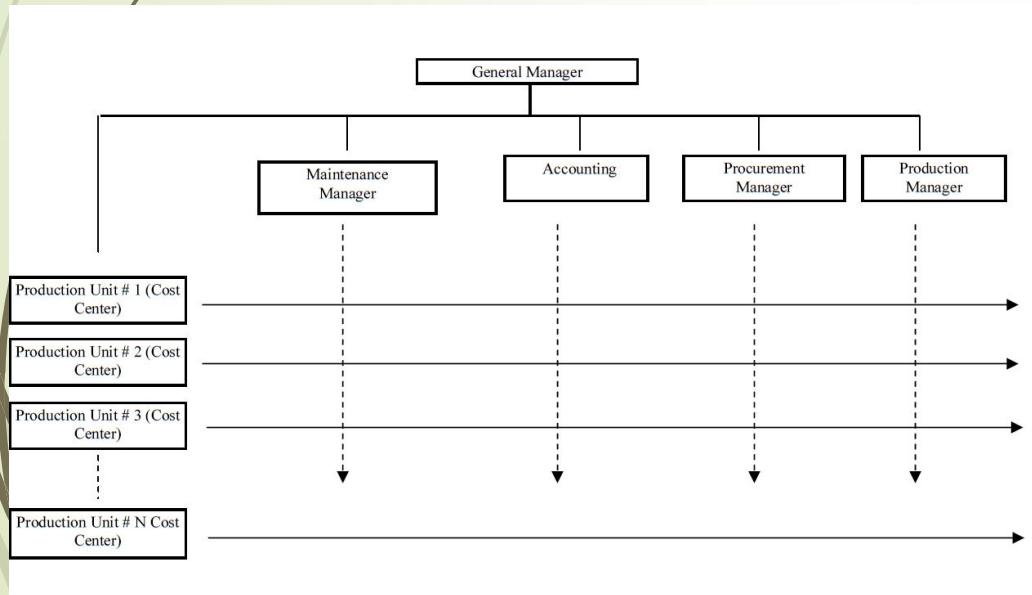
MAINTENANCE ORGANIZATION CHART



Ref. Haroun & Dufluaa, Research Gate 2009

Hybrid (Centralization & Decentralization)

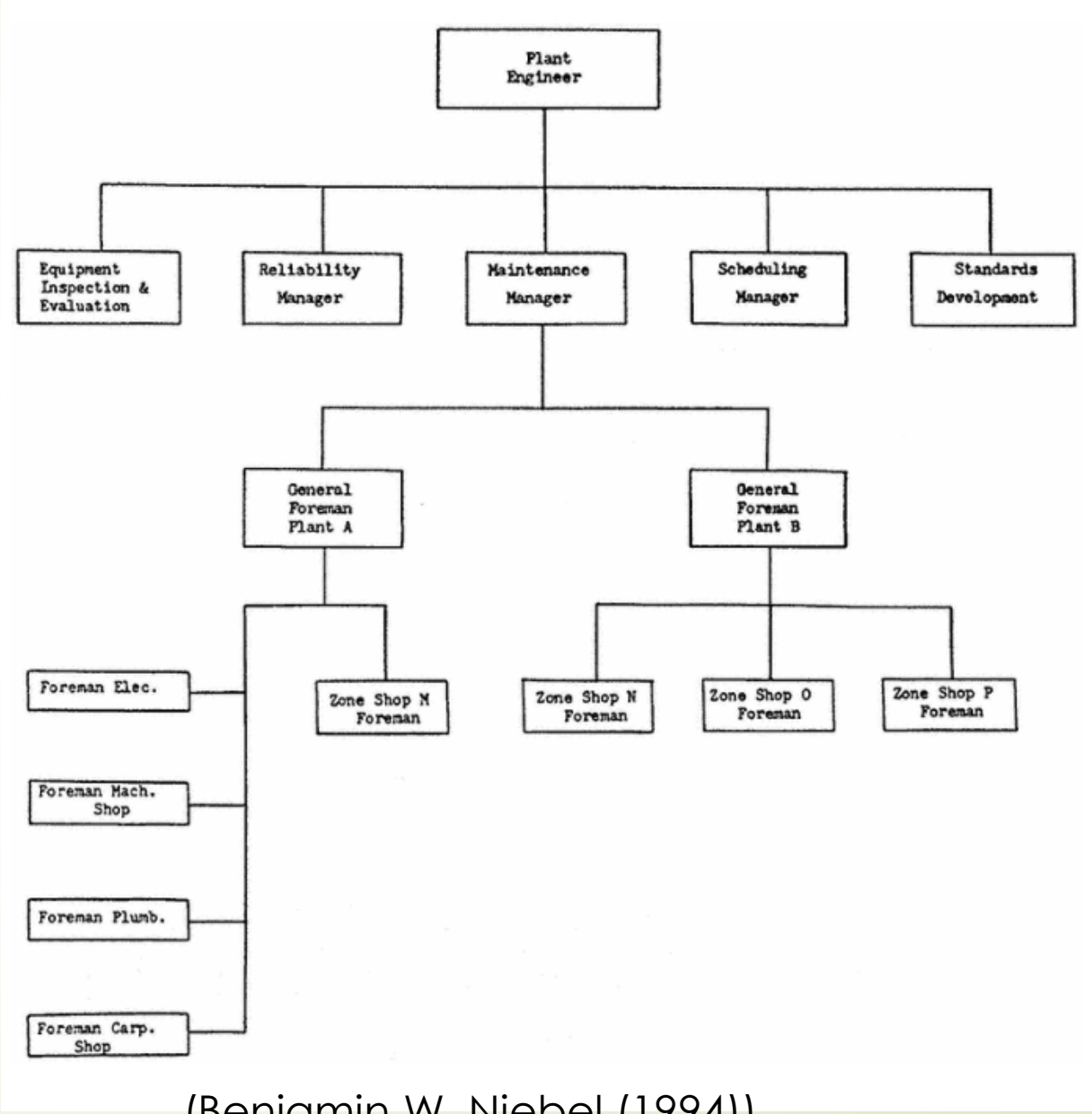
- In some cases a compromise solution that combines centralization and decentralization is better.
- This type of hybrid is called a cascade system.
- The cascade system organizes maintenance in areas and what ever exceeds the capacity of each area is challenged to a centralized unit.
- In this fashion the advantages of both systems may be reaped.
- The typical organization for such sequence is for large organizations.



(Benjamin W. Niebel (1994))

Example (Hybrid)

A chart of Maintenance organization that combines decentralized and centralized maintenance.
The typical organization for such sequence is for large organizations.



(Benjamin W. Niebel (1994))

Recommendations on which type

- **In small and medium-sized companies, centralized maintenance is recommended.**
- **In larger and more complex companies, a hybrid of centralized and decentralized maintenance is recommended with decentralization taking place only when either**

(a) The work load is such to keep specialists working optimum time

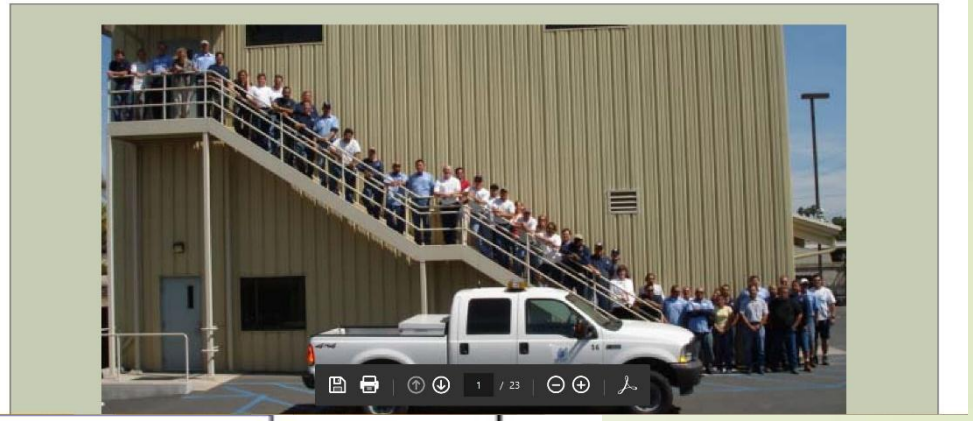
(b) The nature of the facility or facilities is such that immediate maintenance or repair is needed in order to keep the equipment running,

(c) It is the most cost-effective method of organization.

(Benjamin W. Niebel (1994))

The Operations and Maintenance Department

The Operations and Maintenance Department (O&M) operates and maintains the San Diego County Water Authority's (Water Authority) Aqueduct Delivery System,



OPERATIONS & MAINTENANCE DEPARTMENT

Gary Eaton
Director of Operations & Maintenance

System Operations: Joe Wegand
O&M Manager

System Maint./Construction: Gary Stine
O&M Manager

Water Quality: Timothy Suydam
O&M Manager

Operational Planning: John Galleher
O&M Manager

Administration: Lisa Prus
Supervising Management Analyst

Administrative Support
Escondido Office Management
Contract Administration/Purchasing
Emergency Preparedness
Records Management
Department Budget
Maximo Administration
Dept. Business & Strategic Planning
Policies & Procedures
Quagga Mussel Control
O&M Department Website

Lorrie Teates
Management Analyst
Alecia Rangel
Asst. Management Analyst
Carol Olvera
Administrative Assistant
Sandra Fairchild
Sr. Office Assistant
Sherrie Worrell
Sr. Office Assistant
Jason Ubaldo
Student Intern
Leizel Umali
Student Intern

Energy: Greg Ortega
Water Resources Specialist

System Operations: Danny Allison
System Ops. Supervisor

Aqueduct Operations
SCADA Control & Monitoring
Equipment Calibration
Shutdown Planning
Water Sampling
Power Production
AFO Monitoring
Dam Operations & Monitoring
Quagga Mussel Monitoring
CIP Design Review

Bill Bachman
Sr. System Operator
Jim Ilzaina
Sr. System Operator
Ron Oreb
Sr. System Operator
Scotty Butler
Sr. System Operator
Christian Castaing
Sr. System Operator
Larry Dobbs
Sr. System Operator
Adrian Varela
Sr. System Operator
Don McLain
System Operator II
Will Kane
System Operator II
Mark Underwood
System Operator II
Mark Kaczmarek
System Operator II
Chris Clemens
System Operator I
Javier Chavez
System Operator I

Technical Services: Brian Lightbody
Elect /Electrical Supervisor

Electrical/Electronics Maintenance
Calibration of Flow metering Instruments
Fiber Optic Cable System Maintenance
SCADA Communication Systems
Facility System Upgrades
Locks/Access Cards/Security
CIP Design Review

Greg Tucker
Sr. E/E Technician
Tom Marschinke
Sr. E/E Technician
Steve Ramsey
Sr. E/E Technician
Emanuel Nwagbo
Sr. E/E Technician
Jose Fragozo
Sr. E/E Technician
Glenn Thorpe
Sr. E/E Technician
Brent Young
Sr. E/E Technician
Michael Tabbert
Sr. E/E Technician
Jim Truett
E/E Technician II
Kevin McBride
E/E Technician II
Sue Erman
E/E Technician I
Vacant
E/E Technician I

Mechanical Maintenance: Steve Carpenter
System Maint. Supervisor

Pipeline Repairs
Mechanical Equipment Services
Facility Maintenance & Painting
Pipeline Shutdown Services
CIP Design Review
Line Structure Painting

Al Earnest
Sr. Maint. Technician
Mike Stansel
Maint. Worker I
Mark Ancheta
Sr. Maint. Technician
Sal Serrato
Maint. Worker II
Mike Shafer
Sr. Maint. Technician
Jim Beedle
Maint. Worker I
Rick Switzer
Sr. Maint. Technician
Todd Hall
Maint. Worker II
Eduardo Bosa
Sr. Maint. Technician
Robert Carrego
Maint. Worker II
Joel Aguilar
Sr. Maint. Technician
Richard Ruiz
Maint. Worker II
Andy Mogi
Maint. Technician
Moises Montiel
Maint. Technician

Facilities Maintenance: Rachael Loring
System Maint. Supervisor

Access Road Grading
Culvert Maintenance
ROW Vegetation Maintenance
ROW & Fee Property Maintenance
Heavy Equipment Operations
Pipeline Shutdown Support
Welding, Fabrication & Construction
Facility/Structure Repair & Upgrades
Facility Maintenance & Painting

Gary Shaffer
Sr. Maint. Technician
Karton Chenelle
Maint. Technician
David Rivera
Maint. Worker I
Sebastian Riquelme
Sr. Maint. Technician
Chris Luna
Maint. Worker II
Dean Vargo
Sr. Maint. Technician
Luke Hollbrook
Maint. Worker I
Thad Ostrander
Sr. Maint. Technician
Andrew DeWitt
Maint. Worker II
Ken Teter
Maint. Worker II

Fleet/Rotating Equipment Services: Al Garza
System Maint. Supervisor

Fleet Maintenance & Repair
Light & Heavy Duty Vehicle PM
Vehicle/Equipment Acquisition & Disposal
Mobile & Bridge Crane Inspection/Repair
Equipment Fabrication
Vehicle Accident Investigation
Rotating Equipment Services

Mark Christman
Fleet Mechanic II
Joe Carroll
Fleet Mechanic II
Vacant
Fleet Mechanic II
Rick Burke
Maint. Technician
Doug Llamas
Maint. Technician

Aqueduct Protection
Corrosion Monitoring
Corrosion Guide Drawings
Pipeline Condition Assessment & Monitoring
Pipeline Rehabilitation Schedules
Member Agency Agreements

Eric Holm
Sr. Engineering Tech.
George Smith
Sr. Engineering Tech.
Lynn True
Management Analyst
Brendan Sheehan
CC – Corrosion Engineer
Daryl Akieka
CC – Corrosion Tech.
Jason Kletchka
CC – Corrosion Tech.
Allison Johnston
Student Intern

Planning/Modeling/CIP Support: Tom Harpin
Principal Water Res. Specialist

Facility Planning
Aqueduct Operating Plan
Systeo Modeling
Asset Management
System Schematics & Operational Diagrams
CIP Technical Liaison
CIP Design Review
O&M Peak Services Oversight
ESP Operating & Delivery Plans
ESP Operating Forecast/Schedule
ESP Agreements/MOUs
CAD Drafting & Graphics
Electrical/Instrumentation Guide Drawings
Record Drawings

Nathan Faber
Sr. Water Res. Specialist
David Dow
Water Resources Specialist
Vince Bond
CC – Electrical Engineer
Nadir Hossain
Student Intern

Admin Services: Terri Romero
Safety Officer

San Diego County Water Authority

Revision Date: 1/11/10
Revised By: CAD

LEGEND & NOTES:
(Grayed Text) – Denotes Authority Temporary Employee
CC – Denotes Contract Consultant
Temp. – Denotes Temporary Agency Staff
PT – Denotes Part-time

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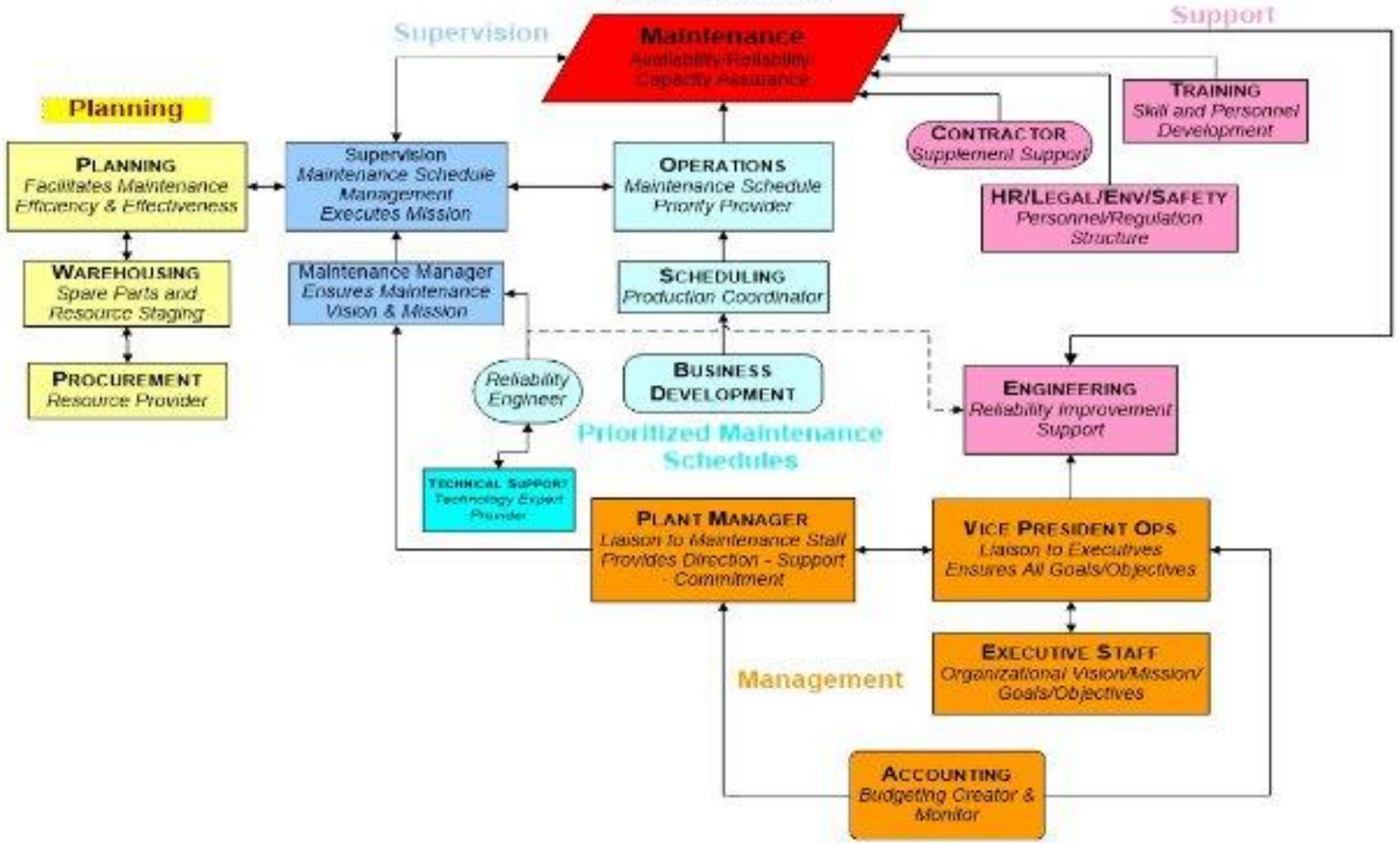
Functional Maintenance Organizational Structure



GOVERNMENT OF DUBAI

Dubai Municipality Organizational Chart 2016

DUBAI MUNICIPALITY

Dubai Municipality Chairman

Director General

Municipal Council

Deputy Director General

DG's Office

Communication & Community Sector

Support & Development Office

Recreational Facilities Department
- Dubai Safari Section
- Children's City Section
- Landmarks & Theme Parks Section
- Promotions & Recreational Events Section

Corporate Marketing & Relations Department
- Corporate Marketing Section
- Public Relations Section
- Media & Publication Section
- Dubai Municipality Club Section

Knowledge & Innovation Department
- Knowledge Exchanging Section
- Innovation & Proposals Support Section
- Documentation & Information Management Section

Customers & Partners Relations Department
- Customer Care Section
- Partnership Section
- Communication Section

Legal Affairs Department
- Legislation & Legal Opinion Section
- Litigation Management Section
- Judicial & Administrative Section

Strategy & Corporate Excellence Department
- Strategic Planning & Corporate Performance Section
- Corporate Organization & Operations Section
- Corporate Assessment Section
- Excellence Programs Section

Financial Audit Department
- Technical & Financial Audit Section
- Revenues & Financial Statements Audit Section
- Expenses Audit Section

Accreditation & Conformity Department
- Laboratories Accreditation Section
- Inspection Bodies Accreditation Section
- Certification Bodies Accreditation Section

Corporate Support Sector

Support & Development Office

Finance Department
- General Budget Section
- Accounting Section
- Treasury Section
- Compensations Section

Human Resources Department
- Human Resources Planning Section
- Human Resources Recruitment Section
- Human Resources Development Section
- Salaries & Services Section

Contracts & Purchasing Department
- Warehouse Section
- Purchasing Section
- Engineering Contracts Section
- Specialised Contracts Section
- Supplier Relations Management Section

Information Technology Department
- Electronic Transformation Section
- Applications Development Section
- Technical Infrastructure Section
- Information Systems Security Section
- Users Support Section

General Revenues Department
- Hotel Establishments Revenues Section
- Housing & Markets Revenues Section
- Services & Claims Revenues Section

General Support Sector

Support & Development Office

General Maintenance Department
- Dubai Municipality Buildings & Facilities Maintenance Section
- Government Buildings & Facilities Maintenance Section
- Technical Services Section

Transportation Departmetn
- Vehicle & Equipment Maintenance Section
- Technical Support Section
- Materials Management Section
- Administrative Support Section

Assets Management Department
- Assets Management Section
- Market Management Section
- Investment Section
- Security & Administrative Section

Municipality Centres Department
- Al Kifaf Centre
- Al Manara Centre
- Hatta Centre
- Al Towar Centre

Architectural Heritage & Antiquities Department
- Architectural Heritage Studies Section
- Architectural Heritage Projects Design Section
- Architectural Heritage Projects Execution Section
- Antiquities Section

Environmental Health & Safety Control Sector

Support & Development Office

Health & Safety Department
- Occupational Health & Safety Section
- Public Safety Section
- Consumer Product Safety Section
- Health Control Section

Environment Department
- Environmental Planning & Studies Section
- Environmental Control Section
- Costal Zones & Waterways Management Section
- Environmental Awareness Section
- Natural Resources Protection Section

Dubai Central Laboratory Department
- Construction Materials Laboratory Section
- Food & Environment Laboratory Section
- Consumer Products & Commodities Laboratory Section
- Renewable & Electromechanical Energy Laboratory Section
- Product Conformity Assessment Section
- Metrology Laboratory Section
- Business Development & Support Section

Food Safety Department
- Food Studies & Planning Section
- Food Inspection Section
- Food Trade Control Section
- Permits & Applied Nutrition Section

Sustainability & Renewable Energy Application Department
- Sustainability & Renewable Energy Section
- Research & Sustainability Studies Section

Environment & Public Health Services Sector

Support & Development Office

Waste Management Department
- Cleaning Services & Operations Section
- Specialized Cleaning Section
- Waste Treatment Section
- Technical Support & Studies Section
- Administrative Support Section

Public Health Services Department
- Clinic & Medical Services Section
- Veterinary Services Section
- Public Health Pest Control Section
- Abattoirs Section

Drainage & Irrigation Network Department
- Pumping Stations Section
- Irrigation Systems Operation & Maintenance Section
- Drainage Networks & Stations Maintenance Section
- Technical & Administrative Support Section

Drainage & Irrigation Department
- Drainage & Irrigation Planning & Design Section
- Drainage Construction Projects Section
- Irrigation Construction Projects Section
- Drainage Services Section

Sewage Treatment Plan Department
- Al Aweer Plant Process Section
- Jabel Ali Plant Process Section
- Sewage Treatment Plants Maintenance Section
- External Sewage Treatment Plants Support Section

Public Parks & Horticulture Department
- Horticulture Section
- Horticulture Services Section
- Parks & Recreation Section

Engineering & Planning Sector

Support & Development Office

Survey Department
- Geodesy Hydrographic Survey Section
- Cadastral & Property Survey Section
- Land Information & Site Plan Issuing Section

Planning Deparment
- Planning Research Section
- Planning Legislation Section
- Land Allocation & Services Section
- Advertisement Section

Building Department
- Building Permits Section
- Consultants & Contracts Qualification Section
- Engineering Supervision Section
- Building Inspection Section
- Research & Building Systems Section

General Projects Department
- Projects Design Section
- Projects Construction Section
- Landscaping & Beautification Section
- Minor Projects Section
- Engineering Support Section

Geographic Information Systems Management Department
- Geographic Information Systems Development Section
- Geographic Information Systems Data Section
- Geoinformation Network Section
- Geographic Information Systems Service Section

UNITED ARAB EMIRATES
MINISTRY OF INFRASTRUCTURE DEVELOPMENT

ORGANISATIONAL CHART

- **The Minister**
  - Institutional Development Department
  - Governmental Communication Department
  - **Under Secretary**
    - **Assistant Under Secretary ,Support Service**
      - Information Technology Department
      - Tenders & Contracts Department
      - Finance Resources Department
      - Human Resources Department
      - Legal Affairs Department
    - **Assistant Under Secretary, Housing & Urban Planning**
      - Design Department
      - Urban Planning Department
      - Project Planning Department
      - Housing Department
      - Technical Studies Department
    - **Assistant Under Secretary, Works**
      - Maintenance Department
      - Roads Department
      - Execution Department

Conclusion

Engineering Judgment

- is the vital tool in the assessment of the damages and causes of concrete deterioration and failure of structural elements
- Tests helps in visualizing the problem and making the decision. And what remains is an automatic implementation of repair methods and repair materials.

Prevent

- Done by:
- Periodical inspection
- Monitoring
- Routine maintenance

Pre-Design

- It would be of importance and good practice from the design stage to indicate the structural elements that will be exposed to severe environmental agents or special loading conditions and attention is given to special periodic inspection

The Goal?

- intelligent maintenance systems is to achieve and sustain the structures fully functional during their life cycle with self-maintenance capabilities

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