

Project Integration Management

The aim of this Project Management Area is the coordination of different project aspects; in particular:

- **General Plan Development**

Collect the different Planning Processes results in a Single Coherent and Complete Document

- **Project Plan Execution**

Proceed with the Project Development by applying the predefined activities

- **Project changes control**

Coordinate the Changes along the whole project

Project Integration Management

1.1 General Plan Development

- .1 Inputs**
 - .1 Other Planning Outputs**
 - .2 Historical Information**
 - .3 Organizational Policies**
 - .4 Constraints**
 - .5 Hypothesis**
- .2 Tools, and Techniques**
 - .1 Project Planning Methodology**
 - .2 Stakeholder skills, and experience**
 - .3 Project Management Information System (PMIS)**
- .3 Outputs**
 - .1 Project General Plan**
 - .2 Support Details**

1.2 Project Plan Execution

- .1 Inputs**
 - .1 Project General Plan**
 - .2 Support Details**
 - .3 Organization Policies**
 - .4 Corrective Actions**
- .2 Tools, and Techniques**
 - .1 Skills, in General Management**
 - .2 Skills, on the Product and Experience**
 - .3 System of Work authorization**
 - .4 Revision Meeting**
 - .5 PMIS**
 - .6 Organizational Procedures**
- .3 Outputs**
 - .1 Job Results**
 - .2 Requirements, Changes**

1.3 Project Change Control

- .1 Inputs**
 - .1 Project General Plan**
 - .2 Performance Report**
 - .3 Requirements, Changes**
- .2 Tools, and Techniques**
 - .1 Control System changes**
 - .2 Configuration Management**
 - .3 Performance, Management**
 - .4 Additional Planning**
 - .5 PMIS**
- .3 Outputs**
 - .1 Updates, on General Plan**
 - .2 Corrective Actions**
 - .3 Lessons, Learned**

Practical Objectives of the General Plan Development

Development Phase Objectives are:

- ◆ **Provide a Guide for the project execution**
- ◆ **Document the assumptions related to Planning**
- ◆ **Document planning decisions related to alternative choices**
- ◆ **Facilitate Stakeholders Communication**
- ◆ **Define reviews in Contents management, Scope and Timing**
- ◆ **Provide a basic reference for progress measuring and monitoring and management control**



Input for the General Project Development

Other Planning Processes Outputs

all the planning processes outputs are Input for this phase in addition to the Work BreakDown Structure (WBS), to the Support detail and to specific inputs (i.e. Cash Flow Previsions)

Historical Information

The use of historical data related to previous projects is required to support the hypothesis assumption verification

Organizational Policy

All the formal and informal policies of the involved organizations. For instance: Quality Management (process audit, continuous improvement objectives), Staff (guidelines for hiring and firing, staff appraisal systems), Financial Control (Report and Control Systems, accountability codex, commissions)

Constraints

All the constraints limiting action capability (i.e. budget)

Hypothesis

all assumptions about in certain factors, that usually involve a certain risk level assumption

Tools for the General Project Development

Project Planning Methodology

Each structured approach to guide the Project Team in the project development may include simple or complex spreadsheets, templates and simulation models, risk analysis model, monte carlo etc.

Stakeholder Skills and Experience

Every person has skills and experiences useful to the project and they must be used during the project development

Project Management Information System (PMIS)

These are the systems and techniques used to collect, integrate and disseminate the different processes outputs in Project Management; they normally include both manual and automated systems

General Project Development Output

Project General Plan (Project Plan)

It is a formal document that is approved and is the reference for the project execution management and control.

It should be distributed according to the scheme provided by the communications.

It include:

Project Contract

Objective (deliverables, objectives)

PMBs (Perf.Meas.Bas.) par costs-times

Staff (key or required people)

Open Points and on going decisions

Connected Management Plans (i.e. Scope and Schedule Management Plan)

Costs Estimation, Starting Date and Responsibilities at the WBS level for the control

PM strategies for the different areas

Work Breakdown Structure

Milestones and Main Target (times)

Critical Risks (hypothesis, constraints, reactions)

Support Details

Normally they include:

- **Output for the planning processes; not included in the Project Plan**
- **Additional Information or documents developed during the development.**
- **Technical Documentation (specifications, projects etc.)**
- **Fundamental Standards Documentation**

This material must be reorganized in order to easy reference

Performance Measurement Baselines (PMBs) vs Project Plan

The Performance Measurement Baselines (PMBs) are key documents for the project control and the working progress evaluation.

It is therefore a Management Control which normally changes only occasionally and in front of officially approved changes in the project scope (in order to guarantee a solid reference for the project status evaluation).

The Project Plan is, as already said, a set of documents evolving during the project based on the new information incoming and it is a useful tool for the project overview.

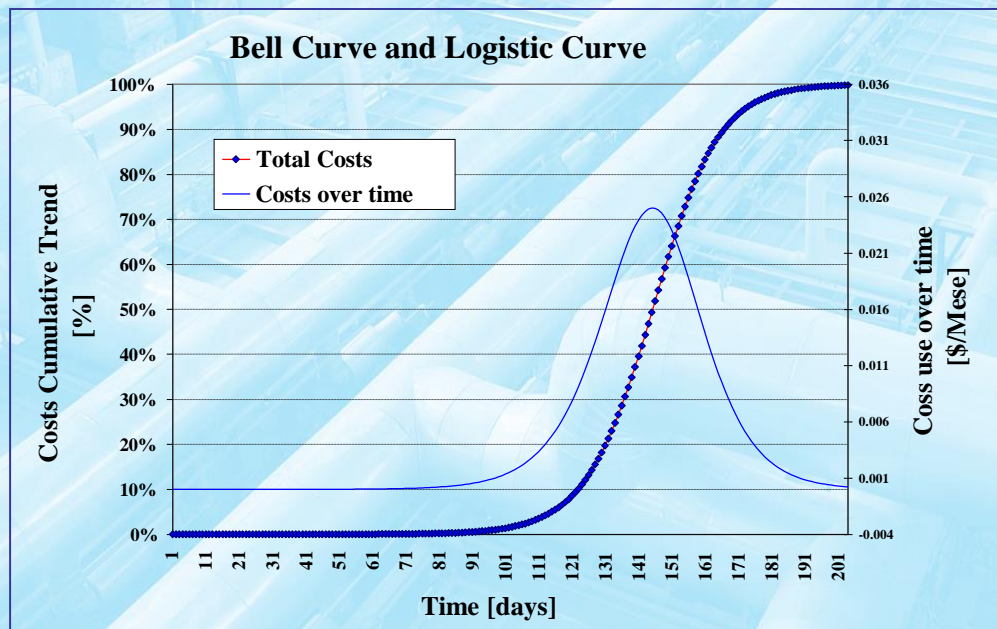
The Logistic Curve for Plant Projects

The Logistic Curve is the typical example of PMB and it may represent :

Physical Produced Quantities (i.e. Produced Pipe)

Performed Work Equivalent in Man/ Hours (i.e. Engineering)

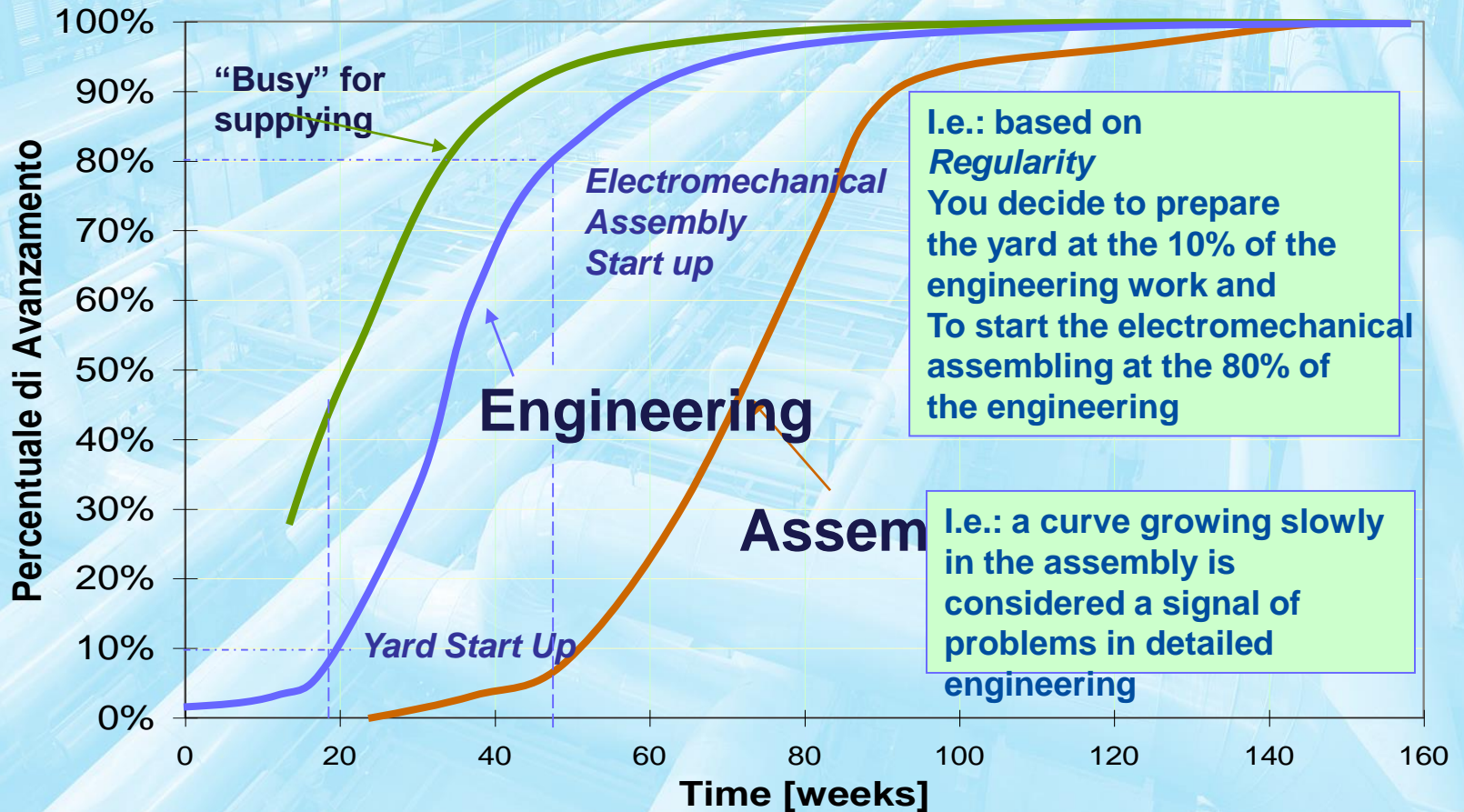
Payed Costs (i.e. General Project progress)



The man-hours could be defined as **Actual Man Hour** (really used hours) or **Standard Man Hours** (measured under standard conditions).

From similar historical cases it is possible to create some **"regularity" curves** to be used as a reference and support for milestones definition

Correlations between Progress and Regularity Curves

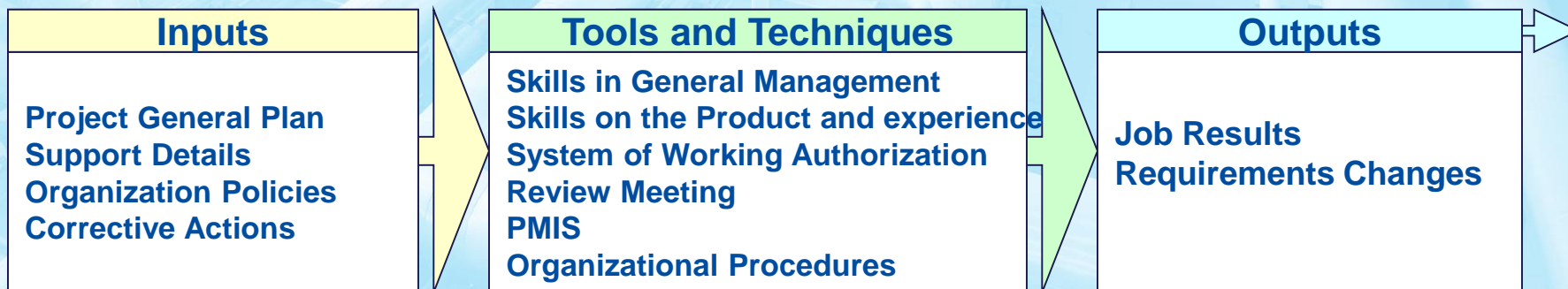


Project Progress

- 1. Activity Specifications: i.e. implemented pipe meters or laid cables km***
 - 2. Man Hours: i.e. 200 hours of electrical engineering, it could be defined as actual hours (Actual Man Hour) or Standard (Standard Man Hour)***
 - 3. Economic Valorization and Accounting Progress***
- The progress is the ratio between the produced quantity and the expected one.**
 - The progress is expressed as a rate or as a cumulative value**
 - The progress is used both to exercise control over a project that sometimes to regulate the Cash Flow**

General Plan Execution

In this phase the Project Manager and Project Management Team work together by coordinating the different technical and organizational groups composing the project



General Plan Execution Input

Project General Plan

Key Elements are obviously the **PMB**, the **risks management plan**, **supplies and objectives** among the **General Plan components** obtained during the development.

Support Details

Obtained from the development phase

Organizational Policies

All the formal and informal policies of all the involved organizations **impact on the project execution**

Corrective Actions

It is the result of the different control processes and includes **all the actions devoted to address the project to its objectives.**

Tools for the General Plan Execution

Skills in General Management

Include the classic management capabilities such as leadership, communication capability, negotiation.

Skills on the Product and Experience

Obviously the PMT (project management team) must have a good knowledge of the product; they are acquired through staff planning and acquisition

System of Working Authorization

They are the formal procedures for work execution authorization; obviously it is required a balance between the applied control value with the related costs and time (i.e. verbal authorization vs. written authorization).

Review Meeting

They are predefined meetings to share information about the project. Obviously they are scheduled at different levels and with specific deadlines (i.e. the project team once a week and once a month with the customer).

PMIS

Systems of collection and diffusion of project data

Organizational Procedures

Formal and Informal Procedures about the organization developing the project

General Plan Execution Output

Job Results

They are obviously the results of the project execution and include the deliverables delivery, the realized product quality etc..

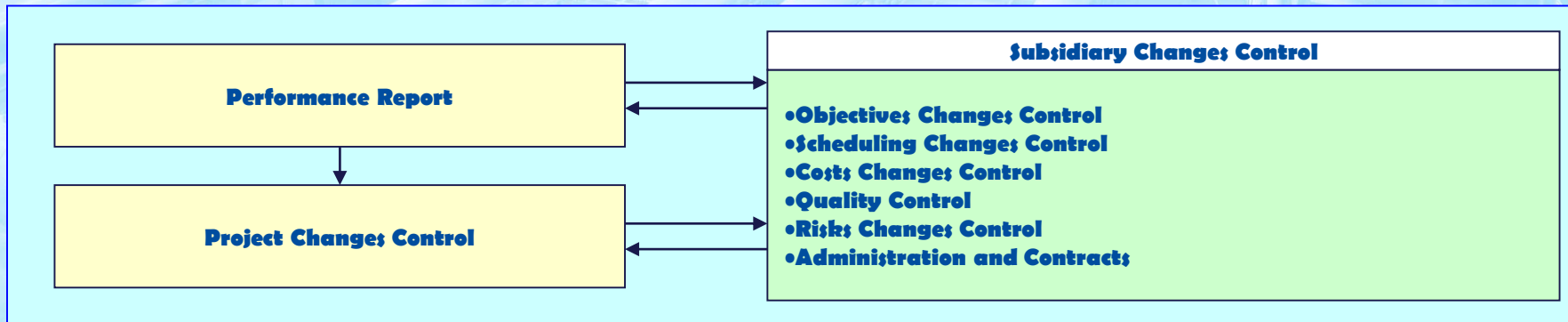
Requirements Changes

Allow you to redefine the project (extend, modify costs and budgets, etc..) they are completed after the completion of the various works.

Project Changes Control

The control of the eventual changes is connected with the following three possibilities:

- Influence the factors, creating convenient changes
- Identify the changes
- Manage the on going changes



Obviously this requires:

- To keep the PMB's integrity; only objectives changes must impact on the PMB's.
- To guarantee the product objectives changes are integrated with the project objectives changes
- To Coordinate the changes through the different sectors

Input for the Project Changes Control

Project General Plan

It is the guide for comparing and controlling the changes

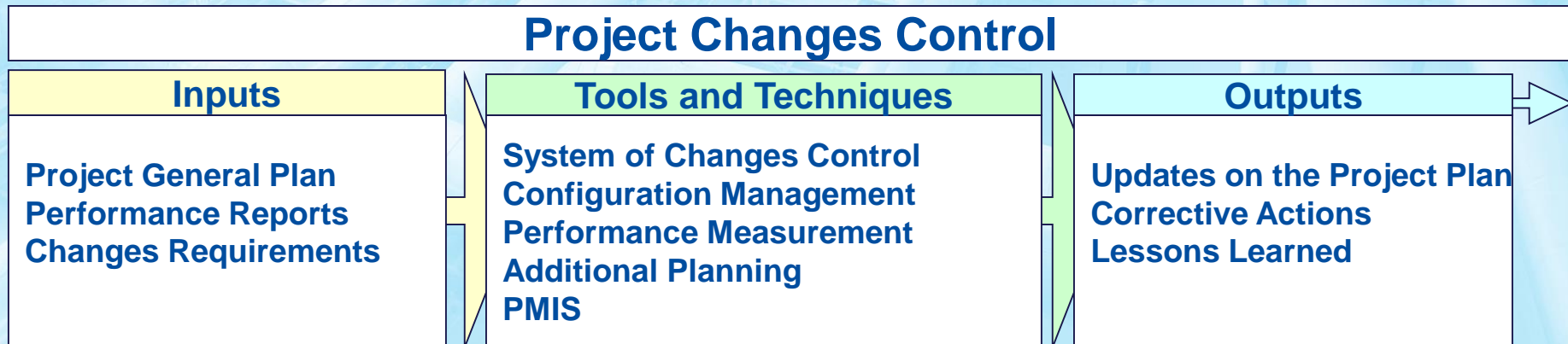
Performance Reports

They allow to evaluate the project performances and warn about future problems

Changes Requirements

All the formal and informal requests (i.e. verbal, oral, internal and external) requiring corrective actions or updates on project planning.

Project Changes Control



Tools and Techniques for the Project Changes Control

System of Changes Control

It includes the documentation reporting all the formally necessary procedures step by step to make every possible update. Often there is a CCB (Change Control Board) Director approving or denying requests for change, of course, the CCB responsibilities should be well-defined by the project stakeholders. This system must include procedures for changes to be implemented without prior authorization for specific activity categories.

Configuration Management

Any document used for direction and technical and administrative control in order to:

- Identify and document a component characteristics
- Check updates on these characteristics
- Record and report the change and its progress
- Check the components and the system to verify its conformity

Performance Measurement

Performance Measurement Techniques (i.e. gained value) to evaluate the impact of corrective actions

Additional Planning

All the additional activities (i.e. new estimation of costs) necessary to correct the planning

Project Management Information System

Informative Systems for PM

Results of the Project Changes Control

Updates on the Project Plan

Each change applied to the Project General Plan or to the support details; these results must be notified and shared with the stakeholders

Corrective Actions

Actions to guarantee the project changes control

Lessons Learned

Due to implemented changes, discussions and updates and considering the obtained results, it is necessary to document the lessons learned in order to collect them in a historical database for both supporting the current project that other present and / or future projects

Project Scope Management

This management area is intended for the project objectives management and for ensuring that the project includes only the activities necessary to achieve them. There are two types of scope:

- **Product Scope**

Functions and Features to be guaranteed for a Product or a service

- **Project Scope**

The work to be done in order to deliver the product based on specific features and functions

The Product Scope is usually managed with tools such as Life Cycle Analysis etc..

The Product Scope is controlled by the specific product analysis, while the Project Scope is checked against the plan; they obviously must be highly integrated

Project Scope Management

2.1 Preparation Analysis

.1 Inputs

- .1 Product Description
- .2 Strategic Plan
- .3 Project Selection Criteria
- .4 Historical Data

.2 Tools and Techniques

- .1 Project Selection Methodologies
- .2 Experts Opinion

.3 Outputs

- .1 Project Charter
- .2 Project Manager Assignment
- .3 Constraints
- .4 Hypothesis

2.2 Objectives Planning

.1 Inputs

- .1 Product Description
- .2 Project Charter
- .3 Constraints
- .4 Hypothesis

.2 Tools and Techniques

- .1 Product Analysis
- .2 Costs/Benefits Analysis
- .3 Objectives Identification
- .4 Experts Opinion

.3 Outputs

- .1 Report on Objectives
- .2 Support Details
- .3 Objectives Management Plan

2.3 Objectives Definition

.1 Inputs

- .1 Report on Objectives
- .2 Constraints
- .3 Hypothesis
- .4 Other Planning Output
- .5 Historical Data

.2 Tools and techniques

- .1 WBS Templates
- .2 Decomposition

.3 Outputs

- .1 WBS

2.5 Control of Objectives Changes

.1 Inputs

- .1 WBS
- .2 Performance Reports
- .3 Change Requirements
- .4 Objectives Management Plan

.2 Tools and Techniques

- .1 System of Change Control Objectives
- .2 Performance Measurement
- .3 Additional Planning

.3 Outputs

- .1 Objectives Changes
- .2 Corrective Actions
- .3 Lessons Learned

2.4 Objectives Check

.1 Inputs

- .1 Job Results
- .2 Product Documentation

.2 Tools and Techniques

- .1 Inspection

.3 Outputs

- .1 Formal Acceptance

Preparation Analysis

This process aims at the formal recognition of the new project existence or the approval of a project to be switched to the next phase.

The project is often not formally started until it is completed a feasibility study, an advance planning etc.

Generally the projects are authorized based on:

- **Market Request**
(i.e. an automotive company decides to build a new plant for increasing production)
- **Economic Needs**
(i.e. new product development to increase revenues)
- **Customer Request**
(i.e. a nation commissioning a power plant)
- **Technologic Developments**
(i.e. development of a new mobile phone based on new available batteries)
- **Law Constraints**
(i.e. development of a toxic waste disposal project in front of a new law)

Preparation Analysis Input

Product Description

All documents, including the product/service features and specifications, as well as the connections with the activities necessary to develop it. Often the product description is provided by the customer.

Strategic Plan

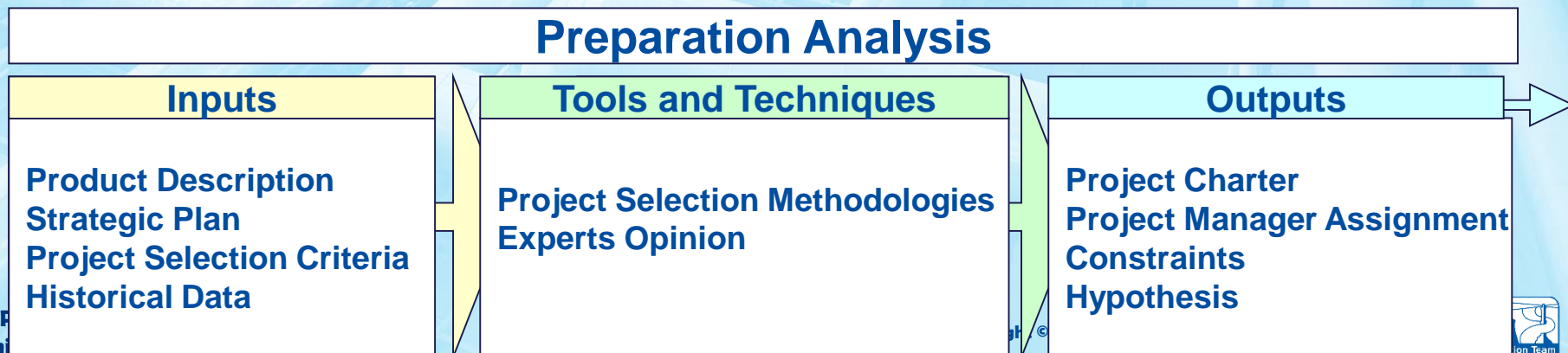
All the projects must aim to the achievement of the strategic objectives to be evaluated for project selection

Project Selection Criteria

They are really various and they define the selection guidelines (i.e. market share, profitability, promotion etc.)

Historical Data

Historical Data related to previous cases, important for the selection



Tools and Techniques for the Preparation Analysis

Project Selection Criteria

It is possible to identify two wide categories of selective methods:

- Based on the Earnings assessment: comparative approaches, economic models, performance evaluation
- Based on the constraints optimization: mathematical models, Linear optimization, multiobjective analysis, etc..

These methods allow to develop DSS (Decision Support System) that are based both on traditional techniques (decision trees, forced choice) than on specific ones (Analytic Hierarchical Process, logic Analysis, Simulation, etc.)

Experts Opinion

The Experts Opinion is often required to achieve the final decisions and it is expected to use:

Specific Division of the company structure
Consultant
Technical Professional Associations
Industrial Groups

Preparation Analysis Output

Project Charter

The Project Charter is the document that formally recognizes the project existence; it must include directly or by reference:

- ***The contractual needs to be achieved by the project***
- ***The Product Description***

The Project Charter is defined by a proper manager external to the project and provides a mandate to the Project Manager for projects under contract and the contract serves as the Project Charter

Project Manager Assignment/Identification

The Project Manager is generally defined as early as possible in a project development; he must be identified before implementing the general planning development and possibly before having set up an extended part in the planning

Constraints

Conditions constraining the PMT (budget, contract fees etc.)

Hypothesis

All the accepted hypothesis on uncertain factors, generally these involve a certain risk level which is any case necessary for the objectives planning

Tools and Techniques for Objectives Planning

Product Analysis

This analysis is based on techniques devoted to a better comprehension of the product, these include: value engineering, systems engineering value analysis, function analysis, QFD (Quality Function Deployment)

Costs/Benefits Analysis

These techniques involve the qualitative and quantitative determination of cost (outlays) and benefits (returns) based on the different possible alternatives; the comparison is also based on the analysis of classic economic parameters such as payback period, ROI, IRR etc..

Alternatives Identification

To complete a proper identification of possible alternatives there are several techniques that are typical of general management (i.e. brainstorming, lateral thinking)

Experts Opinion

Expert Opinion is generally used to support this phase

Objectives Planning Output

Objectives Report

The Objectives Report is a reference for future decisions and to share a common knowledge of these.

It includes:

- **Work Description SOW (Statement of Work)**
- **Project Motivation to evaluate future trade-off**
- **Project Product, a short brief about the Product**
- **Project Deliverables, summary about sub products**
- **Project Objectives (at least costs, times, quality)**
They must be characterized by type, measure unit and quantitative values relative/absolute

Support Details

They encourage the use of documentation and include constraints and hypothesis reports

Plan for Objectives Management

The document defines how the project goal is managed

Job Description

A key point is to correctly define the job description to be done, at this phase it is important both technical and contractual clear understanding. The SOW (Statement of Work) is defined as the narrative description of the work required for a project. This is sometimes defined by the customer and often instead is developed by the PM Team and proposed to the customer for approval.

In this second case there are two types of SOW: SOW used in the proposal CSOW (Contract Statement of Work), as well as a WBS (Work Breakdown Structure) and a CWBS (Contract Work Breakdown Structure).

Obviously it is necessary to take care of the contract terms in order to avoid discrepancies between SOW / WBS and CSOW / CWBS.

Mistakes in this phase are very difficult to be solved and often they are fatal to the project good success.

SOW: Problems Causes

The main problems causes are due to:

- **Mixing tasks, objectives, approvals and special instructions**
- **Using imprecise words (optimum, approximately, at)**
- **Lack of structural order or chronological**
- **Wide variability of the required activity**
- **Wide variations in the job details description**
- **Lack of review by a third party.**

Examples from real cases:

SOW for a new type of sports car airbag requires a minimum of 10 tests, the budget is set to 15 for security, at the end of the tests, the customer declares them not significant and requires 10 more for an extra cost of 500 million.

In a power plant design in the middle of the desert it is remarked that the request "civil support" includes a 40 km road to connect the town with an extra cost of 60 billion.

The Navy in the SOW requires water testing for a torpedo; the prototype is tested in hydraulic tanks, however, the Navy defines water as the actual conditions of the Atlantic Ocean, so it is required to repeat all the tests in the sea with an additional cost of several billion

The CSOW requires to transport materials in ventilated containers; the load is located in open-top containers; during the travel a series of torrential rainstorm damaged goods, the customer declares that he intended containers aerated from below: the question is in the hands of a judicial court to decide the correct meaning of the term.

SOW: Guidelines for the PM

**Statement of Work Handbook NHB5600.2
NASA, Feb 1975**

- The Project Manager or its referees must review the documents authorizing the project and defining its goals as well as review studies and contracts related to the current development level; it is necessary to collect a bibliography of related studies and examples of similar cases of SOW .
- It is necessary to issue a WBS copy and to start immediately a coordination between the elements of the CWBS and SOW; every activity of the preliminary CWBS must be extended in a SOW with a corresponding encoding.
- The PM can build a team to prepare SOW including skilled personnel with technical expertise in the project area including also representatives of acquisitions, financial management, manufacturing, quality control and in addition other involved activities.
- Before you start preparing the SOW, the PM must hold a preliminary meeting summarizing the CWBS program and the nature of the SOW that is devoted to be a reference over time.
- The PM can assign specific teams to identify specifications, criteria and documentations to be included in the SOW by assigning their definition to specific responsible, the members of these teams need to identify and obtain copies of all the technical equipment necessary for the project.
- The PM shall prepare a detailed checklist highlighting the mandatory and optional elements of the SOW
- The PM should emphasize the use of preferential lists for the definition of standards, manuals, standards, hardware and software to be used in the project technical development
- Cost estimated by the experts must be reviewed by those who prepare the SOW in order to identify non-essential components to the project
- The PM shall prepare a preliminary scheduling for the coordinated collection of fragments of the SOW allowing to adhere to the RFP (Request for Proposal) issues schedule and obviously this activity should be enough in advance to facilitate coordination and ensure that they will finish before RFP preparation.

SOW: Guidelines for the Documentation

- Each SOW, long more than two pages, must have an index consistent with the CWBS encoding.
- In the SOW it is convenient to minimize the presence of elements not included in the CWBS
- Precise and clear description of Activities (several readers) because it will be the base for the contract
- Eliminate ambiguity, define the government obligations, set deadlines for the approval activities and define in detail the materials / services required to the customer (nature, condition, weather etc..)
- Remember that any even temporary control activity external to the contractor can lead to a loss of responsibility by them.
- In the specifications definition use rarely passive terminology (not *HVAC commissioning can be done*, but the contractor must do the HVAC commissioning), use the word "must" rather than "may" for all the activities requests.
- Limit the abbreviations, provide a list at the beginning of the SOW, the first once you should a complete definition of the short term.
- If it is necessary, divide the responsibility among contract, subcontractors and customers, to devote a specific SOW section to outline in detail these aspects.
- Not ask for extra technical specifications, define your goals and let the contract the modes.
- Define clearly the specifications for both technical and contractual issues, never say "as required", but specify who is in charge of checks and assessments.
- Not include not familiar material on the project, define the specification on project technical data separately in an appendix and avoid that it becomes more extensive than necessary.
- Not repeat specifications already defined in other documents, rather refer to these

Statement of Work Handbook NHB5600.2
NASA, Feb 1975

SOW Checklist

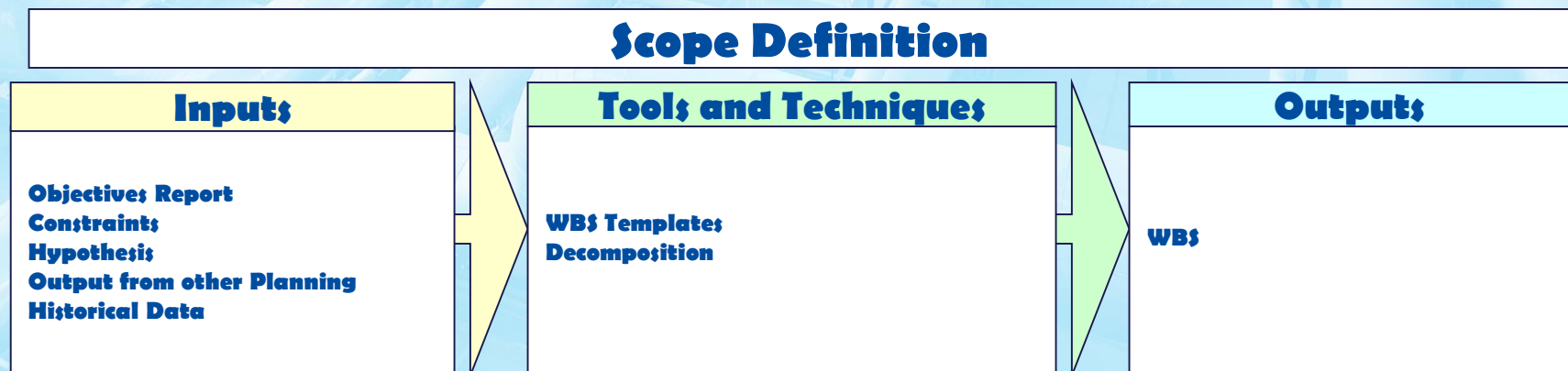
- **The SOW, if used in combination with the CWBS, allows the contractor to evaluate manpower and resources required by each project activity?**
- **The contractor's duties are defined in detail in order to make clear what are its commitments and to allow the representative signing the acceptance reports to understand whether activities reports have been completed?**
- **SOW parties are written so as not to require clarification about when and what the contractor is required to do?**
- **When necessary, references to other documents are clear? Properly cited? They are needed or may be partially hidden?**
- **Technical specifications and / or demonstrations are applicable? If yes, are they really referring to the SOW elements?**
- **The directives are distinguishable from the general information?**
- **Is there a specific time for each deliverable? Using work days or calendar?**
- **The deliverables amounts are properly defined?**
- **Is a spell check of the headlines provided? Guaranteed comparability between the sub? Consistency title text? Are you using a consistent system of coding in the SOW (alphanumeric or multi decimal)?**
- **Is it possible to cross reference with the CWBS?**
- **Regulations have been used for acquisitions?**
- **Is it removed all the unrelated material / services?**
- **The SOW guiding elements and the configuration at low level can be summarized as a CWBS third level?**
- **All technical data are summarized in Appendix?**
- **Have we checked all specifications related to safety?**

Scope Definition: Input & Output

This Activity involves the division of the main project deliverables in smaller and more manageable components in order to:

- **Improve the estimation accuracy of Costs, Time and Resources**
- **Define a reference basis for the project control**
- **Facilitate the tasks and responsibilities assignment**

The outputs of processes in other areas of expertise should be used as reference to evaluate the influence on the project as input to this activity. As output, we obtain the WBS (Work Breakdown Structure) structure deliverables



Tools and Techniques to define the Objectives

Work Breakdown Structure Template

Often WBS related to previous projects are used as template for the new development on the basis of analogies. However, some areas have WBS standard or semi standard to be used as reference (template).

Decomposition

The methodology purpose is the subdivision of the deliverables in subclasses easy to be managed in terms of planning, execution, monitoring and closure.

It develops through steps such as:

- Identify the key elements (often deliverables and Project Management)
- Decide if it is possible to make appropriate estimates of time and costs for each element
- Identify the deliverables components in a tangible way
- Verify decomposition correctness
 - Verify that the low level terms are necessary and sufficient to complete the parent element
 - Verify that each term is clearly and fully defined
 - Verify that each item is planned, defined in the budget and assigned to an organizational unit as responsible

WBS: the Project Manager planning

In the Project planning the Project Manager must organize the work in small elements that are:

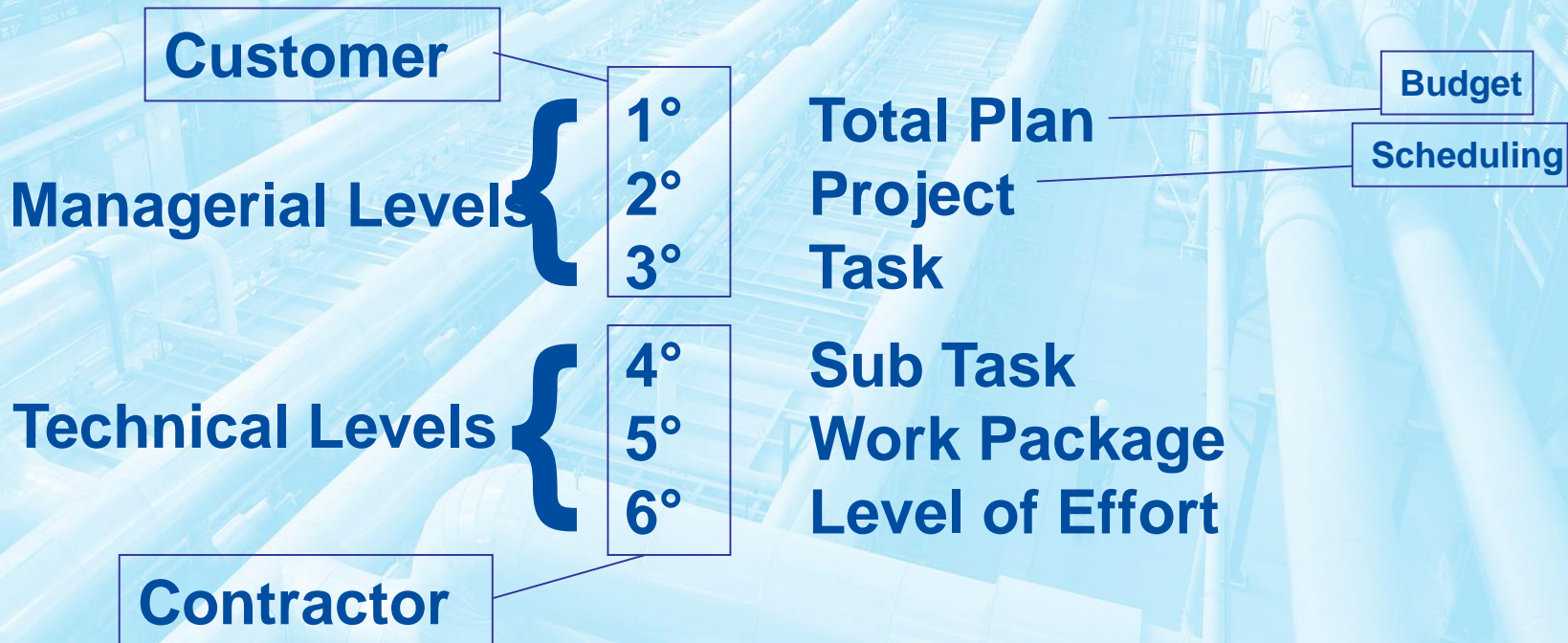
- Manageable:** chance to assign authority and responsibility
- Independent:** with minimal interface with the other activities
- Integrable:** in order to combine them in general packages
- Measurable:** to estimate the progress and the success

If WBS is a key element because it provides an overall project description as a sum of elements

- Supports making a Planning
- Allows estimating costs and budgets
- It is organized in order to control time, cost and performance
- Goals can be connected to corporate resources
- You may establish procedures for scheduling and reporting
- You can start building a network and a management control
- It is possible to define the responsibility for each element.

WBS: a Hierarchical Structure

WBS is a hierarchical structure dividing the work in elements and sub elements at various levels:

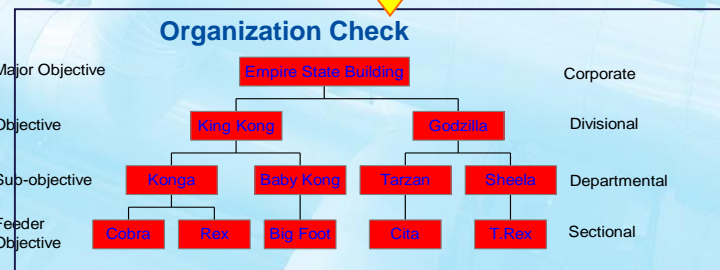
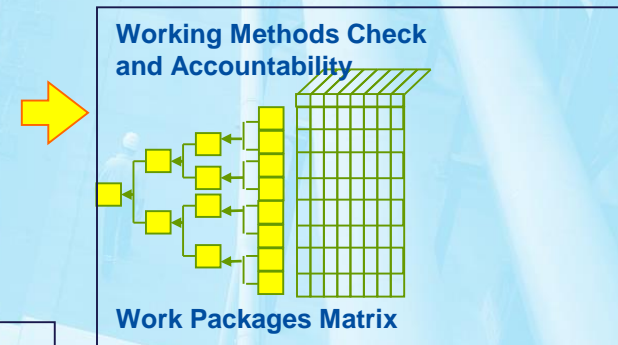
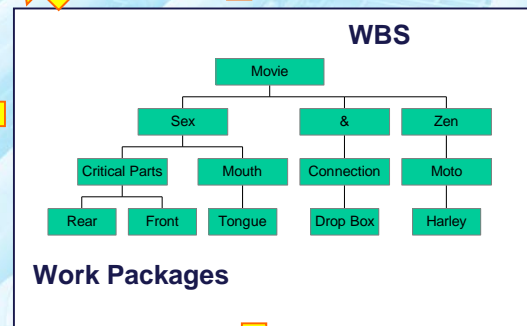
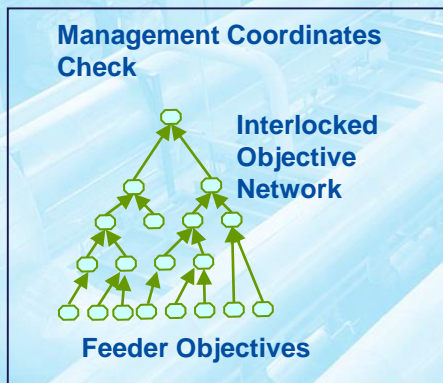
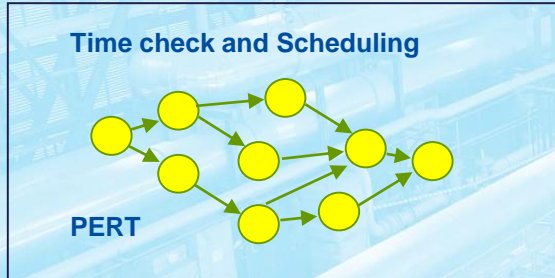


WBS is used for: responsibility matrix, network scheduling, costs, risk analysis, organizational structure, objectives coordination, controls.

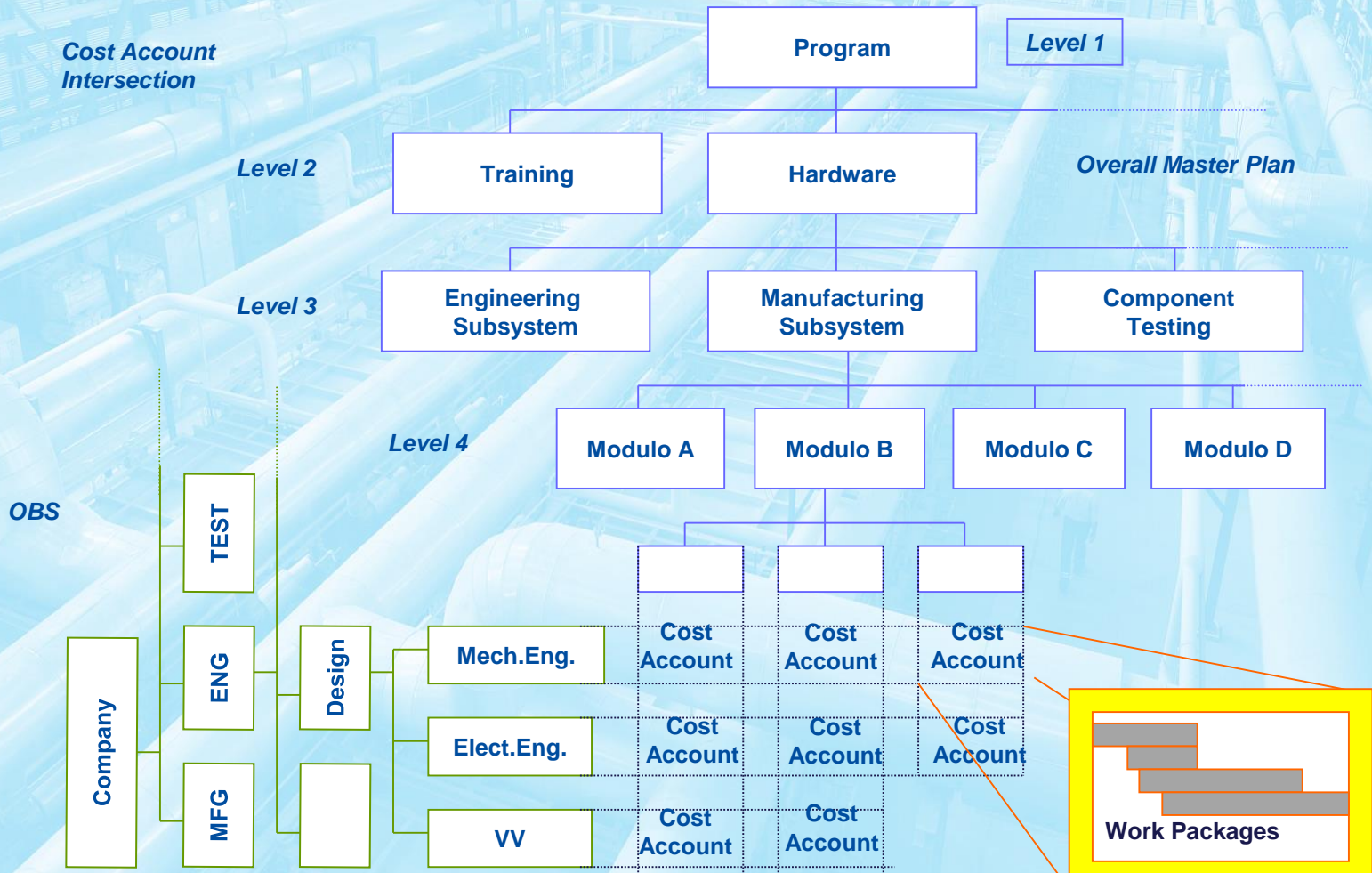
WBS: General Concepts

- The first three levels of the WBS represent an integration effort and should not be linked to specific business units, whose efforts should instead be included in levels 4 and 5.
- The sum of all the elements belonging to a layer must represent the overall work.
- Each working activity must be assigned to one and only one level.
- The project management level is sometimes called the Work Package level and may correspond to any level between 2 and 6
- The WBS must include a description of the objectives and required efforts : it aims to reproduce the customer requests within the WBS.
- Usually the best policy for PM is to leave the Line Manager responsible for identifying the risks in the SOW
- Some companies try to define the levels 1-3 uniquely for all projects by changing only levels 4-6: that works for companies carrying out many projects quite similar.

WBS: Structure for Control and Evaluation



The Critical level of Work Packages Management



Work Packages

Longer are the work packages and more difficult and subjective is the WIP (work in process) evaluation, except if you introduce intermediate milestones.

The WBS activities must:

- **Be clearly defined as the beginning and end.**
- **Be used to compare results and expectations.**
- **Be estimated on the total time (not when they start and end).**
- **Be structured in order to reduce to the minimum checks and documents.**
- **Representing the working units at the level at which work is performed.**
- **Clearly distinguish a work package from those assigned to the single functional group.**
- **Include starting and ending dates definition with reference to practice realizations.**
- **Specify a budget in terms of money, man hours or other.**
- **Limit the work to be developed to short periods in order to reduce the WIP**

WBS Example for a Plant

Program: New Plant Construction and Start-Up 01-00-00

Project 1: Analytical Study 01-0100

Task 1: Marketing/Production Study 01-01-01

Task 2: Cost Effectiveness Analysis 01-01-02

Project 2: Design & Layout 01-02-00

Task 1: Product Processing Sketches 01-02-01

Task 2: Product Processing Blueprints 01-02-02

Project 3: Installation 01-03-00

Task 1: Fabrication 01-03-01

Task 2: Setup 01-03-01

Task 3: Testing and Run 01-03-01

Project 4: Program Support 01-04-00

Task 1: Management 01-04-01

Task 2: Purchasing Raw Material 01-04-02

WBS Development

Sometimes, the WBS is defined by the customer; if the contractor develops it, the PM must take into account:

- **Plan Complexity and Technical Specifications (i.e. SOW)**
- **Project Cost**
- **Available Time for the project**
- **The specific available resources**
- **The internal structure of control and contractor and customer management**
- **The Subcontractor number**

Take into account the following guidelines:

- **WBS must be easy to understand**
- **All the scheduling should refer to the WBS**
- **You have not reduce the activities to a very low level (cost/benefit)**
- **Flexible WBS to objectives changes**
- **Many elements of the WBS varies between 0.5% and 2.5% project cost at the lowest level**

WBS: Decomposition Problems

At Levels 1-3, the activities definition may easily be based on WBS templates, but this is not possible for levels 4-6, in fact:

Subdividing the work activities in smaller ones may lead to the definition of hundreds or thousands of cost items too complex to manage, but typically it is convenient to keep the work packages about 200-300 hours, with about two weeks duration, obviously this involves an extreme ramifications on larger projects (i.e. with a million hours of direct job).

The branching approach allow the cost and performance control only if the line manager are able to carry out these checks.

The WBS is the basis for the activities scheduling (PERT, ADM), obviously on the low level the inter-correlations among the activities become too complex and numerous to allow any analysis.

WBS: Guidelines for the Development

- **Develop the WBS by dividing the whole activity in discrete and logic sub elements, by including eventually more Accounting Centers and more contractors on each element if necessary.**
- **Control the WBS in terms of completeness, compatibility and continuity of the proposed works**
- **Verify that the WBS meets the functional aspects (engineering, manufacturing, test) and of project (hardware, services etc.) including obviously the costs**
- **Control that the WBS provides the subdivision of all the logic works**
- **Define the responsibility for each element of the WBS**
- **Verify that the company report and measurement skills are compliant with WBS elements**

Checklist for the WBS

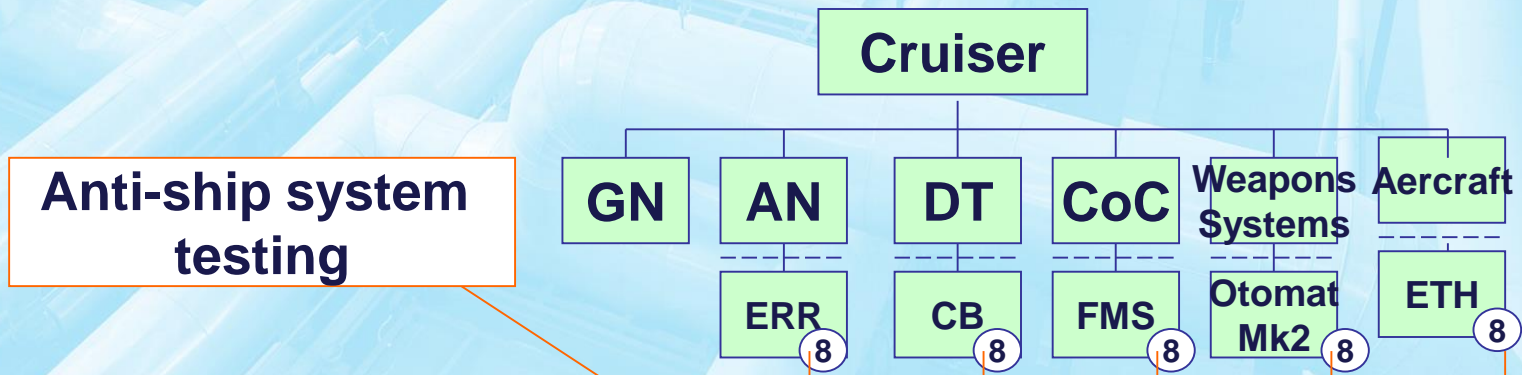
- **Develop a preliminary WBS to keep as a reference for the first 3 levels;**
- **Ensure that the contractor is able to extend, in accordance with its business capacity, the WBS in the case of evolution by other contractors;**
- **Following negotiations, the CWBS included in the contract should not go below the 3 level**
- **Ensure that the CWBS is consistent with the defined reportage skill**
- **Ensure that the CWBS is consistent with the organizational and management system of the contractor**
- **Review the CWBS in order to find correlations between: the specifications, the contractual elements, contractual deliverables, data specifications, the activities and the project management specifications.**
- **Define the CWBS elements at the necessary level (WBS dictionary)**
- **Specify report characteristics for the CWBS elements**
- **Ensure that the CWBS includes measurable entities, with eventual activity level and subcontracts.**
- **Ensure that the total cost of a particular level is equal to the sum of the costs of the elements composing the project at lower levels.**

Rules for the Correct Development of the WBS 1/2

- 0.0) The union of all the activities of a branch is the same set of root activities**
- 0.1) There are no intersections between the activities included in two different branches at the same level.**
- 1.0) Every level transition should be based on the same logic.**
- 2.0) The different levels of the WBS can be developed according to different logics.**
- 3.0) Each level of the WBS should be grouped in order to facilitate the research of WP (work packages) useful for planning and control.**
- 4.0) Reducing the WP size it becomes easier the management by the direct manager and more difficult the project control for the high number of WP**
- 5.0) The WBS is then crossed with the OBS (Organization Breakdown Structure) at WP level; any other transverse interactions at the branches**

Rules for the Correct Development of the WBS 2/2

- 6.0) The WBS parties must be filled up by the responsible for the management and control whether internal or external.**
- 7.0) The WBS may be developed ad hoc, or on pre-existing templates.**
- 8.0) The aggregation / disaggregation logic is based on deliverables and objectives statement; it could be useful to plan a coding logic allowing you to aggregate and disaggregate the various items in relation to desired goals.**
- Keep in mind that there may be objectives and functions transverse to the control set in the structure of the WBS; these need to be highlighted and explained.**



Plant Disaggregation Logic

It is possible to use several methods for the decomposition, in the case of industrial plants the following logic are relevant:

Functional:

Divide the plant in subsystems and so in a functional mode for the basic engineering and the start up

Spatial:

Based on the layout in term of linear (piping, roads etc.), layout (traditional plant engineering), three-dimensional (sea platforms, civil construction); obviously it is close to the logic for yard.

Work Processes:

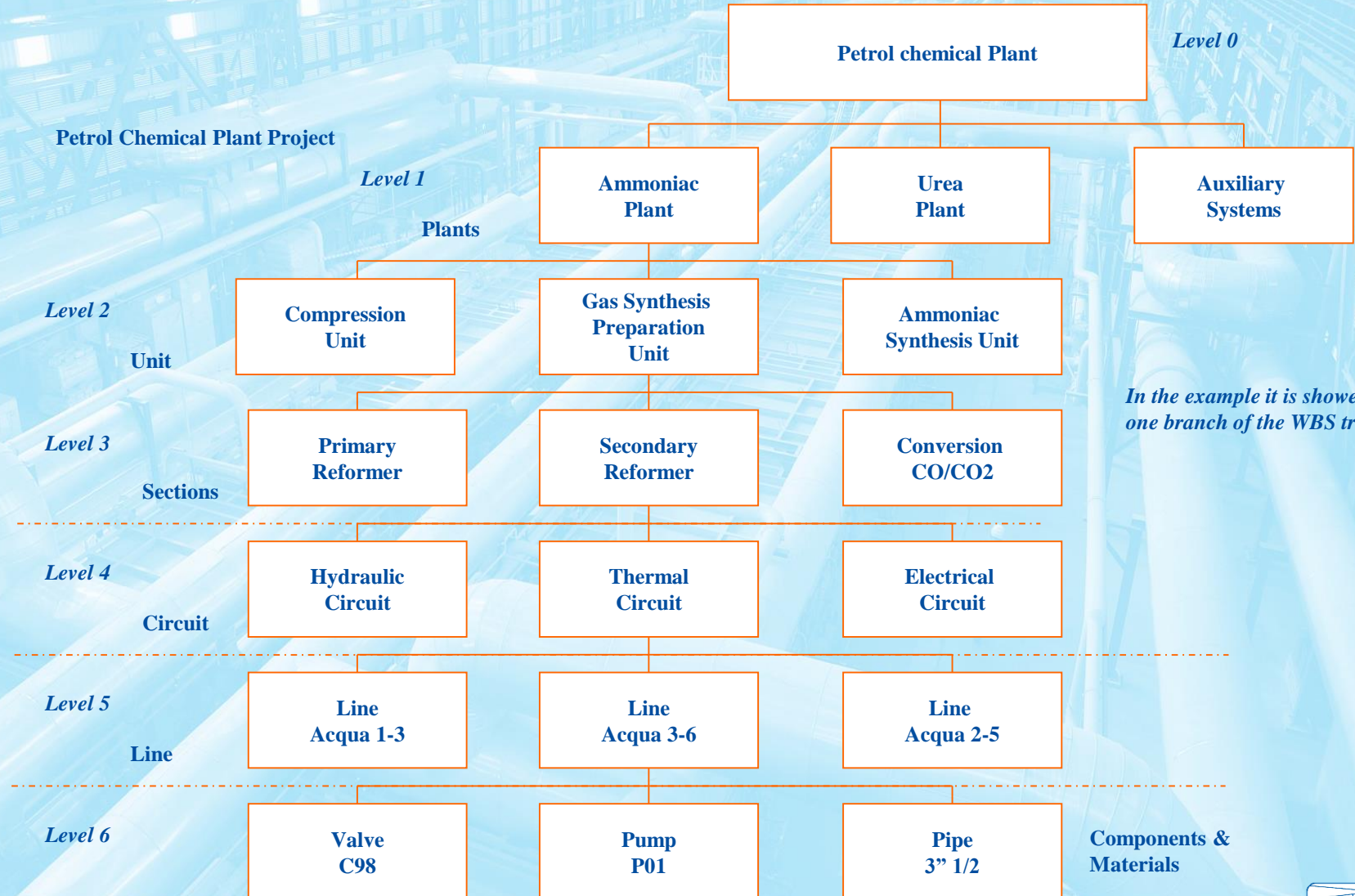
Based on the development processes (i.e. engineering, procurement, construction start up)

Physical Decomposition: related to the product structure and thus similar to the Material Bill, useful for the assembly

Objectives:

Underlining the objectives, the milestones over time is useful for the WB high level and that is often related to a functional logic

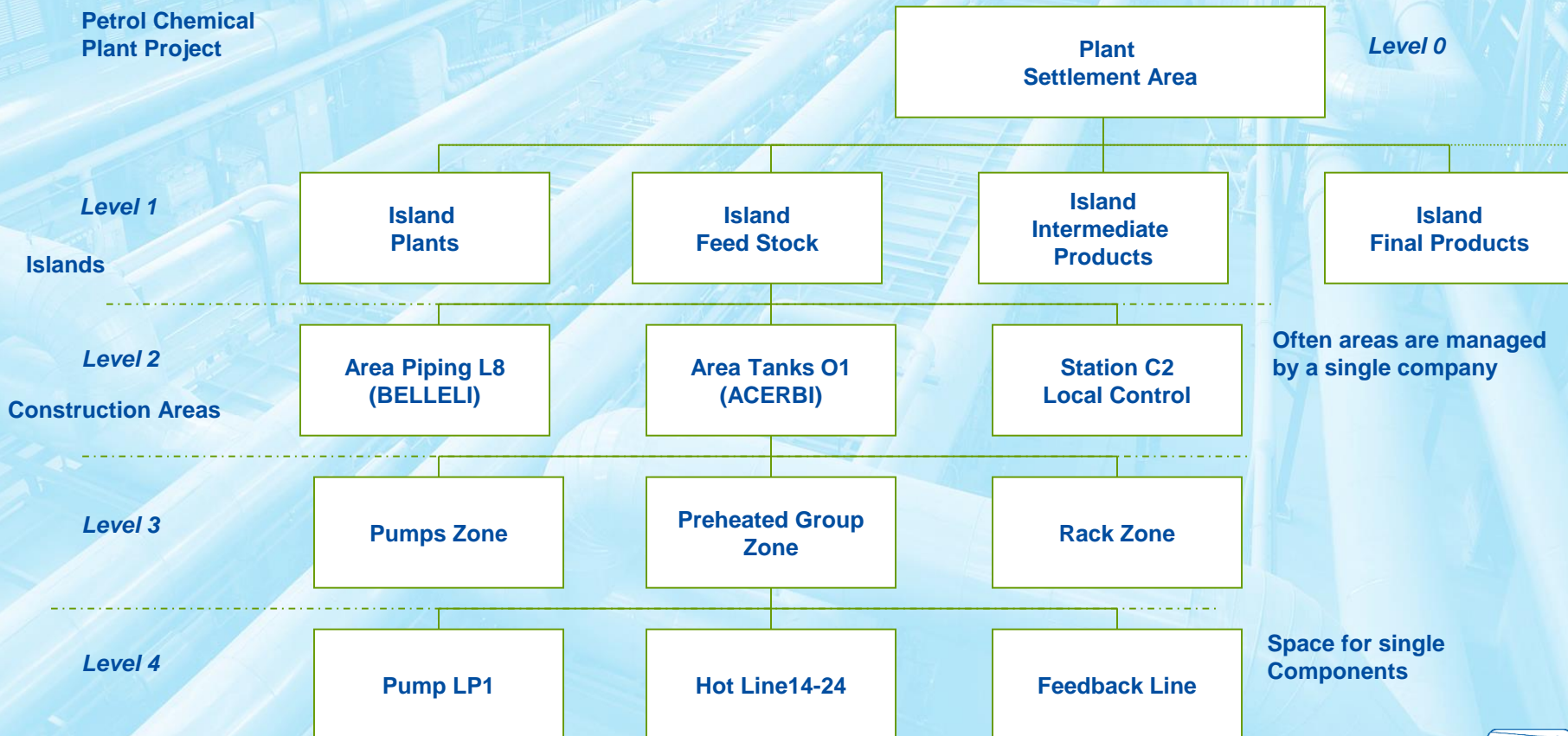
WBS based on Functional Logic



WBS based on a Spatial Logic

In the example it is showed one branch of the WBS tree

Petrol Chemical Plant Project

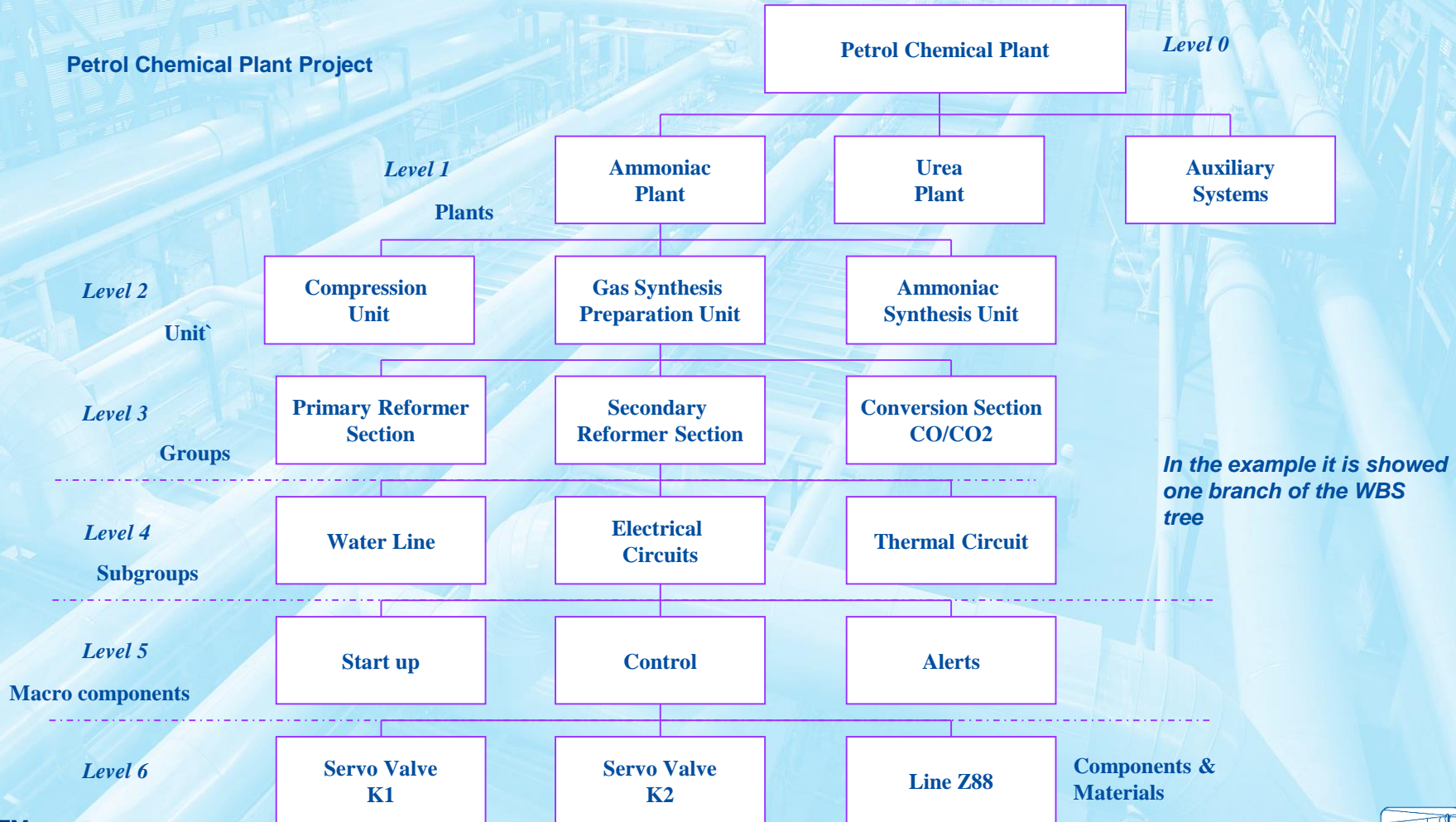


WBS based on Working Processes Logic

Petrol Chemical Plant Project



WBS based on Physical decomposition logic



WBS based on Objectives Logic

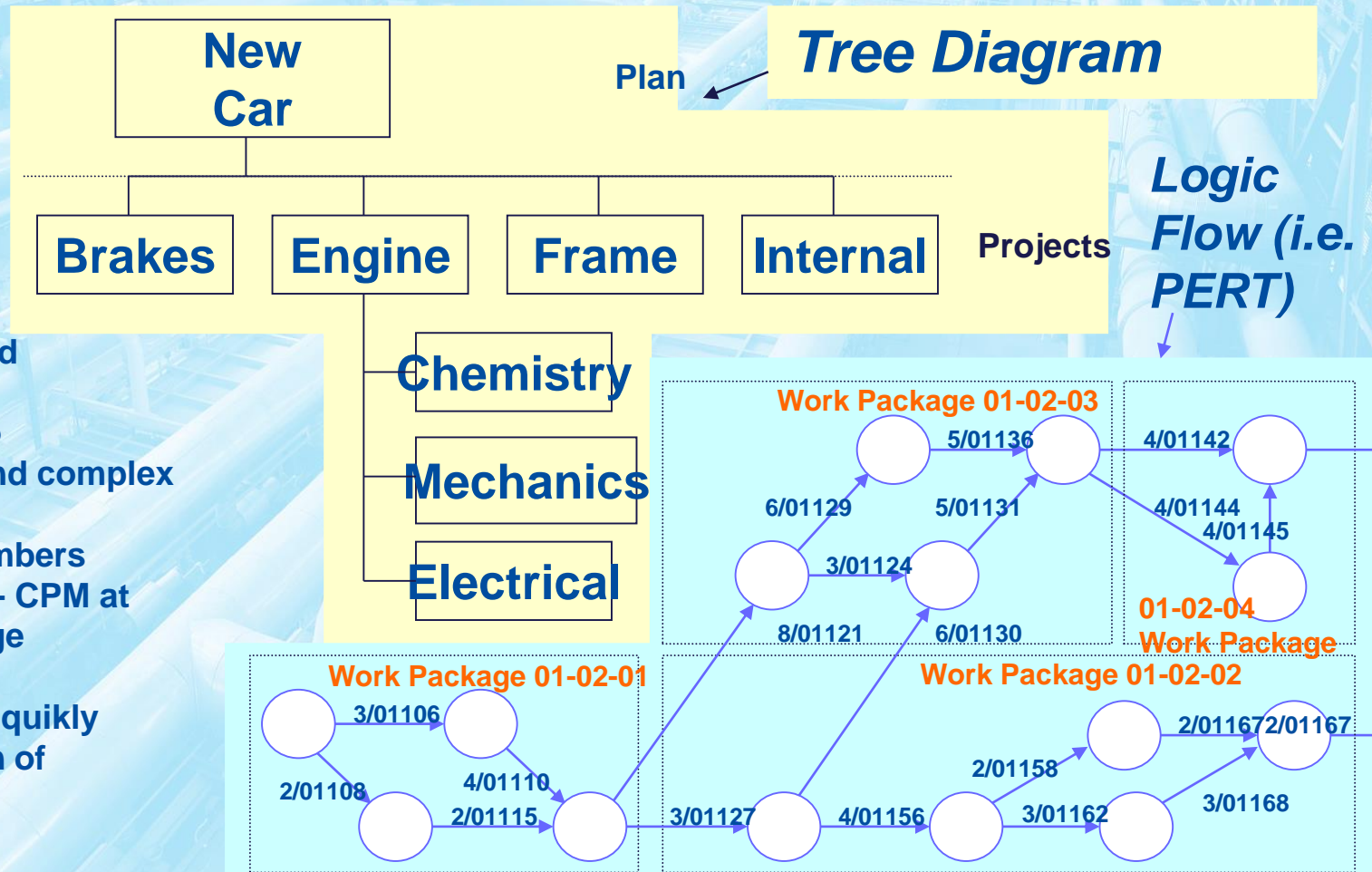


Methods to build a WBS at various levels

There are many methods of subdivision, as already said for the levels 1-3 some companies use always the same pattern. Among the various methods the most used are:

Level	Method		
	Flow	Life Cycle	Organization
Plan	Plan	Plan	Plan
Project	System Life Cycle	Division	
Task	Subsystem	System Department	
Subtask	People	Subsystem	Section
Work Package	People	People	
Level of Effort	People	People	People

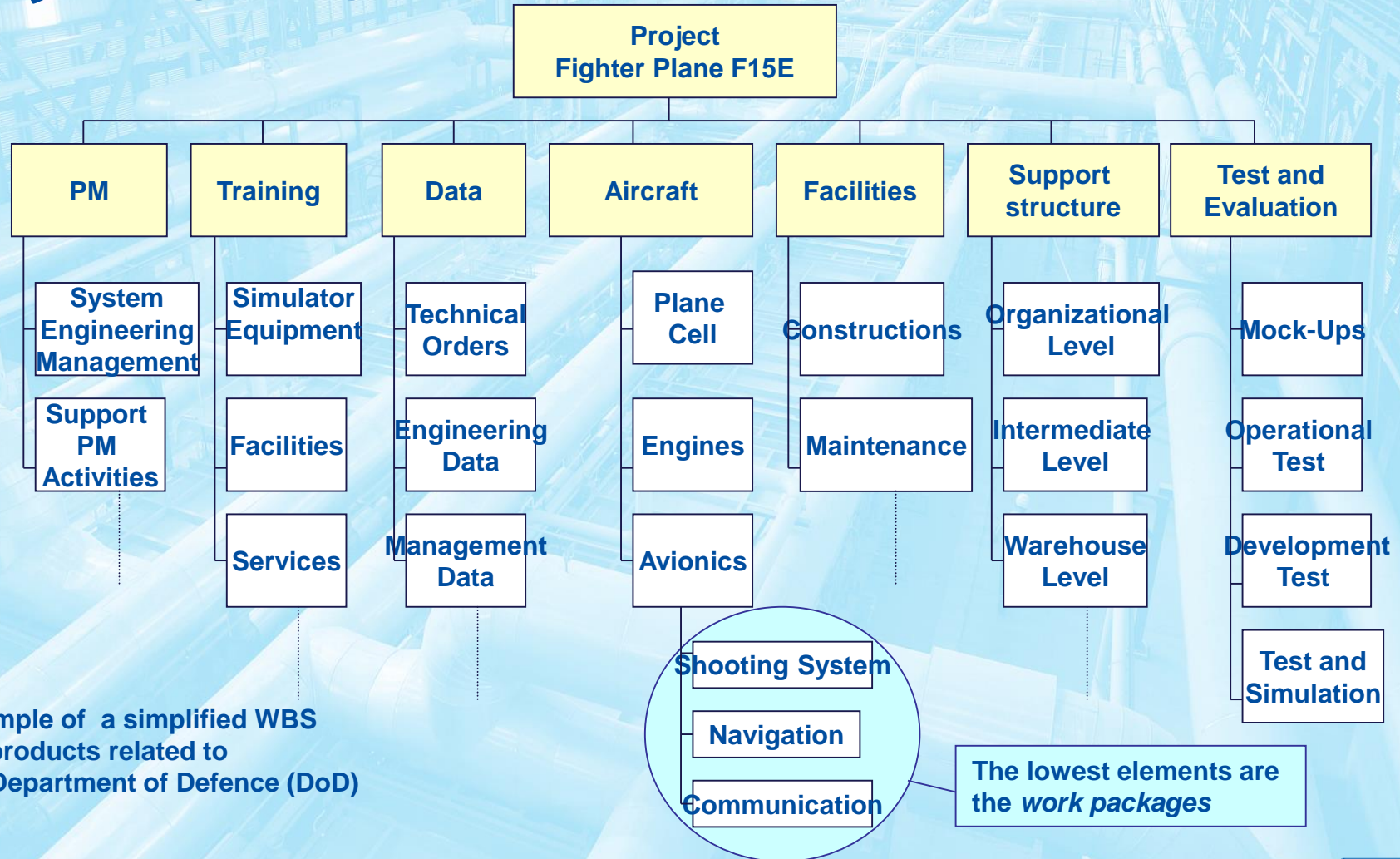
WBS Presentation: Tree Diagram & Logic Flow



N.B.
A too detailed
PERT/CPM
Could be too
expensive and complex
vs.

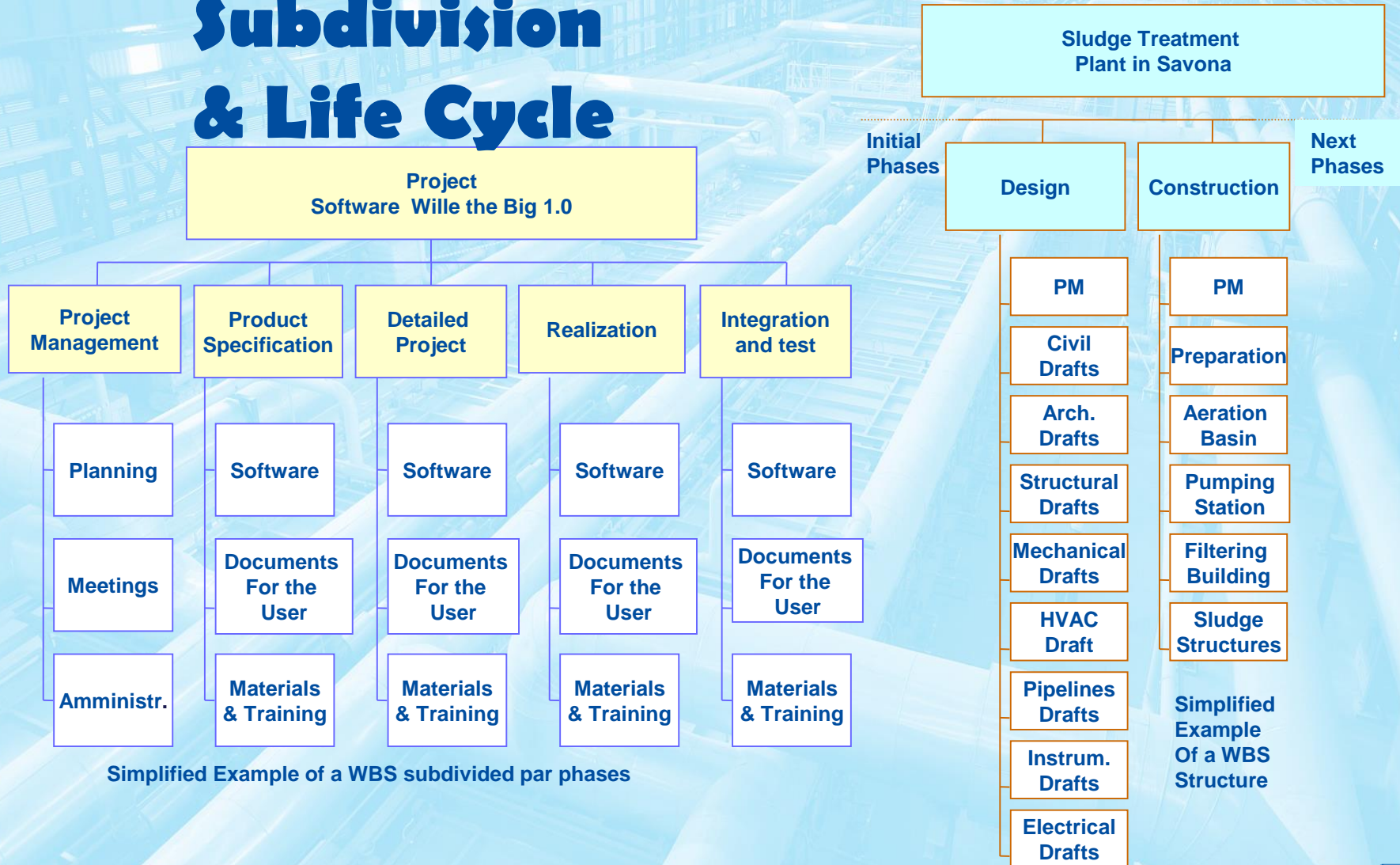
The load numbers
on the PERT- CPM at
Work package
level may
facilitate the quickly
Identification of
the activities

WBS: Work Breakdown Structure



Example of a simplified WBS for products related to US Department of Defence (DoD)

WBS: Structure Subdivision & Life Cycle



Breakdown Structures used in the Projects

other In addition to the WBS there are other Breakdown structure types commonly used for objectives

CWBS Contractual Work Breakdown Structure
less it includes reports and documentation to be provided to the customer; it is normally detailed

OBS Organizational Breakdown Structure
It defines which working elements are assigned to the different organization unit

RBS Resource Breakdown Structure
are Similar to OBS, but it considers staff identification instead of units (useful when there are many individual activities)

BOM Bill of Material
It is the product bill; it is subdivided for basic components, semi- assembled etc.

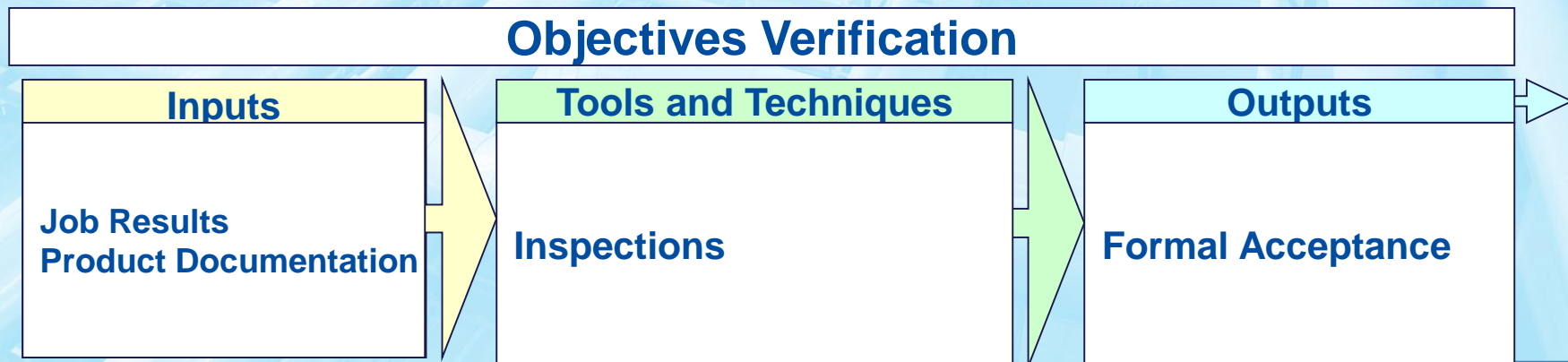
PBS Project Breakdown Structure o Product Breakdown Structure
confuse Equivalent to the WBS and used when the company works on products projects and the terms BOM e WBS

ABS Activity Breakdown Structure
Project Breakdown into phases, macro activities, activities and tasks

Objectives Verification: Input, Tools & Output

This activity is based on produced deliverables and documentation, through inspections, including measurements, examinations and tests, it is checked the compliance to the basic specification; the formal acceptance documentation comes from the customer or sponsor.

This activity is different from the quality control because this focus on the correctness of the achieved results, while this activity is focused on deliverables acceptance.

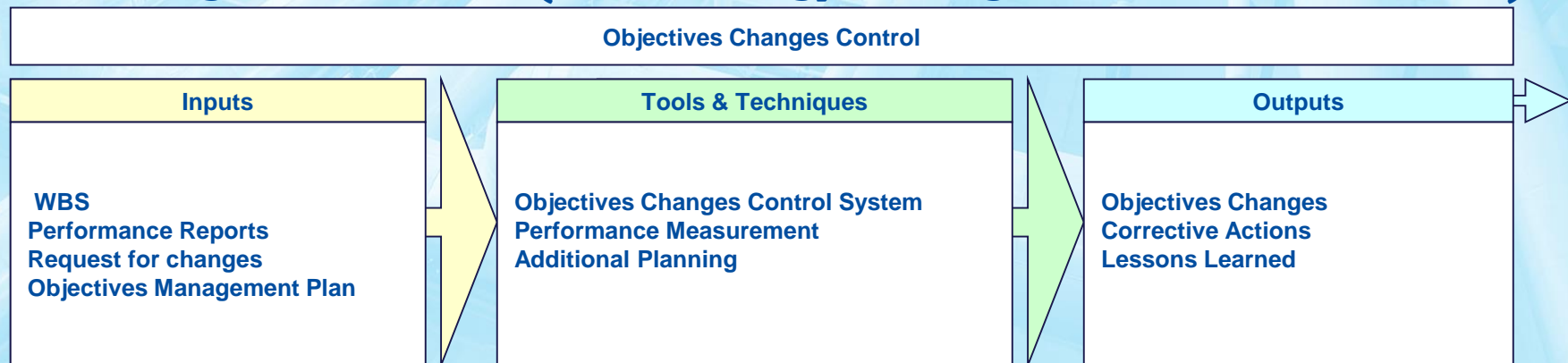


Objectives Changes Control: Input

This activity is based on the developed WBS and on the reports related to the measured performance and on the management plan goal or the document defining how the project goal is managed.

Of course, voluntary or forced objectives changes requests are possible; the requests may be oral or written, direct or indirect, for instance:

- **External Event: Governmental Law Change**
- **Mistake in defining the product aim (i.e. it is not possible to provide certain functions to a new television)**
- **Mistake in defining the project aim (i.e. use of the BOM instead of the WBS)**
- **Change in added value (new technology reducing service environmental costs)**



Tools for Objectives Changes Control

Objectives Changes Control System

It defines the procedures, documents and permissions to manage objectives changes and must be integrated with the Changes Control System (and with the CCB) and with all the control systems of the product scope.

Performance Measurement

Systems for assessing the performance and all its changes in order to identify possible causes.

Additional Planning

Most projects require the development of modifications and additions to the schedule in order to compensate the project evolution.

Objectives Changes Control: Output

Changes in the Objectives and in capacity

Any accepted change to the product capacity / project objectives as defined in the WBS. This involves additional planning to accommodate times, resources and costs, documentation correctness and information to team members.

Corrective Actions

All actions to address a project so that it meets the Expected performance in accordance with the planning

Lessons Learned

All objectives changes must be documented and analyzed in order to extend the company's historical database to support the current project as well as other present and / or future projects

Project Time Management

This management area aims to the required processes to ensure the project completion in time:

● Activities Definition

Identification of the specific required activities to provide the various deliverables

● Activities Relationships Definition

Identification and documentation of mutual dependencies

● Activities Duration Estimation

Estimate of the duration in term of working time for each activity

● Scheduling Development

Combined analysis of durations, dependencies and resources to develop the scheduling

● Scheduling Control

Changes Control in the project scheduling

For small projects these processes could be the same

(*Task* and *Activity* are synonymous often used for different working levels: i.e. an *activity* is composed by *tasks* or vice versa; currently there is not a general convention even if the previous example is very famous)

Project Time Management

3.1 Activities Definition

- .1 Inputs**
 - .1 WBS
 - .2 Reports on Objectives & SOW
 - .3 Historical Data
 - .4 Constraints
 - .5 Hypothesis
- .2 Tools and Techniques**
 - .1 Decomposition
 - .2 Templates
- .3 Outputs**
 - .1 Activities List
 - .2 Support Details
 - .3 Update on WBS

3.4 Scheduling Development

- .1 Inputs**
 - .1 Project Network Diagram
 - .2 Activities Duration Estimation
 - .3 Requests for Resources
 - .4 Resources Availability
 - .5 Calendars
 - .6 Constraints
 - .7 Hypothesis
 - .8 Connections and required intervals
- .2 Tools and Techniques**
 - .1 Mathematical Analysis
 - .2 Durations Compression
 - .3 Simulation
 - .4 Resources Heuristic Leveling
 - .5 Project Management Software
- .3 Outputs**
 - .1 Project Schedule
 - .2 Support Details
 - .3 Schedule Management Plan
 - .4 Update on resources requests

3.2 Activities Relationships Definition

- .1 Inputs**
 - .1 Activities List
 - .2 Product Description
 - .3 Mutual Required Dependencies
 - .4 Mutual Discretionary Dependencies
 - .5 External Dependencies
 - .6 Constraints
 - .7 Hypothesis
- .2 Tools and Techniques**
 - .1 PDM (Precedence Diagramming Method)
 - .2 ADM (Arrow Diagramming Method)
 - .3 Conditional Diagramming Methods
 - .4 Network Templates
- .3 Outputs**
 - .1 Project Network Diagram
 - .2 Update on Activities List

3.5 Scheduling Control

- .1 Inputs**
 - .1 Project Schedule
 - .2 Performance Reports
 - .3 Changes Requests
 - .4 Schedule Management Plan
- .2 Tools and Techniques**
 - .1 Schedule Change Control System
 - .2 Performance Measurement
 - .3 Additional Planning
 - .4 Project Management Software
- .3 Outputs**
 - .1 Update al Project Schedule
 - .2 Corrective Actions
 - .3 Lessons Learned

3.3 Activities Duration Estimation

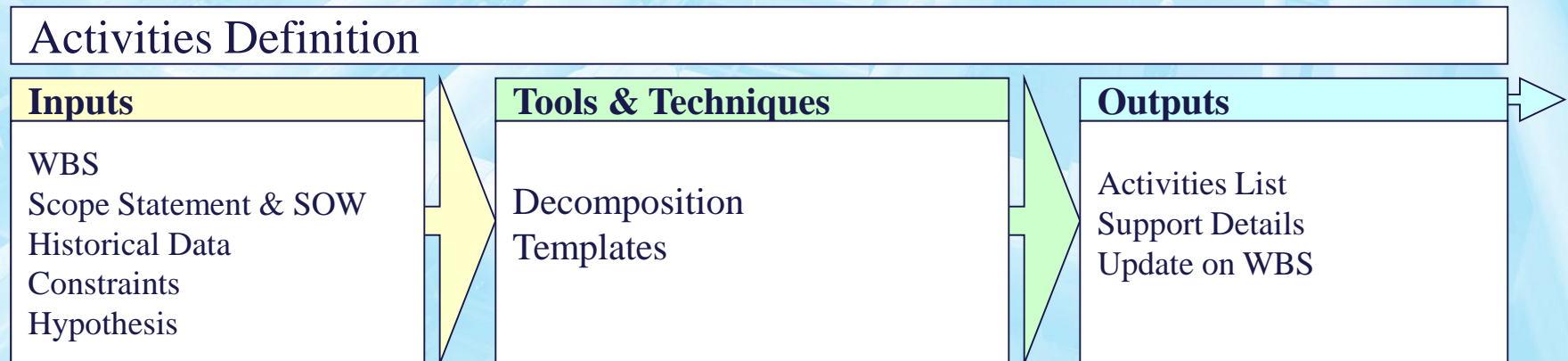
- .1 Inputs**
 - .1 Activities List
 - .2 Constraints
 - .3 Hypothesis
 - .4 Requests for resources
 - .5 Resources Capabilities
 - .6 Historical Data
- .2 Tools and Techniques**
 - .1 Experts Opinion
 - .2 Analogical Estimates
 - .3 Simulation
- .3 Outputs**
 - .1 Activities Duration Estimation
 - .2 Bases used to make the evaluation
 - .3 Update on Activities List

Activities Definition and Input

The aim is to identify and document the specific required activities to apply the project.

Input of this process are:

- ◆ WBS
- ◆ Reports on Objectives and SOW
- ◆ Historical Data related to similar projects
- ◆ Constraints limiting the actions
- ◆ Hypothesis considered as real for the planning scope



Tools and Activities Definition Output

Tools for activities definition:

Decomposition As done for the WBS it requires to breakdown the project into activities (in order to get a hierarchical list of procedural steps, while instead in the WBS that is a hierarchical list of deliverables); this activity is applied in parallel to the WBS creation often

Templates

The list of activities of similar previous projects is used as a template, or a list of activities of a WBS element may be a template for the list of other similar items.

Output for Activities definition:

Activities List It includes a list of all the activities and it is an extension of the WBS in order to check that it is complete and clear and without pleonastic elements

Support Details All the documents of support (i.e. assumptions, considered constraints etc.)

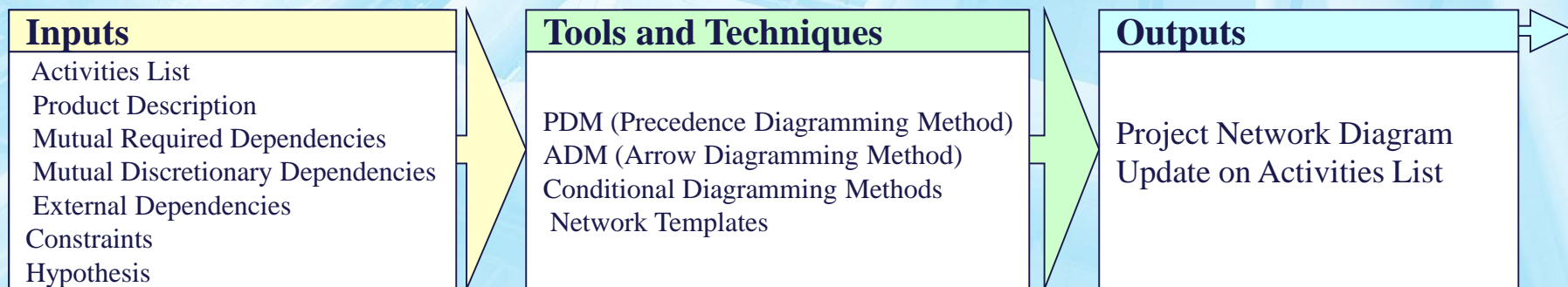
WBS Updates Distribution of *refinements* for the WBS when some required clarification or oversights are identified.

Logic Constraints Definition among the Activities

It is proposed to identify and document the mutual correlations between the activities.

It is possible to use software (SW), but in the preliminary stages of major projects or the sequences definition for small projects it is convenient to continue to work predominantly manually in order to achieve better efficiency and teams coordination.

Typically manual and computer tools are used in a combined way.



Activities Sequencing Input

Activities List

As made for WBS it concerns with project breakdown

Product Description

Often the product description is useful to support the activities temporal order (i.e. the layout of a plant to be built).

Mutual Required Dependencies (*hard logic*)

They are inalienable dependencies constraints (i.e. for a plant foundations are required before overlying structures; for a plane to prototype it comes before testing it).

Mutual Discretionary Dependencies (*soft logic, preferred logic, preferential logic*)

They are dependencies constraints fixed by the Project Team; it is necessary to document them in detail and carefully in order to take into account eventual future re-planning;

They include:

- *Best Practices*, effectively experimented practices in specific sectors
- Specific sequences preferred by the PMT in unusual sectors

External Dependencies

They are relationships linking project activities with external activities; i.e. the institution in charge must carry out the environmental audits before starting the new plant construction.

Constraints

All the constraints limiting action capability (i.e. interference between cranes on the site)

Hypothesis All the accepted hypothesis for uncertain factors.

Tools for Activities Sequencing

Precedence Diagramming Method PDM

It allows to formally present a project through a network where nodes represent activities and the connections represent dependencies and relationships, this technique is also indicated as an AON (Activity On Node).

Arrow Diagramming Method ADM

This method is devoted to the diagram construction through connections of nodes with arrows; if the connections are activities while the nodes represent the dependencies they are called AOA (Activity On Arrow), a typical example is the AOA PERT diagram; a typical case of ADM, where the nodes represent activities is the CPM (Critical Path Method) AON.

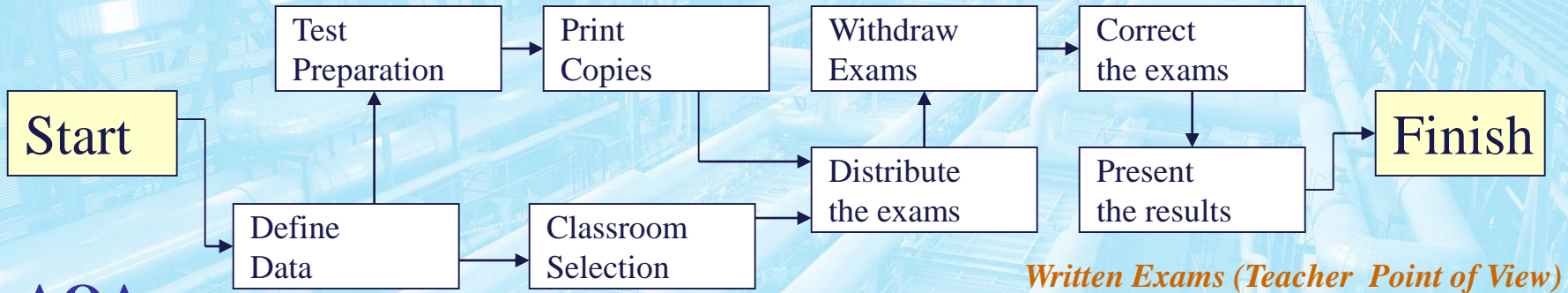
Conditional Diagramming Methods

Include dynamic models, GERT (Graphical Evaluation and Review Technique) graphs allowing to reproduce non- sequential activities (i.e. cycles: a test that must be repeated several times) or conditional activities (i.e. an engineering change taking place only after inspection and defects identification); ADM and PDM don't allow to represent these types of phenomena.

Network Templates

References related to standard planning complete or hierarchically subdivided in sublevels (*subnets* or *fragnets*)

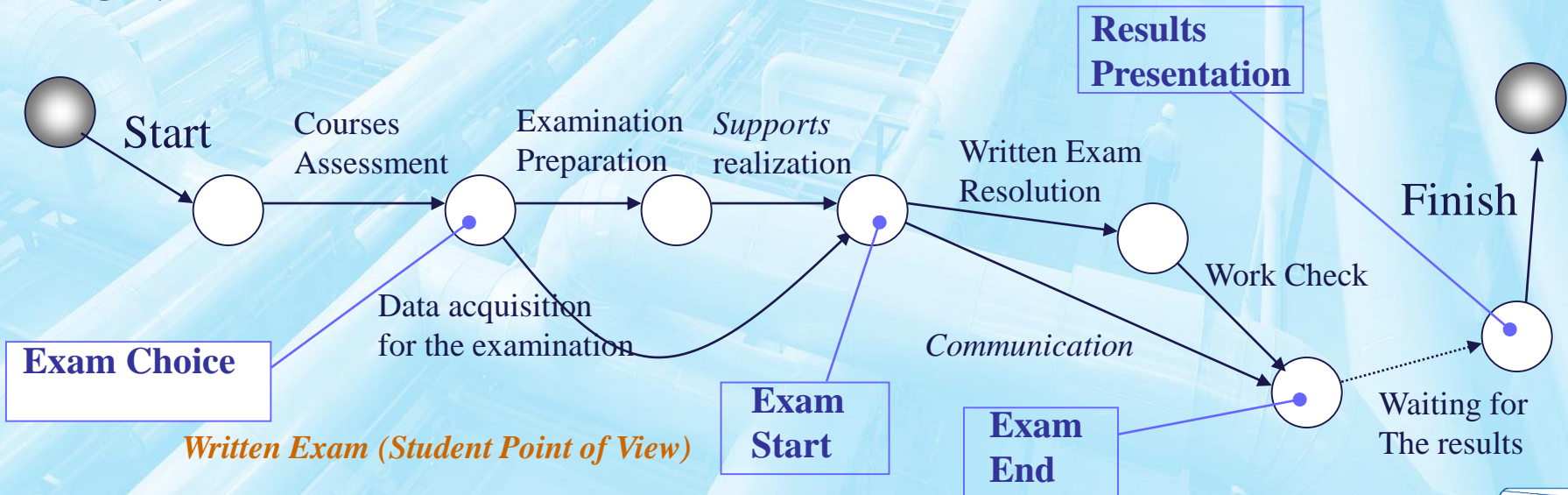
Activity on Arrow & Activity on Node



Written Exams (Teacher Point of View)

AOA

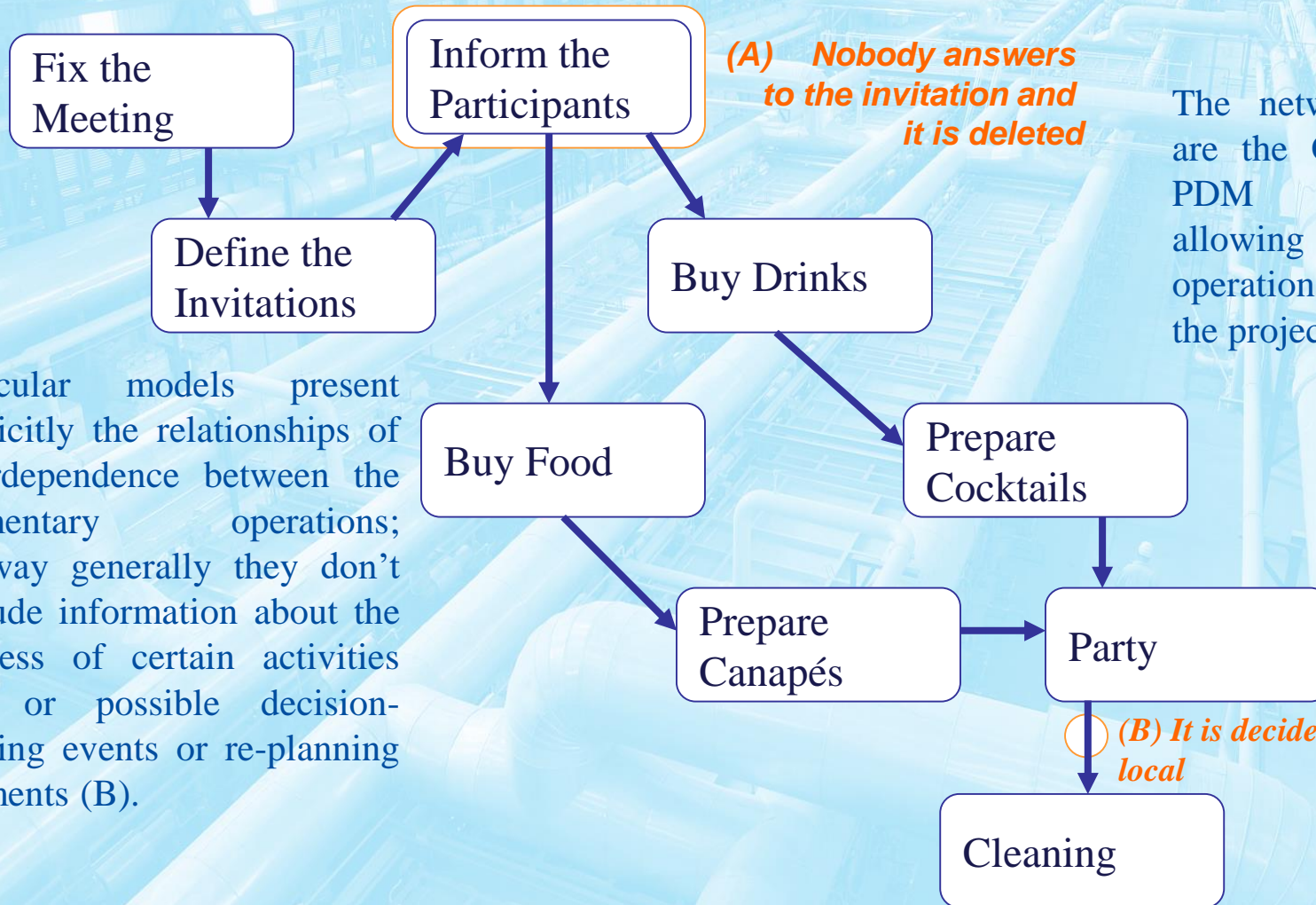
AON



Written Exam (Student Point of View)

Check for Errors

Network Models



The network models are the CPM, PERT, PDM techniques allowing to build an operational model of the project

Reticular models present explicitly the relationships of interdependence between the elementary operations; anyway generally they don't include information about the success of certain activities (A) or possible decision-making events or re-planning moments (B).

PDM Graphs and Dependencies Relationships

The dependencies relationships of priority in PDM may belong to the following four typologies:

- ***Finish-to-Start***: the activity A must finish before starting the activity B
- ***Finish-to-Finish***: the activity A must finish before completing the activity B
- ***Start-to-Start***: the activity A must start before starting the activity B
- ***Start-to-Finish***: the activity A must start before completing the activity B

The most used relationship type is Finish-to-Start. The Start-to-Finish is used only by engineers working as planners; to employ Finish-to-Finish, Start-to-Start and Finish Start-to-on computer software requires to be careful because often their implementation is not sure.

The Sophisticated Precedence Network

Some advanced Project Management Software (SW) allow to work on complex PDM able to use all the mentioned relationships and their potential combinations

Finish-to-Start FS



Start-to-Start SS



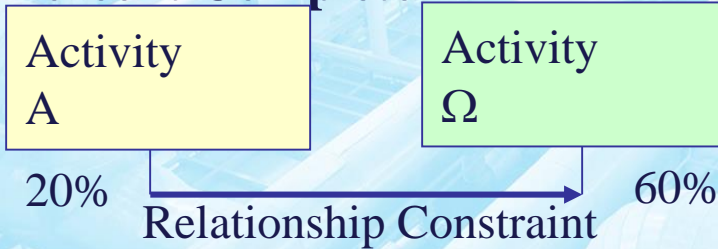
Finish-to-Finish FF



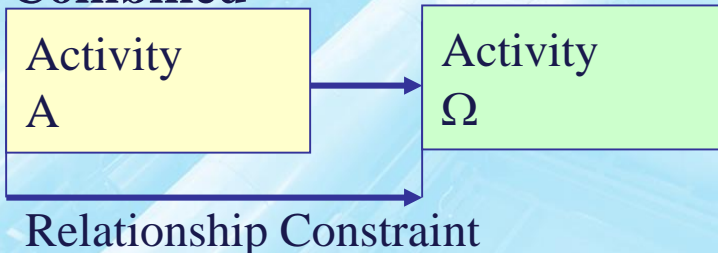
Start-to-Finish SF



Percent Complete

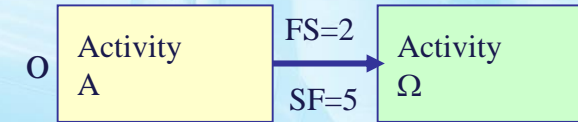
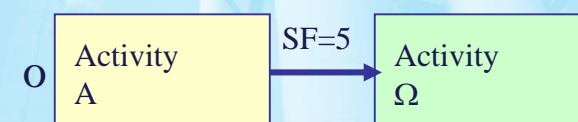
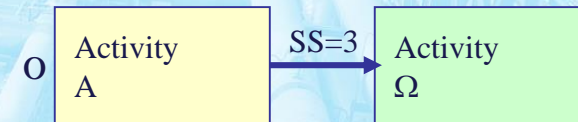
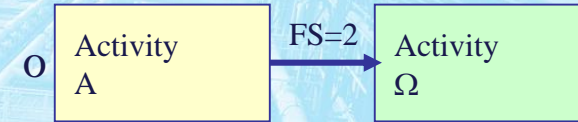
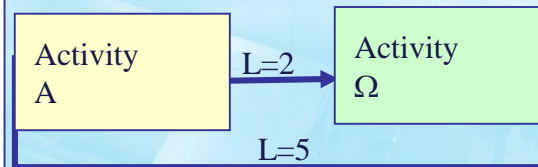
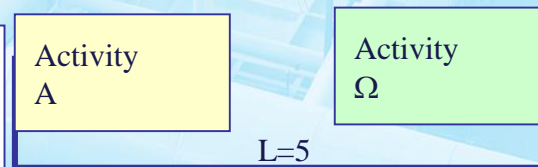
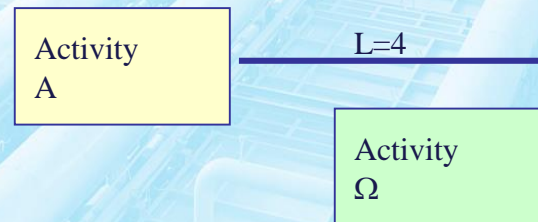
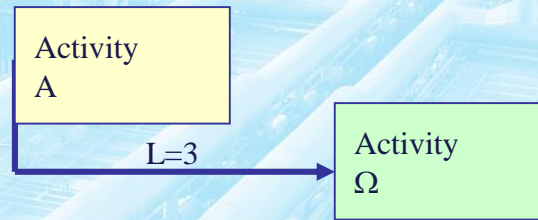
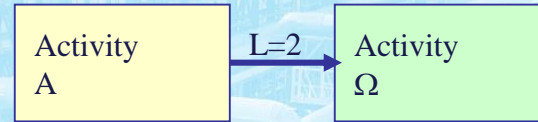
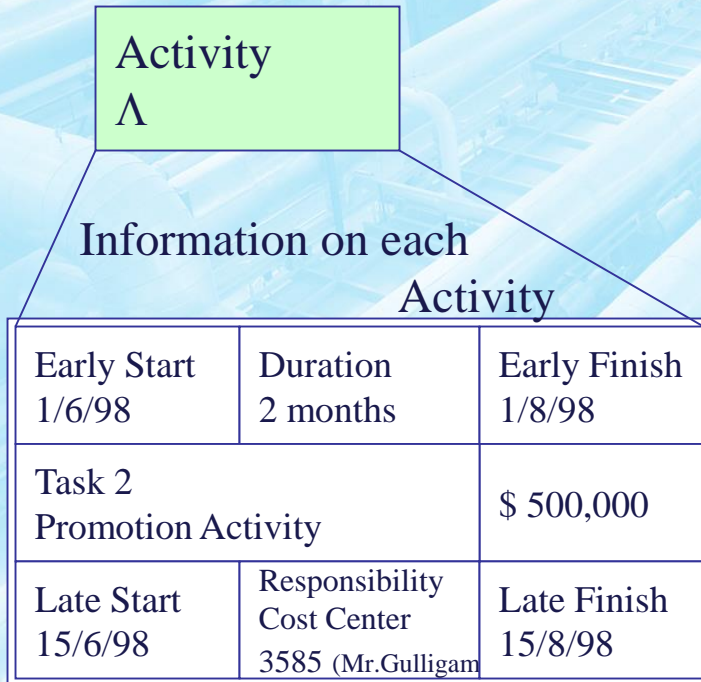


Combined



Different PDM Representations

There are many ways to represent a PDM, for instance in PM Software each activity includes a set of detailed data.

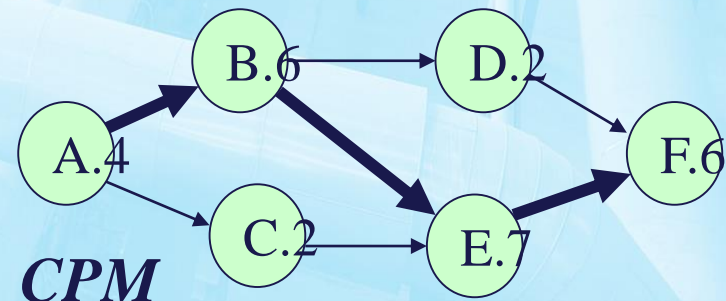
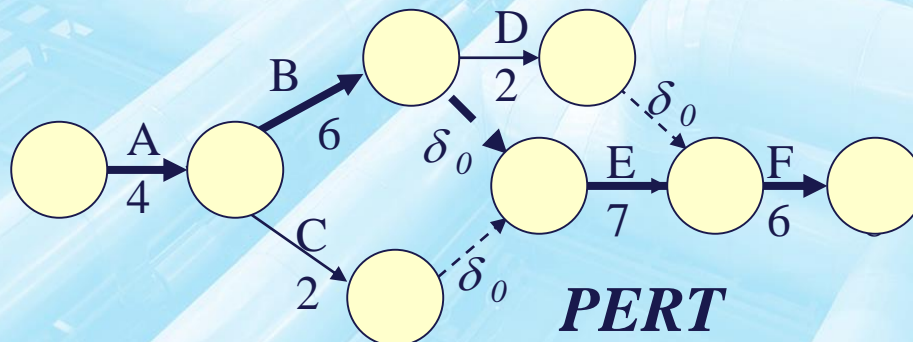


ADM Graphs and Dependencies Relationships

In ADM graphs it is possible to introduce only Finish-to-Start relationships. Thus in order to correctly represent all types of dependencies existing in the project, it is necessary to use *dummy activities* (virtual activities intended to ensure the diagram logical consistency), this is possible both in PERT and CPM diagrams.

The ADM graphs are often less used than PDM graphs during the dependencies identification phase.

ADMs are much more used in the stages of scheduling and project criticalities definition.



PERT History

PERT Project Review Evaluation and Technique

It was developed in 1958-1959 to meet the needs of a "massive engineering era" where Gantt techniques were not effective; it was created by the U.S. Navy Special Projects Office that applied the technique to Polaris weapon system (SLBM) project in 1958 and subsequently it was developed by the consulting company of Booz, Allen and Hamilton.

In 1960 the navy required from PERT that:

- ❖ All individual tasks must be clearly visualized in a network highlighting events and activities, i.e. following the WBS
- ❖ Events and activities should be organized in a logical sequence to identify the critical path; the network can have up to one hundred activities, but no less than ten or twenty
- ❖ The expected times must be based on three criteria: optimistic, pessimistic and the most likely expected by the best experts
- ❖ The critical path and Slack times are computable.

PERT Advantages and Disadvantages

Main advantages of PERT introduction:

- ◆ It allows to define a logic and consequentiality network highlighting where to focus the main efforts.
- ◆ It allows to measure quantitatively the probability to respect specific deadlines
- ◆ Possibility to evaluate the effect of changes on the project
- ◆ It visualizes large and complex structures through clear diagrams

Main Disadvantages are:

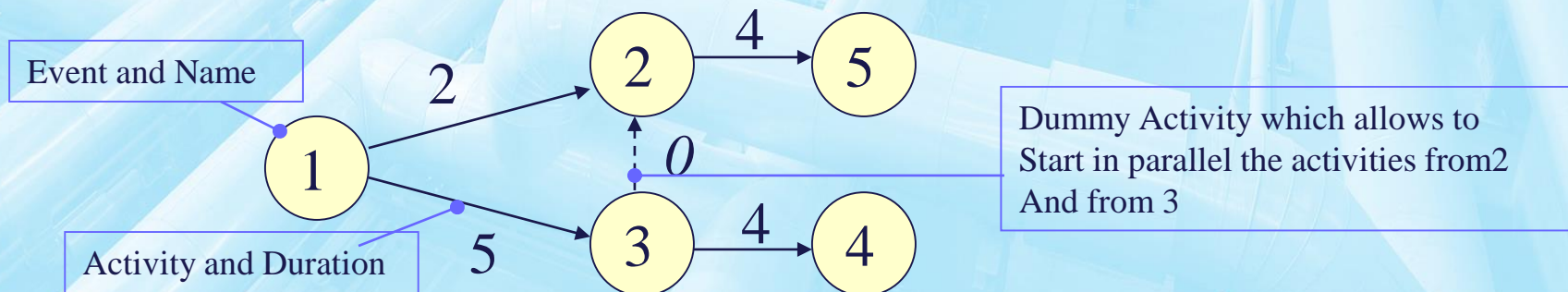
- ⊗ It is quite complex respect of other systems and requires more efforts and costs for its development and the continuous update.
- ⊗ It requires more data from other planning
- ⊗ Its use is restrict to wide projects or to use the PERT / LOB (Line of Balance) for Small/ medium projects

PERT Basic Logic

In the PERT branches are activities while nodes are events.
Starting from the WBS it is possible to work:

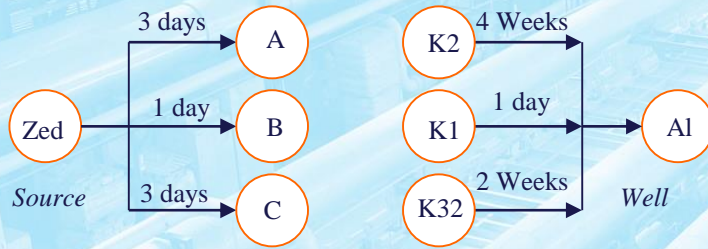
- For WBS levels 1-3 (Management) the reference entities are the milestones so the PERT is developed starting from events
- For WBS levels 4-6 (technical) the most important entities are the activities and so the PERT is developed from branches.

Dummy activities allow to introduce non sequential logic:



PERT Structure

In the PERT nodes are events
And lines are the activities:

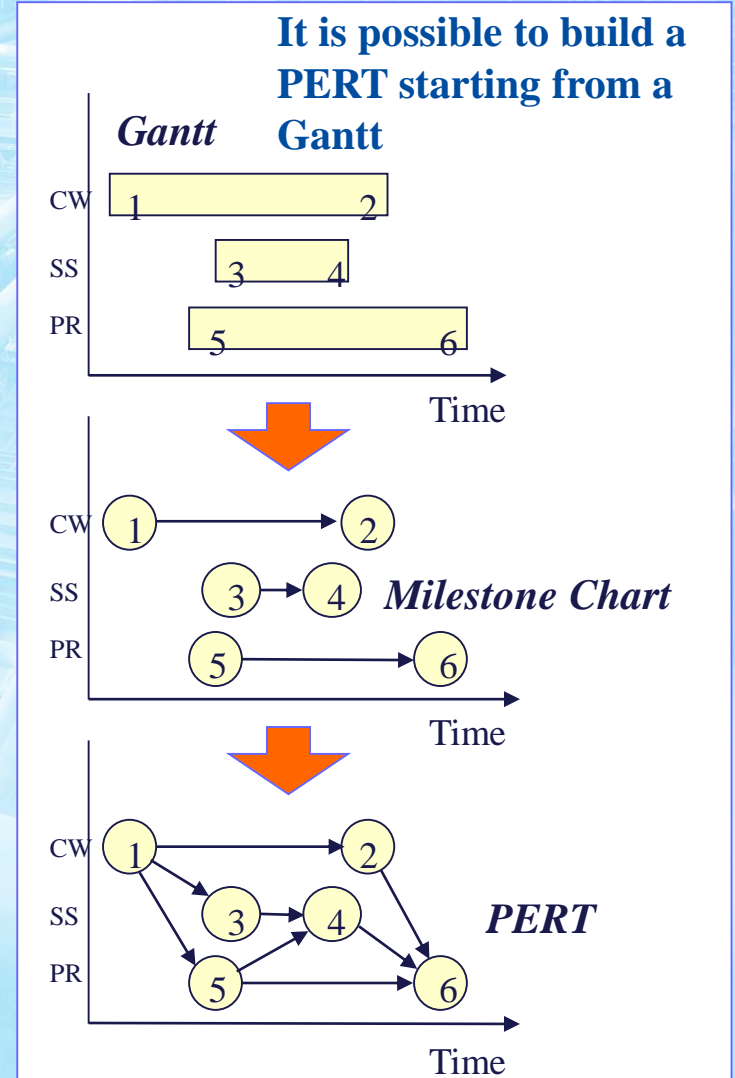


The project conversion into a PERT is based on the analysis of the following questions:

Which activity precedes immediately this job ?

Which activity follows immediately this job?

What activities may occur in parallel.



PERT Preparation

The PERT preparation should follow the following six steps

- 1) The PM writes the activities list
- 2) The PM organizes the activities based on priority criteria (drafts, ADM, PDM, networks etc.)
- 3) The PM reviews the diagram with line managers (experts), and checks it is well estimated, complete and correct
- 4) The functional manager define the PERT by introducing the durations (expectation based on *unlimited resources* because the calendar is not yet known)
- 5) The PM looks at the PERT and checks if it meets the key dates and the project calendar, if not he proceeds to redefine it (i.e. crashing activities) and by asking to manager to remove the “*fat*” from their planning
- 6) The PM fixes the reference dates on the calendar and starts to reorganize the PERT based on *limited resources*.

The CPM as Industrial Reply to the PERT

The PERT introduction often produces costs increases, so that in 60s, when the U.S. Navy started to require providers with the PERT use, companies often used an internal corporate planning and a planning report for the customer (PERT) in a separate and distinct way.

*So, the PERT, born to address the major discrepancies of Gantt charts and based on milestones (unable to show dependencies between activities and events) must compete with a different network system for project presentation such as CPM recently appeared: **CPM Critical Path Method***

Late '50s the American Chemical Group DuPont developed the CPM method that spreads quickly in process industry and in construction projects. The CPM meets the same needs identified by the PERT but paying particular attention to industrial users.

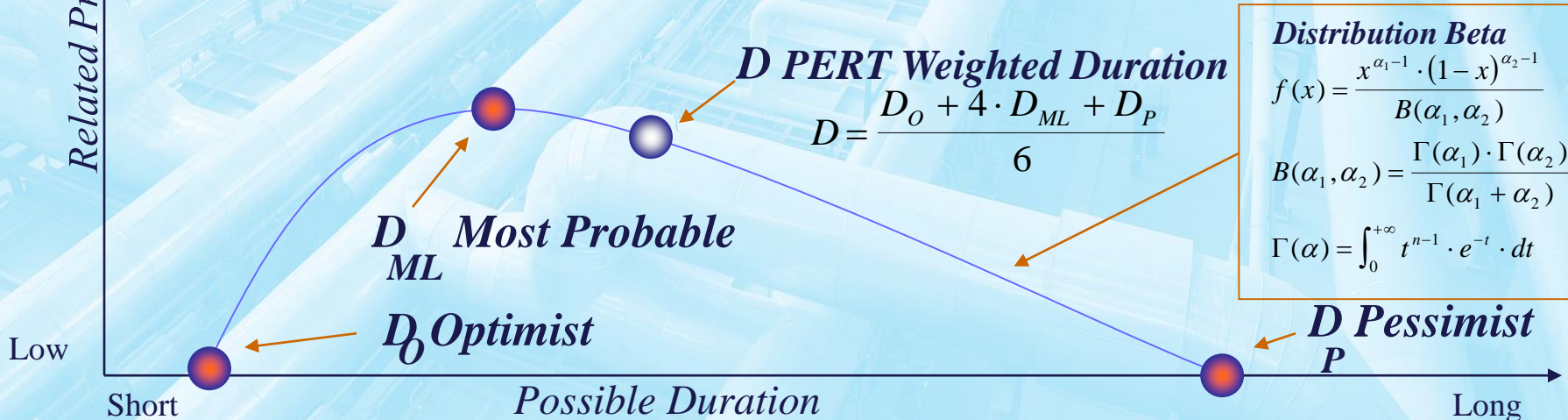
Comparison Among Some Analytical Techniques

Among the main analytical techniques there are:

Critical Path Method (CPM) deterministically computes the parameters Early and Late Start and Ending time, to identify the activities with less flexibility (critical path) based on the more common durations.

Graphical Evaluation and Review Technique (GERT) allows probabilistic treatments both in logics and in durations. It shows the influence of specific activities that could happen only under certain conditions related to stochastic components

Program Evaluation and Review Technique (PERT) uses a sequential network and durations weighted estimates in order to calculate the project duration; often these methods of durations evaluation are also used in the CPM method



Comparison between CPM and PERT

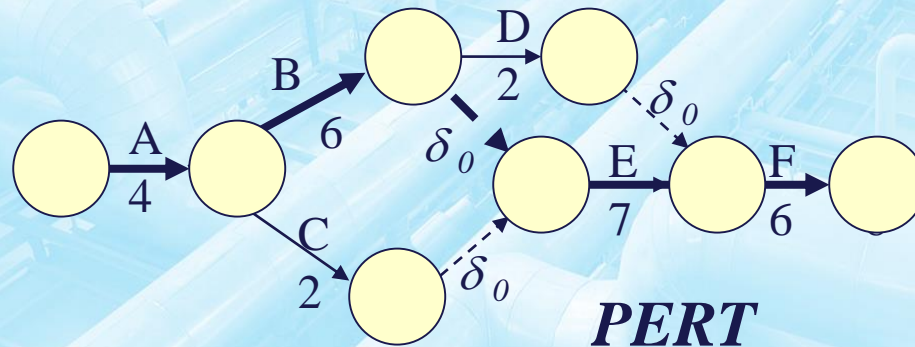
- PERT uses a times assessment based on three estimations (optimistic, pessimistic and usual), while CPM uses a single normal estimation
- Duration estimations are more precise than in the CPM
- PERT is stochastic based on a beta probability function and allows to assess the risk, while the CPM is deterministic
- Both PERT and CPM allow the use of dummy Activities to develop complex logics for the project
- PERT is used to estimate projects involving R&D where times are strongly variable; the CPM is used for construction projects where the dependencies between resources and the times estimation are accurate
- PERT is used in projects (i.e. R & D) where the work completion percentage can not be evaluated before its end (at the final milestone), the CPM is used in projects where it is possible to estimate an activity percentage of completion (i.e. buildings) and correspondingly to charge the cost to the customer

PERT vs. CPM

A fundamental difference between CPM and PERT is that the PERT doesn't allow to estimate the completion percentage (activities where it is not evaluable until its completion):

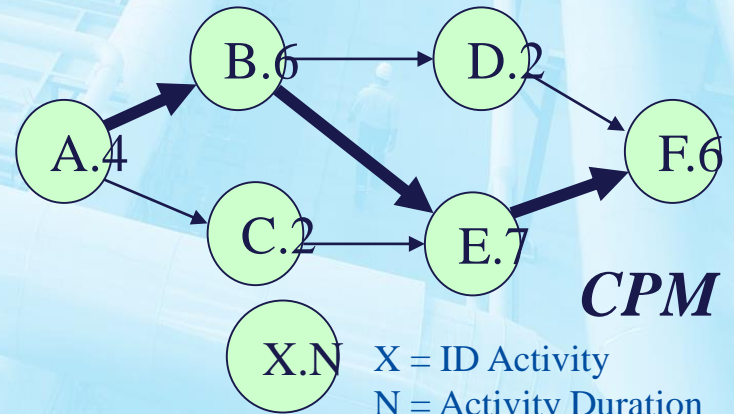
PERT

Event Oriented
 Circles are events
 Activities with Times^(*) ^(**)



vs. CPM

Activity Oriented
 Circles are activities
 Activities with Times and Costs ^(**)



(*) Really it is possible to connect the PERT to the costs
 But generally it is used mainly times
 (**) Obviously it is possible to present PERT and
 CPM both in AON and AOA mode

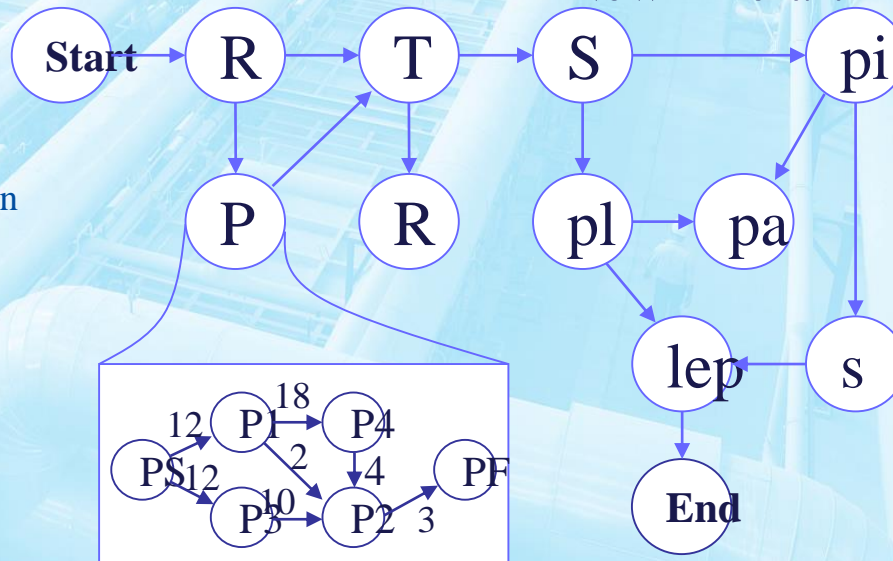
Hierarchical PERT and CPM

If the project complexity is high, it may be appropriate to develop PERT / CPM in a hierarchical way, through a subdivision; for example between different business units. This technique is often used in the case of many contractors and / or subcontractors

Start
R
T
P
S
R
pl
pa
pi
s
lep
End

Project Starting
USAF Request
Notice Issuing
Prototype for Competition
Prototype Selection
Project Review
Mnfr. Production Lines
Mnfr. Serie areo
Mnfr. Infrastructures
Service
Life Extension Progr.
Project Ending

PERT New Aircraft XF-23



PERT Initial Project

Alternative Models to PERT/CPM

Due to the advantages of PERT / Time (CPM / time), they were used by many companies; but in some cases, PERT / time was not adequate; by considering that the key parameters to monitor a project are time, cost and performance it is understandable the development of PERT / costs and PERT / performance.

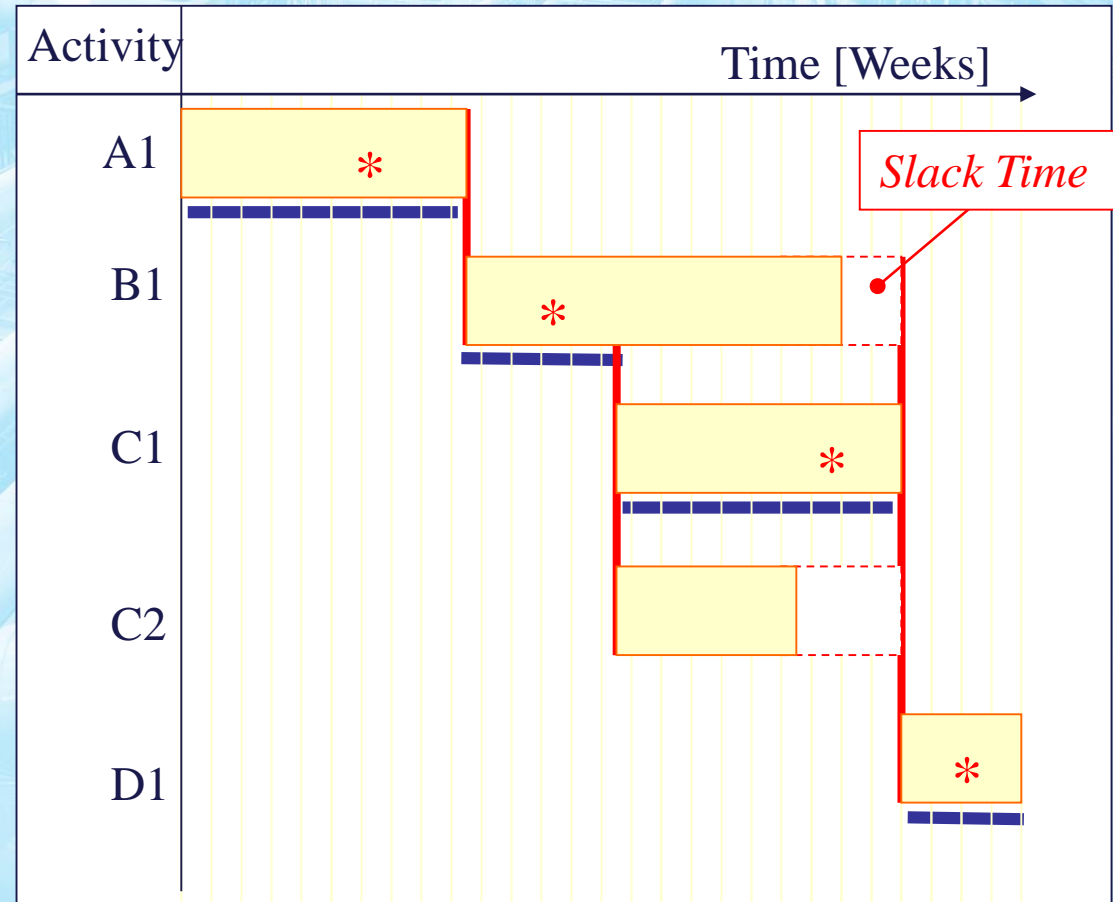
The PERT / cost substitutes times with costs by ensuring all PERT properties and allowing costs control at each level of the WBS; it is then possible to identify critical aspects of the project cost.

In addition there are attempts to develop PERT / schedule, based on the concept that you present the costs associated to the scheduling rather than to the time overcoming (i.e. the system ACP Accomplishment / procedures cost), but these techniques are not much used by companies.

Precedence Networks & PM Software

Most of the SW visualize the PDM through bar diagrams presenting the correlations between the different activities (highlighting directly slack times with hatching and the critical path with color or symbols).

This approach tends to become ineffective if the activities become too complex



PDM derived from Gantt

Activities Sequencing Output

Project Network Diagram

It is a synthetic representation of the project activities together with their corresponding logical relationships of dependence and precedence.

It must include a description of the adopted policy and a comprehensive examination of the unusual adopted sequences.

The PERT is not the Project Network Diagram, but one of the methods to present it, even if it is currently the most commonly used.

Updates on the Activities List

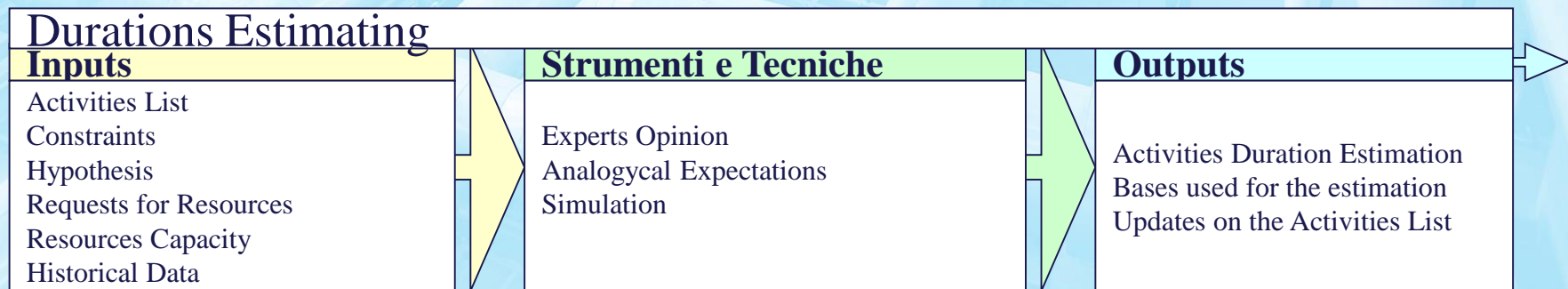
Obviously, during the Project Network Diagram developing, it is possible to get clarifications and changes for the Activities List, then further subdivisions or new definitions.

Activities Durations Estimation and Input

This is probably the most critical phase among those related to the project time management, because it is largely based on assumptions and experts assessments and simulation models results, often related to extremely complex and partially or completely new projects.

As Input it is used the activities list, the list of considered constraints and assumptions, together with data on resources: Requests for Resources (Resources to be allocated to the various activities), Resources Capacity (Potential available resources) .

Obviously, all is attached to historical data including: archives related to previous projects, records on trade durations and distributed knowledge of similar cases in the company.



Tools for Activities Duration Estimation

Experts Opinion

At this step Experts opinions are particularly important, at least for the review phase; in case of inability to obtain them, it is necessary to assume risks and uncertainties.

Analogical Estimations

They are also called Top-Down Estimating, it is based on getting future estimations from past activities and it is generally an extrapolation by experts based on historical data; it is successful when there is a strong similarity with historical data and really acknowledged people making extrapolations

Simulation

It allows transfer experts knowledge into quantitative models; it is based on a full VV&A (verification, validation & Accreditation) phase; in PM often very simple models are used based on Monte Carlo technique and repetitive durations extractions from predefined probability distributions.

Durations Estimating Output

Activities Duration estimation

Quantitative results related to the durations; it is a fundamental a detailed and accurate description of the measurement units (calendar days, working days, weather working days, hours, etc..).

It must include information on variability ranges of the durations: i.e. waste or medium values or standard deviations or risk levels of overcoming the fixed durations.

Basis used for the Estimation

All the documentation describing criteria and computations used to achieve the proposed results.

Updates on the Activities List

Obviously this phase may highlight the need of subdividing or including additional activities for a better evaluation of durations (i.e. the introduction of a new Laser welding process may be more properly planned dividing the delivery time from the assembly and setting time)

Project Schedule Development and Input

The Project Schedule definition is the keystone of the planning. As Input, it includes obviously the Project Network Diagram, the activities estimated durations and the considered assumptions. In addition data related to requests for resources and their availability (considering not only quantity, but also their availability in time and type: part-time, shared, etc..).

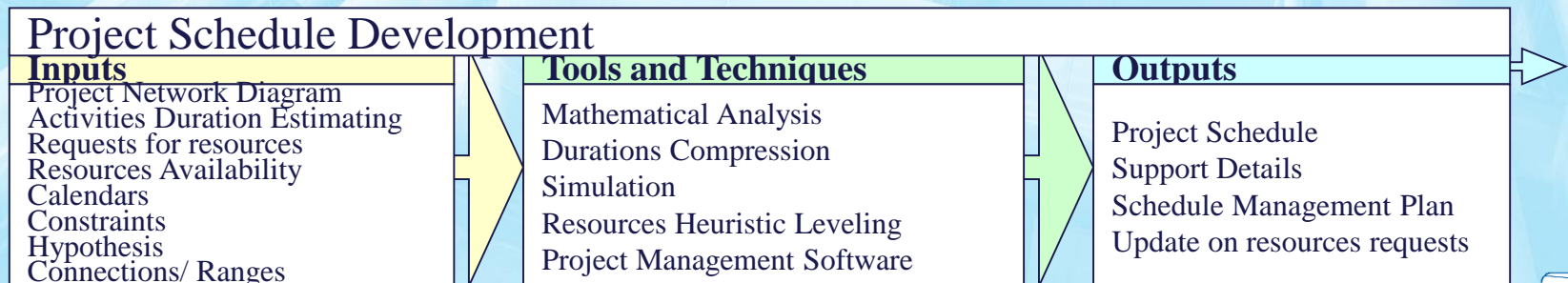
It is necessary to evaluate calendars used to understand how to allocate durations: for certain activities duration covers 24 hours, on other days 8 hours, 12 hours with Saturday, others require positive external weather conditions etc.

The constraints in this case are mainly of two types:

Fixed Dates (by the customer, by legal or market sponsors, they are not modifiable)

Key Events/Milestones: (of the customer, of the sponsor etc., they can be moved, but rarely and with big efforts)

Ranges and required connections (i.e. 48 waiting hours between bonding operation and testing on helicopter parts)



Project Schedule Main Objectives

Scheduling main objectives are:

- ◆ Optimum Times
- ◆ Minimum Costs
- ◆ Minimum Risks

Secondary objectives:

- ◆ Alternatives assessment
- ◆ Optimal Scheduling
- ◆ Resources Effective Use
- ◆ Processes Estimations Finalization
- ◆ Project Easy Control
- ◆ Facilitate costs and time revision

Constraints to be considered

- ◆ Project Calendar (deliverables completion time)
- ◆ Economic Constraints (i.e. cash, cash flow etc.)
- ◆ Limited Resources
- ◆ Direction Approval

Tools for the Project Schedule Development

Mathematical Analysis – Analytical Techniques

Analytical techniques allowing the durations theoretical computation; normally they don't develop the scheduling, but they identify zones where it is possible to introduce the activities by respecting the constraints.

Durations Compression

Methods to compress the durations; there are two main methods *Crashing* (increase resources/costs to compress the activities)

Fast Tracking (parallelize activities that are traditionally in series)

Simulation

The simulation is the best tool if available.

Resources Heuristic Leveling

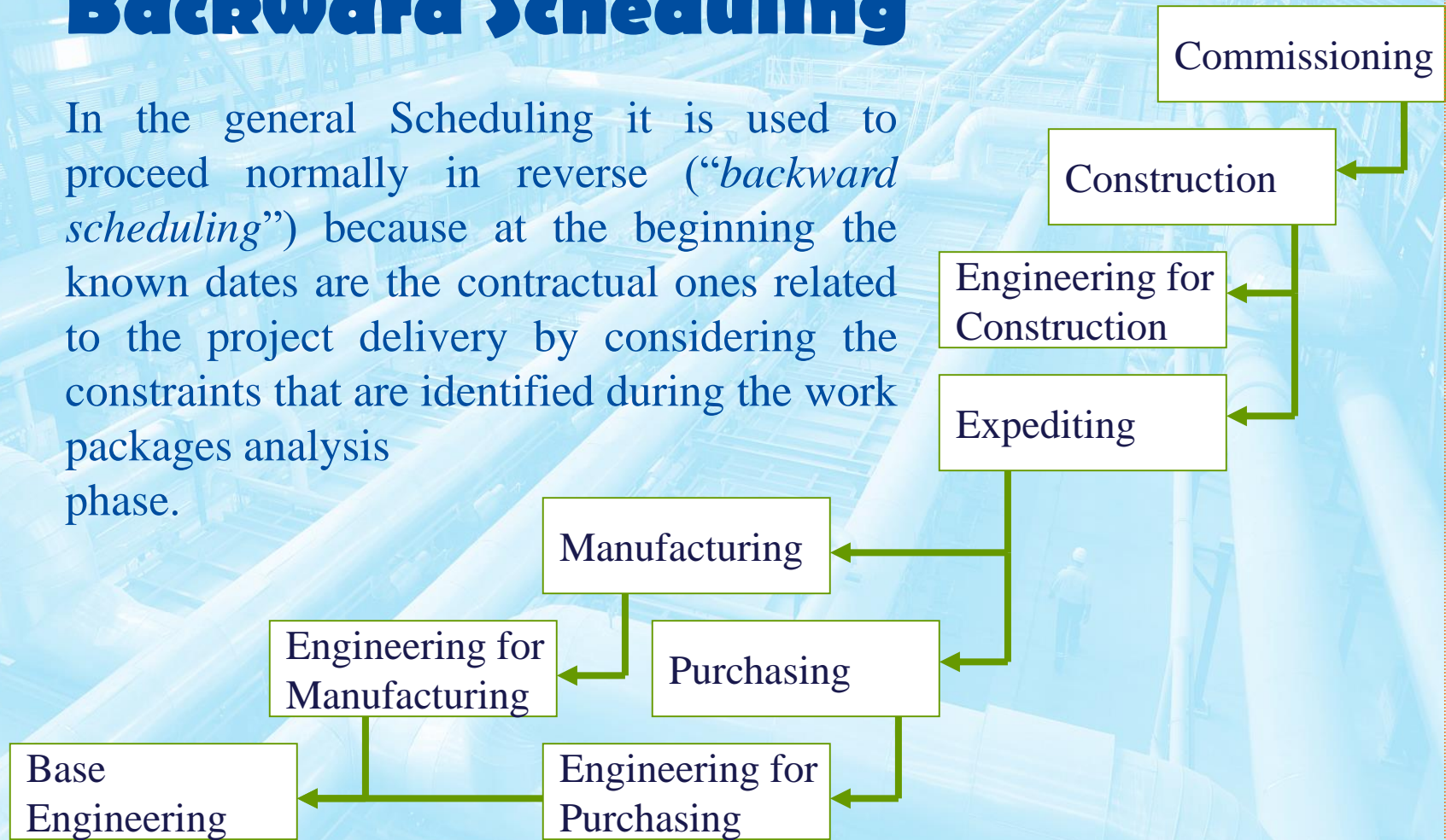
various heuristic techniques for the planning: i.e. planning based on constraints for resources leveling; it is possible to use methods based on artificial intelligence and/or traditional mathematical techniques

Software for the Project Management

Software implementing automatically part of the above mentioned techniques are commercially available and used

Backward Scheduling

In the general Scheduling it is used to proceed normally in reverse (“*backward scheduling*”) because at the beginning the known dates are the contractual ones related to the project delivery by considering the constraints that are identified during the work packages analysis phase.



Rolling Wave for Operational Scheduling

In the operational planning it is often used a periodic re-planning on a short time in order to have a constant upgrade (“rolling wave”)

Examples:

General Yard Planning

Range: month

Time Horizon: whole Project

Frequency: Three months

Detailed Assembly Planning

Range: day

Time Horizon: assembly duration

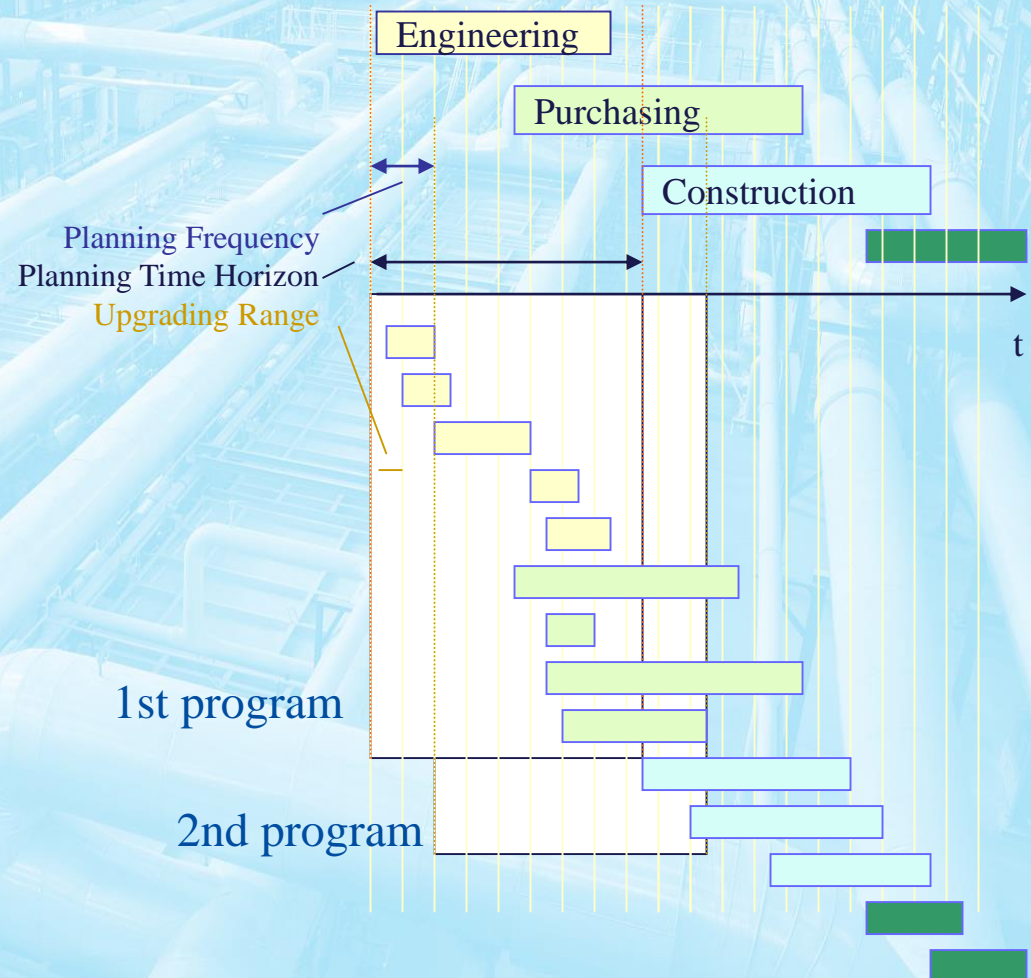
Frequency: weekly

Sub Suppliers Planning

Range: week

Time Horizon: three months

Frequency: weekly



Re-planning Techniques related to Resources

There are two main techniques for the PM to re-plan the scheduling by acting on the resources:

- **Resource Leveling**: Eliminate peaks and downstream in staff demand, with proper requests adjustments in each period; normally that moves the completion dates and increases costs.
- **Resource Allocation**: Use the available resources and reschedule the project network by reusing resources (if possible) for different activities (i.e. using people employed on activities with a slack time on other activities)

Other methods include:

- | | |
|------------------------------------|--------------------------------|
| Delete Project parties | Add more resources |
| Parallelize | Shorten the critical Path |
| Shorten initial activities | Shorten long activities |
| Shorten the easy activities | Accelerate cheap activities |
| Replace activities with other ones | Accelerate |
| Shorten where there are resources | Increase working hours per day |

Parallelization Risk

The activities parallelization allows to strongly accelerate the project but that involves risks and costs to be carefully evaluated:

PERT

- 1 Contract Negotiation Closure
- 2 Contract Signature
- 3 Raw Material and Equipment Order
- 4 Dummy Event

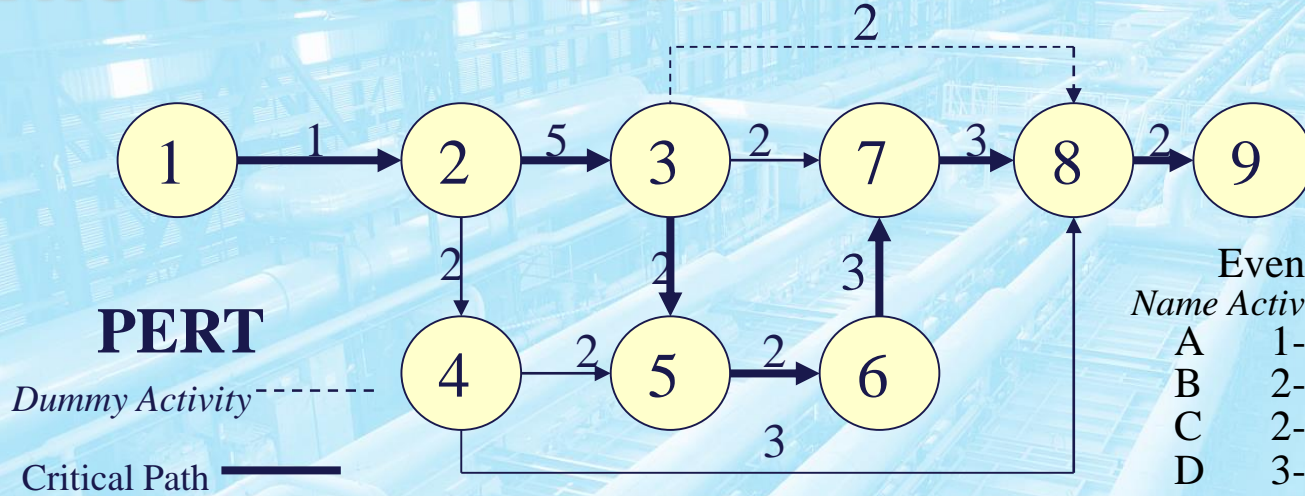
It is possible to accelerate the initial activities by 20 to 16 weeks (-20%) however if the contract changes or it is interrupted you pay a risk; obviously it is possible to use insurance but it implies new costs.

PERT

- 0 Plane Specifications
- 1 Cell Project Delivery
- 2 Weapon System Project Delivery
- 3 Avionics Project Delivery
- 4 Engines Project Delivery
- 5 Project for Prototype Delivery

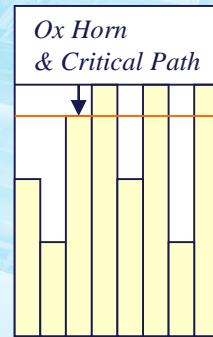
The Project is parallelized and it is reduced from 37 months to 21 (-40%), however in case of design mistakes carried out on the prototype the risk is other 21 months, 5 months delay respect the previous plan (+13%) and engineering design costs doubling

The Critical Path



	Events Sequence			
Name	Activity	Previous	Duration [months]	
A	1-2	==	1	
B	2-3	A	5	
C	2-4	A	2	
D	3-5	B	2	
E	3-7	B	2	
F	4-5	C	2	
G	4-8	C	3	
H	5-6	D,F	2	
I	6-7	H	3	
J	7-8	E,J	3	
K	8-9	G,J, Γ	2	
Γ	3-8	B	2	Dummy

The *Critical Path* includes the activities Having *slack time* (i.e. 1-2-3-5-6-7-8-9)



The Critical Path is fundamental because it provides to the PMT two news:

- Each delay on activities belonging to the critical path generates a delay on the whole project
- It highlights the activities to be considered for the planning

Comparison between Duration and Standard Deviation

Let's consider the following elements in a PERT diagram

- a Optimistic estimation of the duration
- b Pessimistic estimation of the duration
- m The most probable value

Based on the PERT technique the reference durations are calculated as follows:

$$t_e = m = (a + b + 4m) / 6$$

t_e Duration Expected Time equivalent to the m in the CPM

$$s = (b - a) / 6$$

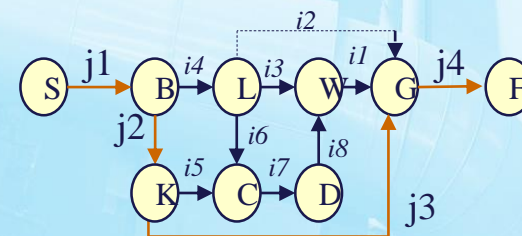
s Standard Deviation (mean square deviation) on the duration

The standard deviation may be useful to compare different activities.

The used percentile is related to a probability (+/- 1 sigma 68%,

+/- 2 sigma 95%, +/- 3 sigma 99). The Standard deviation of the critical path is calculated as:

$$\sigma_{tot} = \sqrt{\sigma_{j1}^2 + \sigma_{j2}^2 + \sigma_{j3}^2 + \sigma_{j4}^2}$$



Critical Path Determination

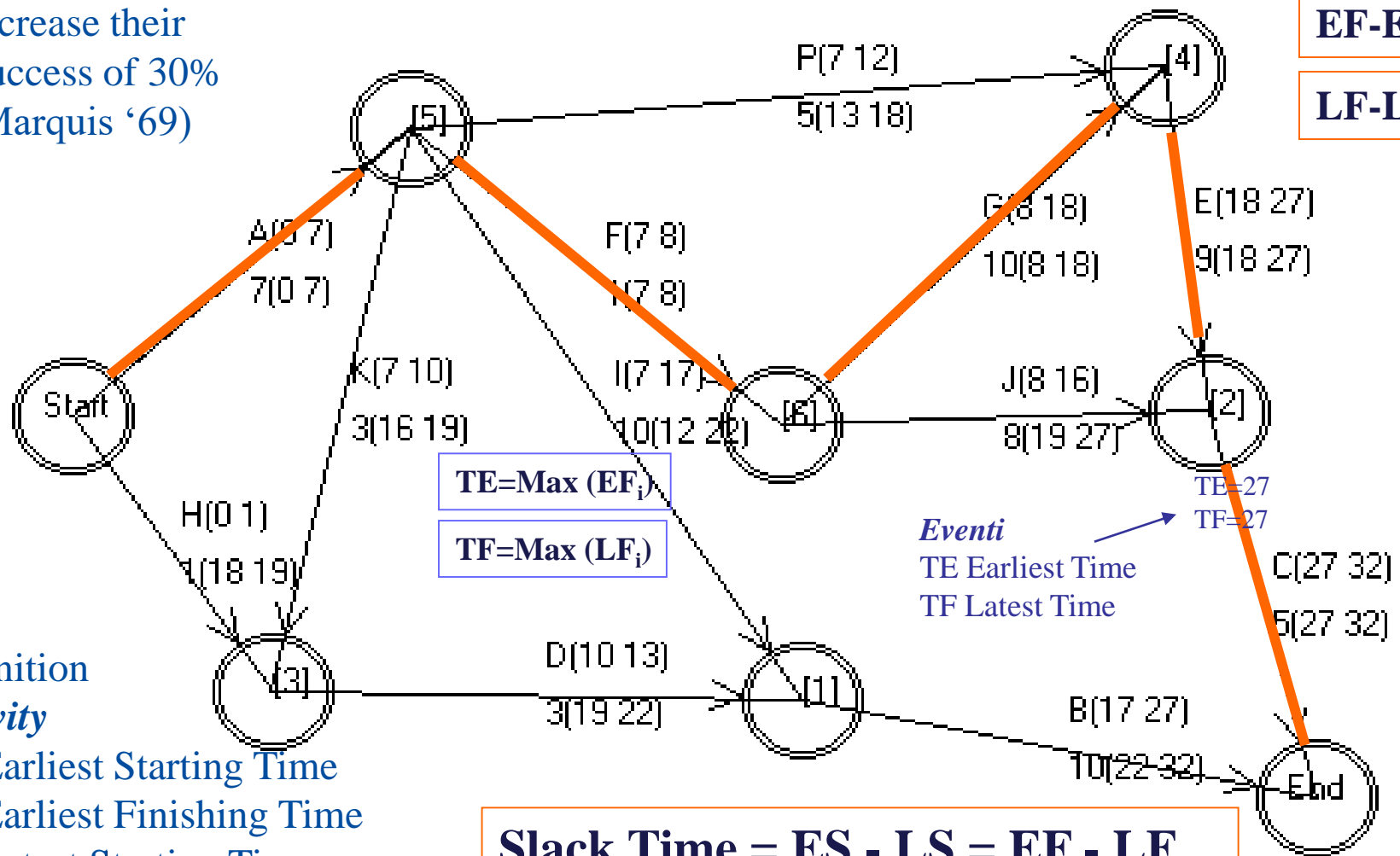
Companies using it
Increase their
Success of 30%
(Marquis '69)

ES EF LS LF

PERT

$$EF - ES = d$$

$$LF - LS = d$$



$$TE = \text{Max}(EF_i)$$

$$TF = \text{Max}(LF_i)$$

Eventi
TE Earliest Time
TF Latest Time

Definition

Activity

- ES Earliest Starting Time
- EF Earliest Finishing Time
- LS Latest Starting Time
- LF Latest Finishing Time
- d Activity Duration

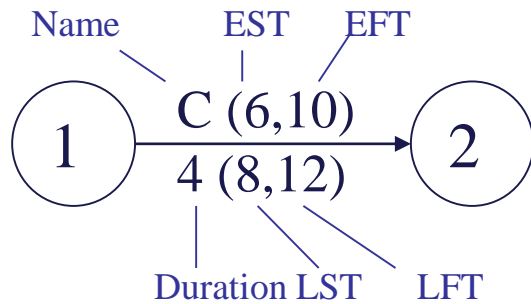
$$\text{Slack Time} = ES - LS = EF - LF$$

$$\text{Critical Activity} \Leftrightarrow \text{Slack Time} = \text{Zero}$$

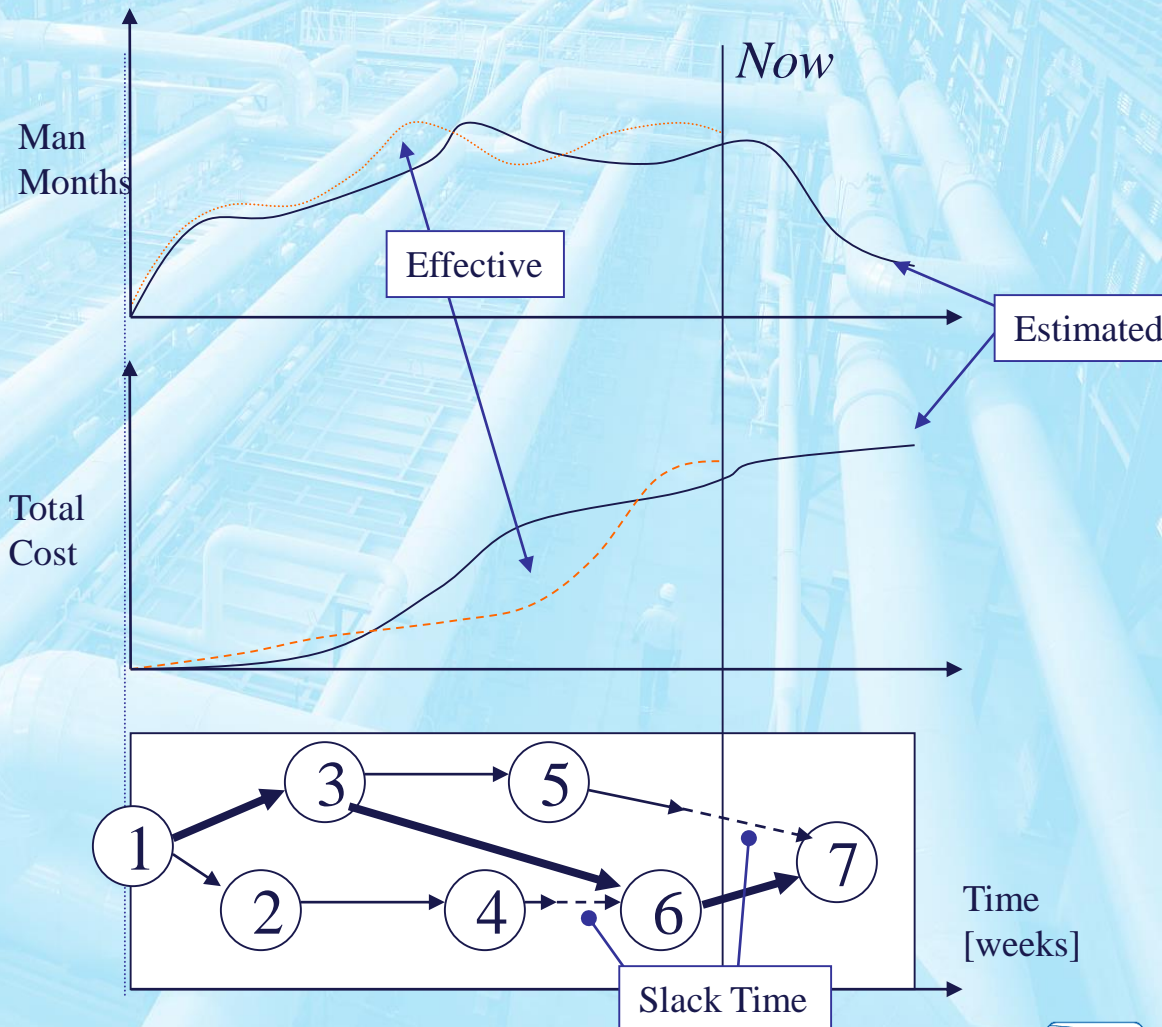


PERT with Time Scale

PERT Typical Representation



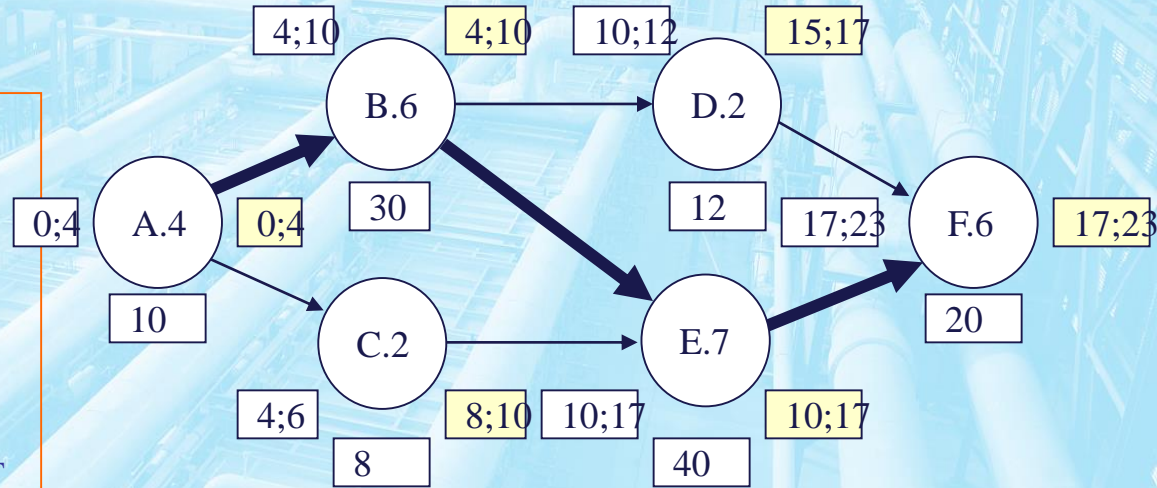
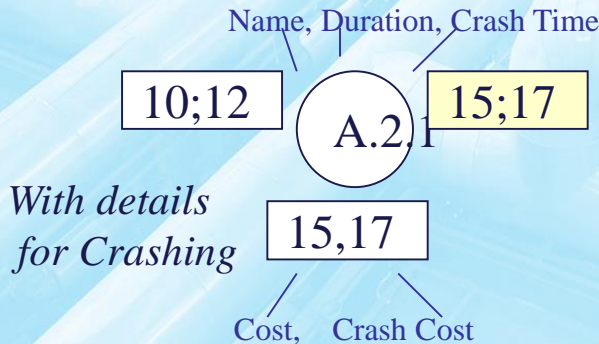
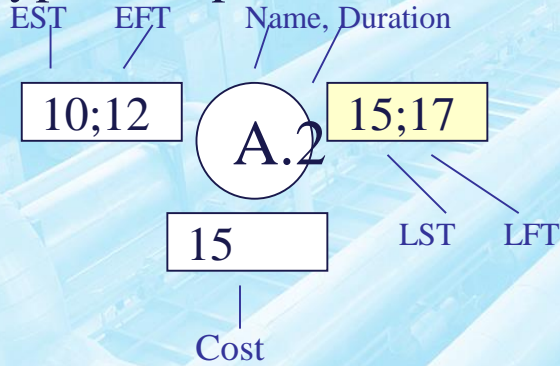
Sometimes to compare costs and resources it is used a PERT Time Representation



CPM: Slack e Crash Times Representation

CPM

Typical Representation

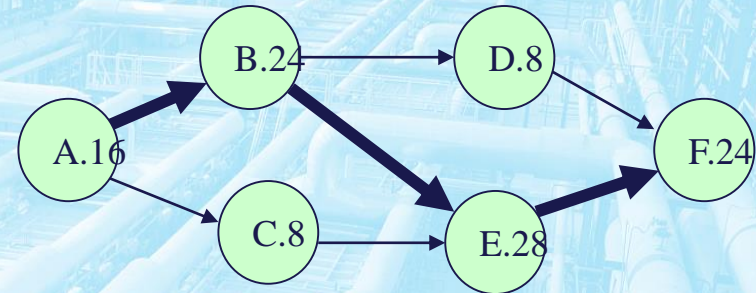


As for PERT also in the CPM it is possible to proceed to Slack Time analysis; in this case the Representation is similar to the PERT even If obviously the activities in this case Become the project network nodes.

In addition it is possible to add information about crash cost and crash time

Crashing Time to Respect Times

The time Crashing allows
To compress the project duration and
it concerns with the activities
shortening against the costs increasing



$X.N$ X = ID Activity
N = Activity Duration

Consider the activities on the critical path with lower crash cost per time unit and compress them by taking into account that at each step the critical path may change.

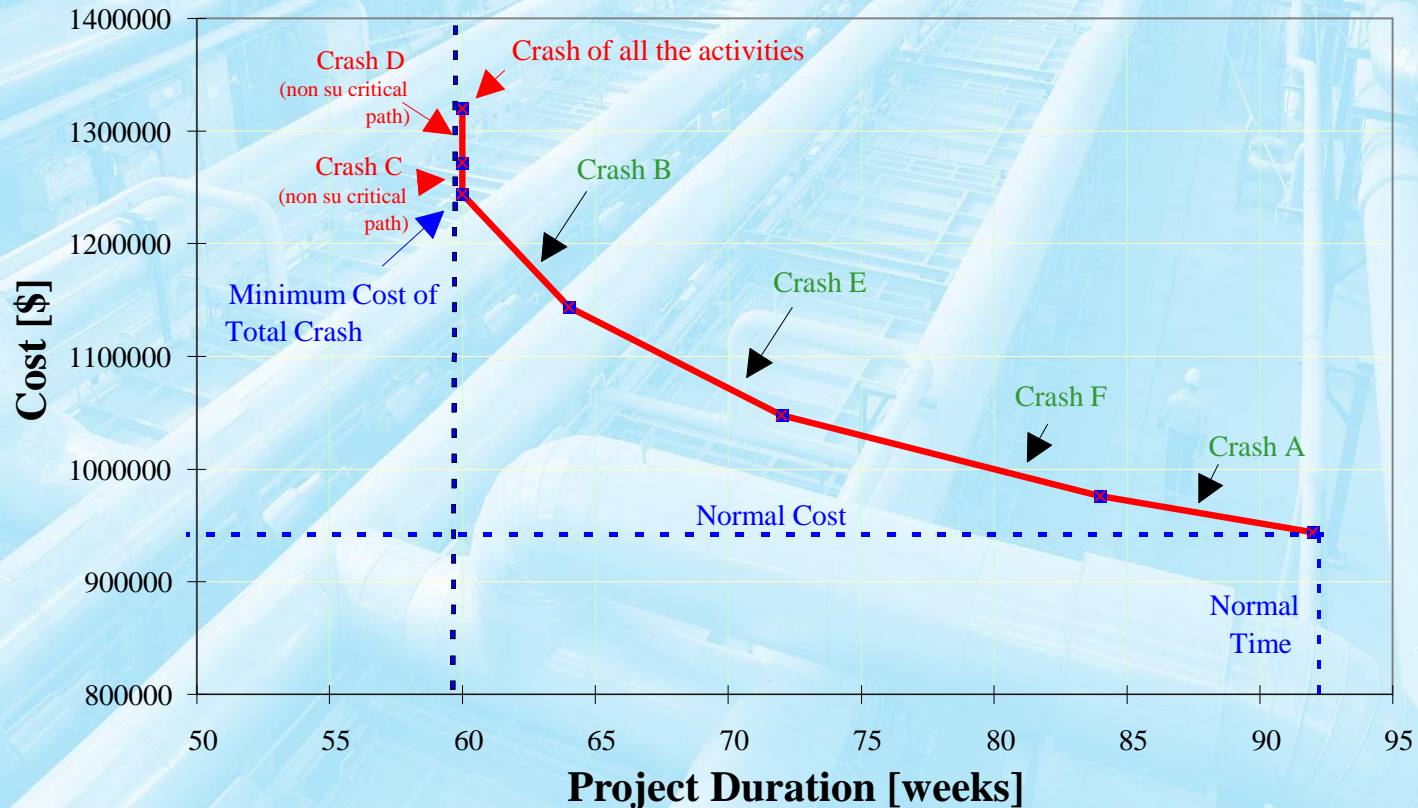
Example: first A (4000 \$/w) then F (6000\$/w), then E (12000\$/w) because both D and C are not on the critical path and finally B (25000\$/w) = costs increasing from 944000\$ to 1.244 m\$ (+32%), with a time reduction equal to 32 weeks (-35%)

Activity	Required Time [weeks]		Cost [\$]		Crashing Cost [\$/week]
	Normal	Crash	Normal	Crash	
A	16	8	80000	112000	4000
B	24	20	240000	340000	25000
C	8	4	48000	76000	7000
D	8	4	96000	144000	12000
E	28	20	320000	416000	12000
F	24	12	160000	232000	6000

Ratio Cost/Efficiency in the Crashing

To apply the Crash technique of the CPM leads to a contraction of the times that are optimized respect of costs

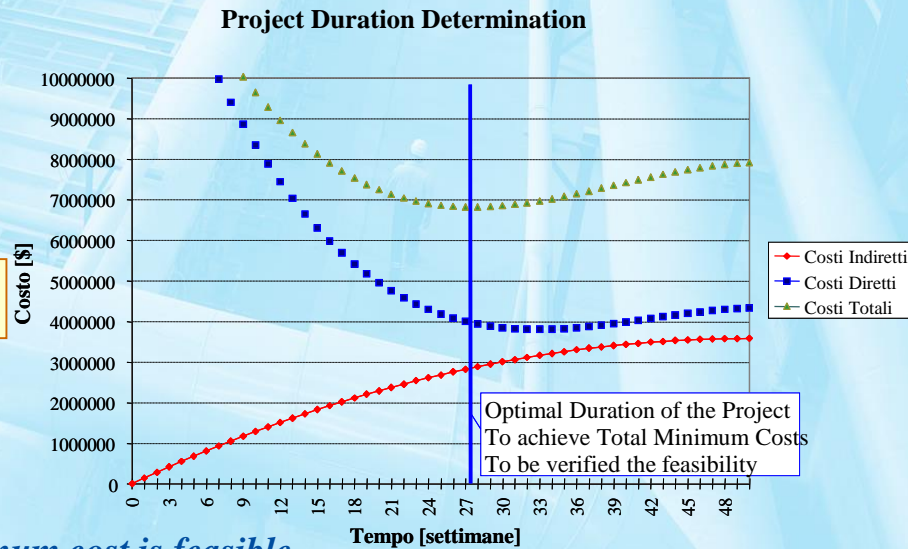
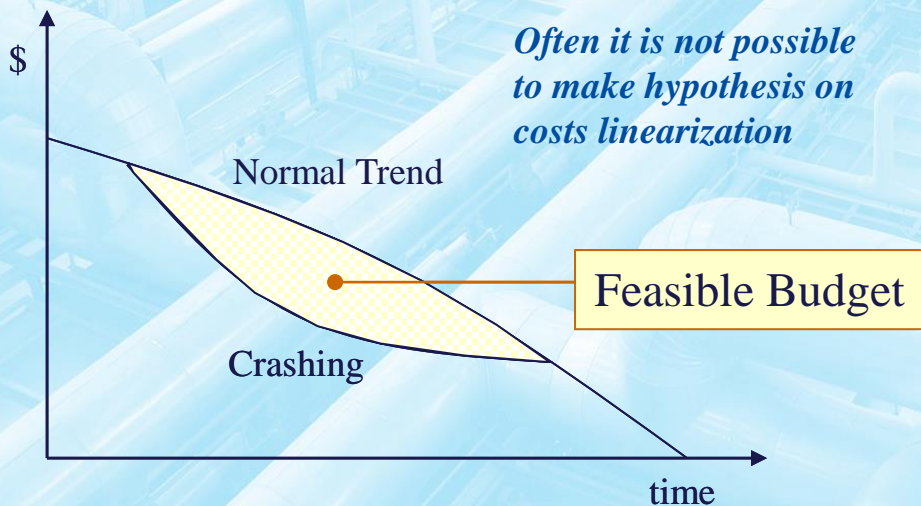
CPM Crashing Cost



Scheduling Real Objective

The procedure balancing times and costs (i.e. Crashing) aims to avoid resources wastes.

When it is possible to estimate direct and indirect costs, it is possible to define feasibility areas in the budget; because often the direct and indirect costs can't be represented linearly, often it is used to reduce the total cost satisfying the feasibility area



It is always necessary to check that the minimum cost is feasible for the considered project

Software for the Project Management

The basic functions provided by SW for PM are classified in five classes:

1) *Planning Tracking e Monitoring*

They support generally CPM, PERT and PDM
Time, costs and resources management.

2) *Reports*

Gantt, Tables, Diagrams and Graphs:

Ernead Value Analysis

Indici di Prestazione e di Costo

Cash Flow Reports

Analisi Path Critico

BCWS Report

BCWP Report

Actual Expenses against Expected Expenses

Report for Standard Performance Monitoring System (i.e. Nasa, DoD,DoE)

3) *Project Calendar*

Definition of working days and weeks

4) *What-if-Analysis*

What happens in specific cases

5) *Multi-Project Analysis*

Some advances SW allows to evaluate parallel projects

SW Classification for the PM

It is possible to identify 3 SW classes for the Project Management

Level I: to manage single projects, they are easy to be used and understood, they don't manage automatic re-scheduling and require eventually to replan the whole project

•**Level II:** to manage single projects, able to provide all the necessary analysis support, with scheduling and automatic control capability.

•**Level III:** to manage more parallel projects by controlling on line th shared databases.

In fact since the last half of 70s to the beginning of 80s companies have invested a lot into SW for mainframe with costs between 75,000 USD and 125,000USD.

These SW were complex and not user friendly. Today there are over 200 SW for the PM some of them for big systems with a cost over 100,000 \$ other ones running on PC and costing about 10\$; the most part of actual tools belonging to 500-1,000\$ cost class has the same capabilities of the first generation.

Today the needs to manage projects distributed in the company, geographically or between contractors requires particular attention on networks communications.

SW Assessment for the Project Management

In 1990 NSTL (National Software Testing Laboratories) by Conshohoken, Pennsylvania spread the following criteria to evaluate SW potentials for di PM:

Example of SW

Performance:

Print Gantt to LaserJet
Print Gantt to PaintJet
Print PERT to LaserJet
Print PERT to PaintJet
Change Views
Recalculate Schedule
Level Resources

Quality:

Gantt on LaserJet
Gantt on PaintJet
PERT on LaserJet
PERT on PaintJet
Resource Leveling

Project

Microsoft

Primavera

Primavera

Project Server

MicroFrame

Remind

Lotus

Project Scheduler

Scitor

Versatility:

Project Calendar
Task Durations
Other Scheduling Features
Resource Information
Leveling
Resource allocation tracking
PERT Charts
Resource Schedule Report
Cost reporting
Earned Value Analysis
Selecting
Import/Export
Multiple Project Support

Gantt Charts
Schedule Report
Resource Profile Report
Cash Flow Reporting
Sorting
Output
Networking
Miscellaneous

Scheduling Constraints
Precedence Relationships
Outlining
Resource Cost Allocation
Task Tracking

Easy of Learning:

Manuals & Learning Aids
Project Set-Up
Tracking Progress
File Management & Printing

General Program Interface
Editing a Project
Preparing Reports
General Ease of Learning

Easy of Using:

Manuals & Learning Aids
Project Set-Up
Tracking Progress
File Management & Printing

General Program Interface
Editing a Project
Preparing Reports
General Ease of Using

Duration Risks: Simulation and Calculus

Through the mentioned techniques and the simulation and/or basic statistics, it is possible to evaluate the risk related to the not respect of a deadline; this is possible by focusing on the critical path (activities in series and so easy evaluation of the total standard deviation), if it is possible to assume that the critical path can't change because of the activities duration variability.

It is possible to manually make computations by assuming normal distributions equivalent to beta ones.

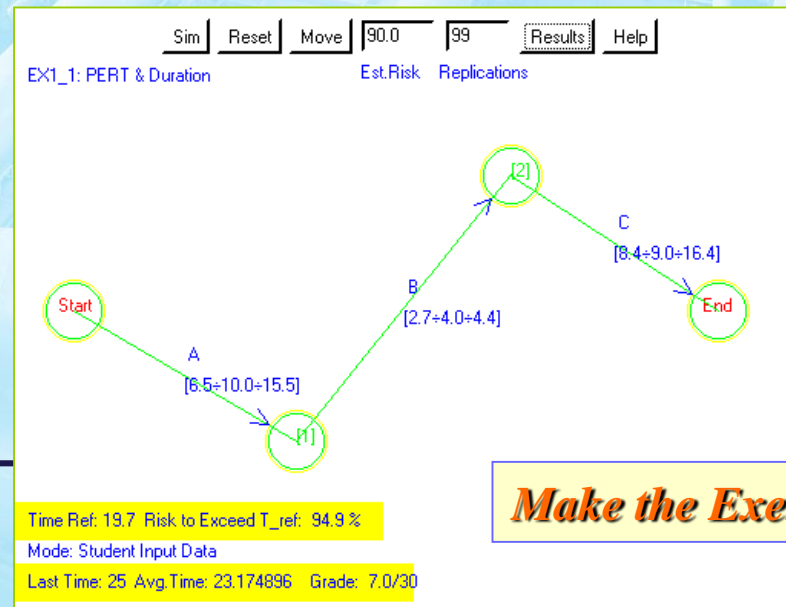
However if the simulation is available, it is more precise and it may consider beta distributions better adapting the real system behavior for which the parameters a, b e m are estimated by experts and represent the available real data.

It is possible to make exercises
To evaluate the real probability of
overcoming the reference risk

$$\mu = (a + b + 4m) / 6$$

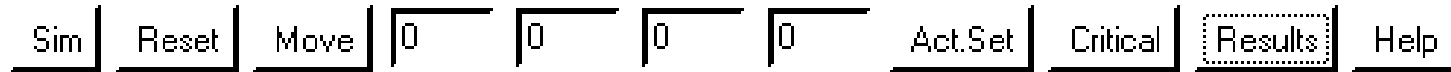
$$\sigma = (b - a) / 6$$

$$\sigma_{\text{tot}} = \sqrt{\sigma_{j1}^2 + \sigma_{j2}^2 + \sigma_{j3}^2}$$



Make the Exercise

PERT & Critical Path Identification, ES, EF, LS & LF

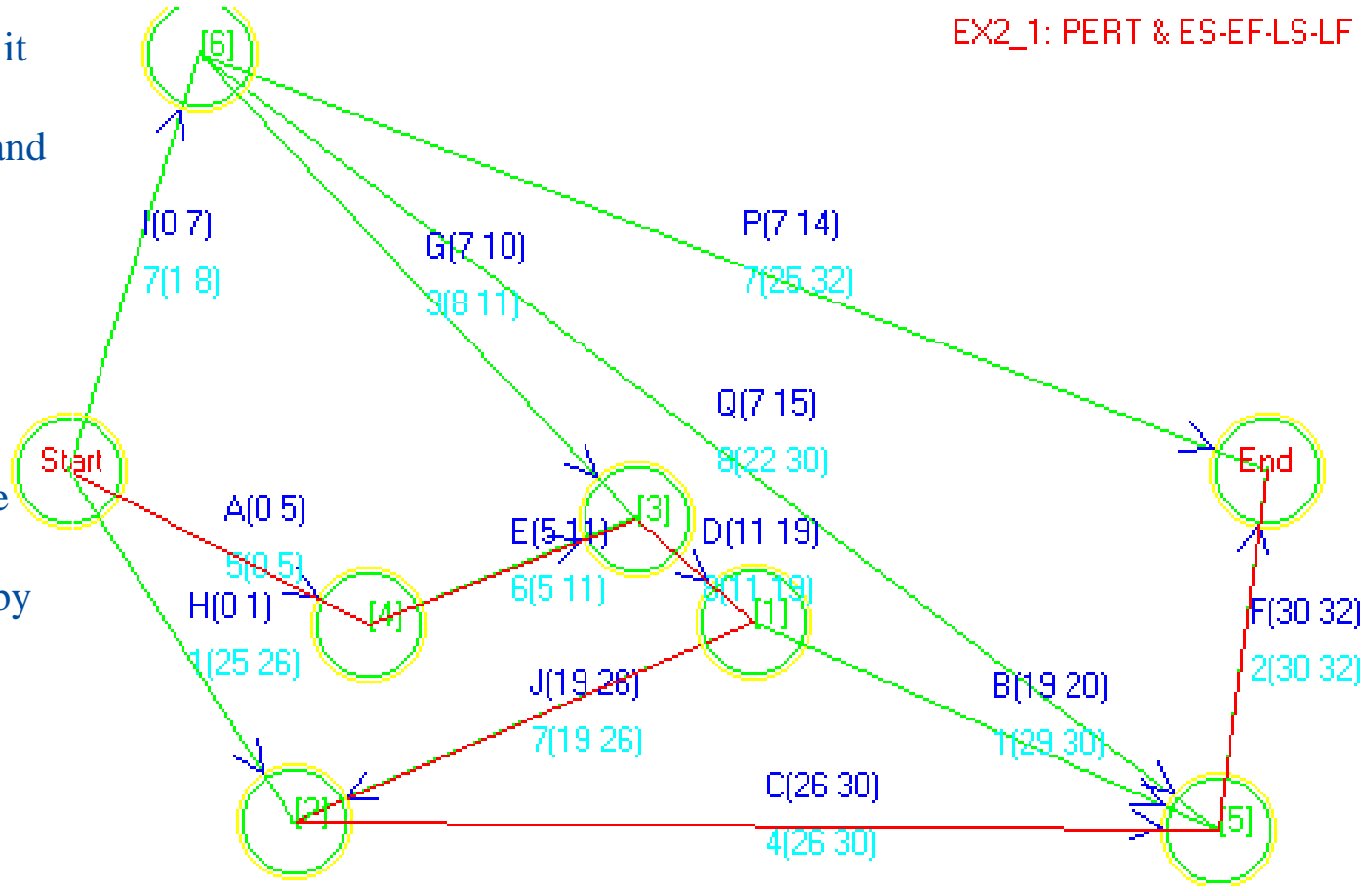


EX2_1: PERT & ES-EF-LS-LF

Even working on PERT, it is possible to define the values ES, EF, LS e SF and the critical path.

The *te* (or the weighted mean values derived by proper mediating the experts estimations) are used;

That is useful to evaluate the activities and the critical path slack time, by focusing on project key events.



Mode: System Simulation Data

Total Time 32

Make the Exercise

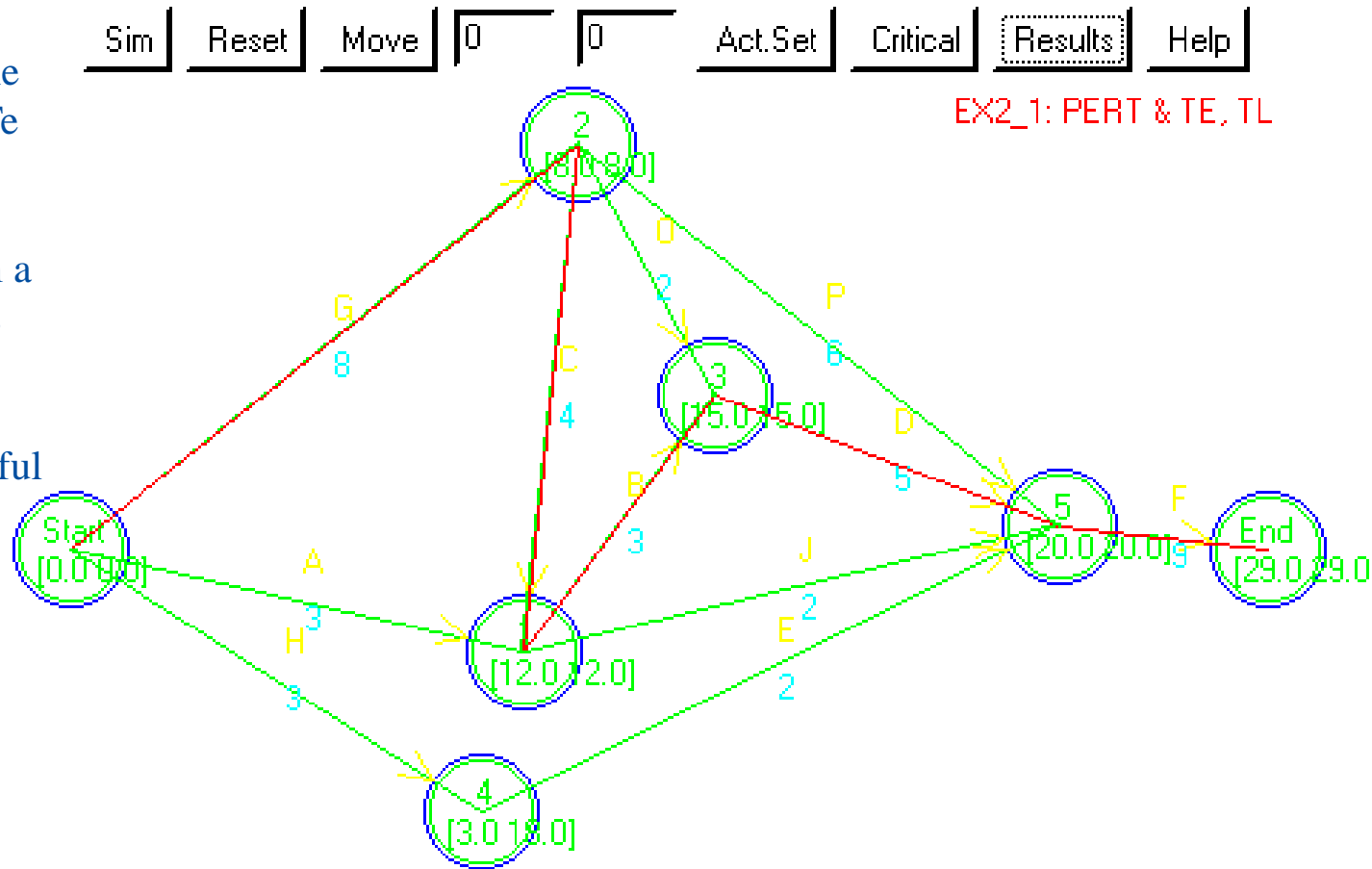


PERT & Critical Path Estimation, Te & e Tf

Since PERT is event oriented, it is useful for the slack time estimation of T_e and T_f events.

Also here activities t_e are used and are derived from a weighted media of factors provided by experts.

This analysis is really useful for events slack time evaluation that are often related to cost and risk parameters.



EX2_1: PERT & TE, TL

Mode: System Simulation Data

Total Time 29

Make the Exercise

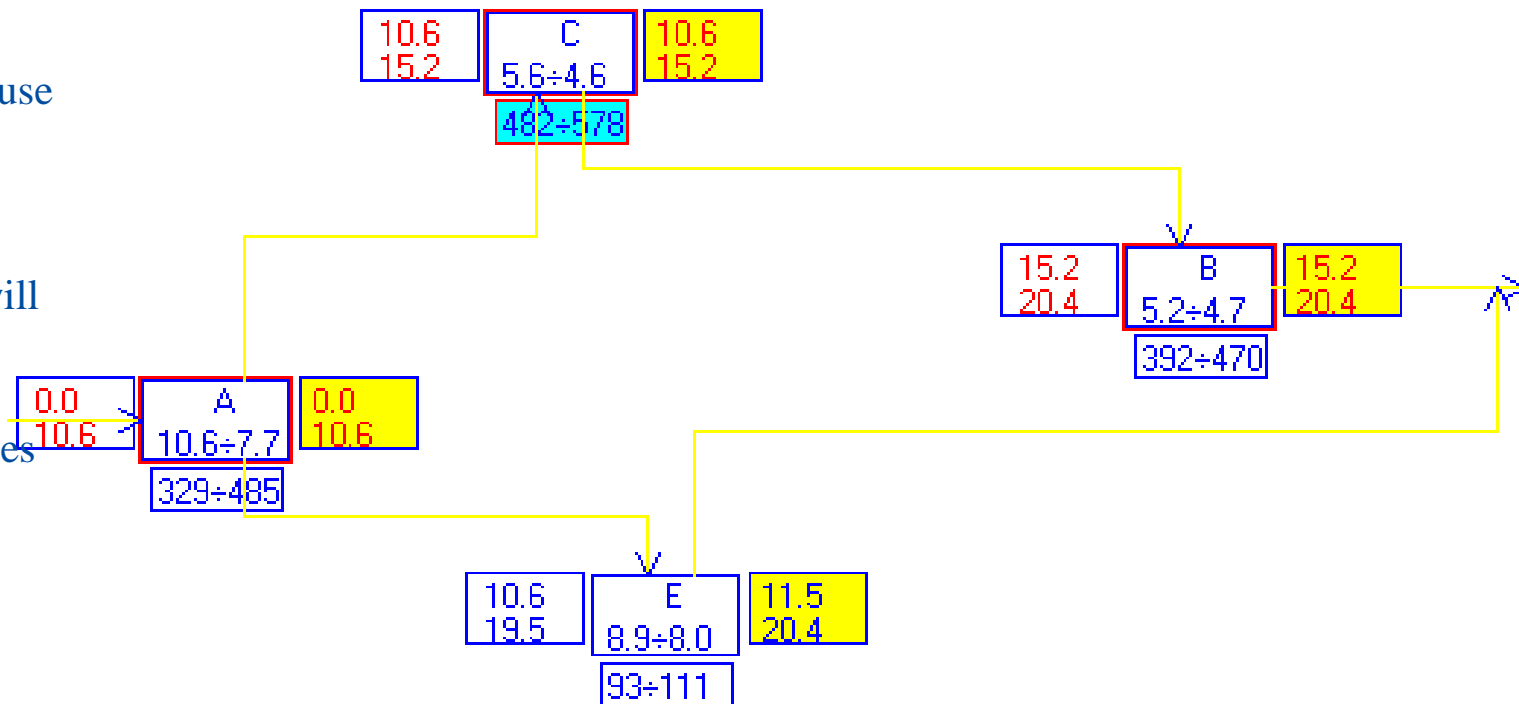


CPM & Activities Crash

Working on CPM, it is possible to make crash analysis to reduce times against costs increasing, in this case the evaluations are deterministic because the CPM m values are used. If it is available a Crash Budget, it will be necessary to search the most convenient activities to be involved

PERT/CPM | Reset | Move | Output | Critical | Crash | Results | Help

EX4_1: CPM & Crashing



CPM Cost:1392.0 \$ Extra Cost:96.0\$ [Crash Budget : 118.0 \$]

Mode: System Simulation Data

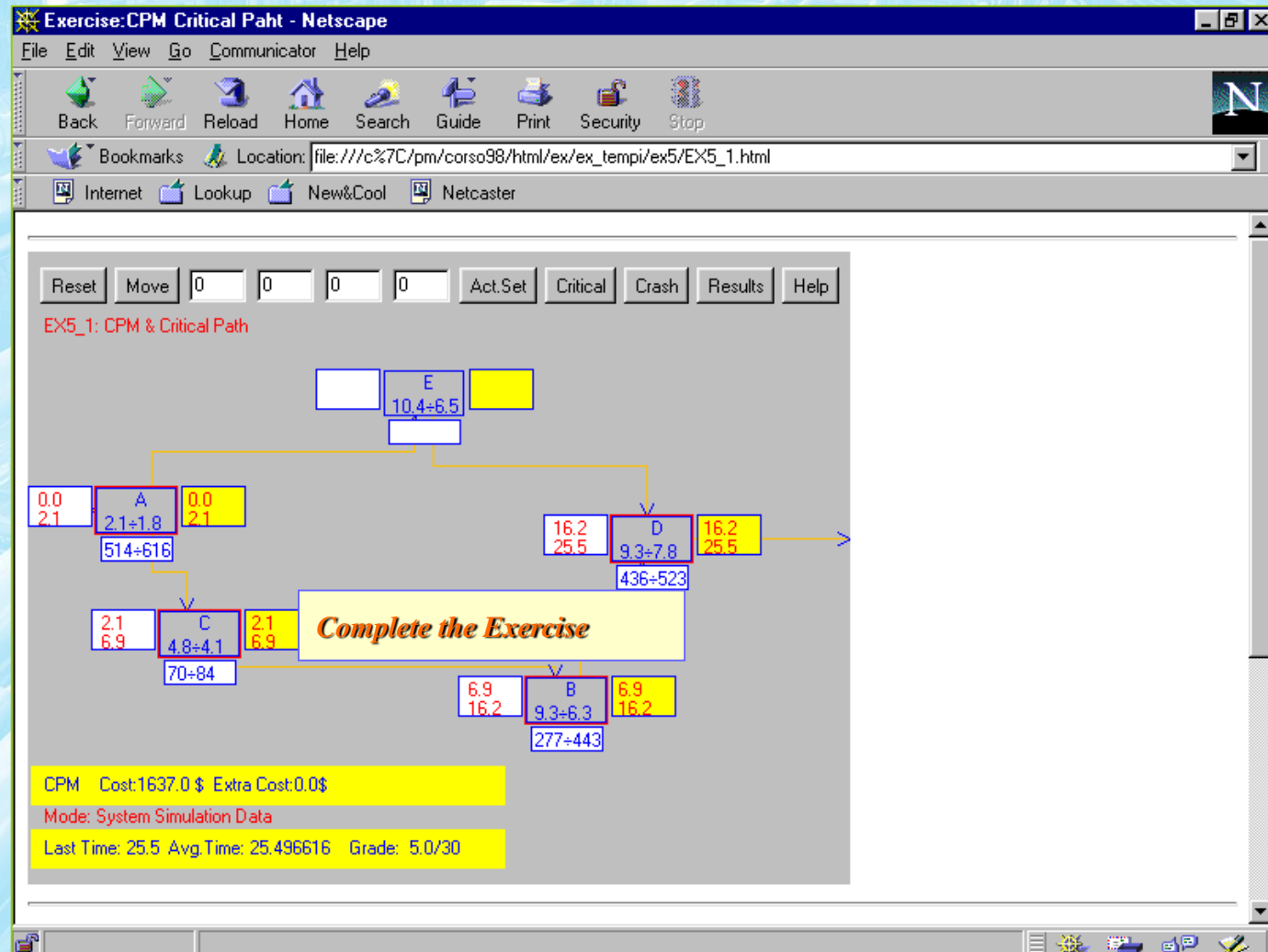
Last Time: 20.4 Avg.Time: 20.401417

Make the Exercise



CPM & Critical Path Estimation, ES, EF, LS & LF

The CPM is Activity Oriented so a critical path analysis highlights activities importance; it is possible to obtain even a costs estimation. As times the durations m (the most probable duration provided by experts in PERT estimations) will be used.

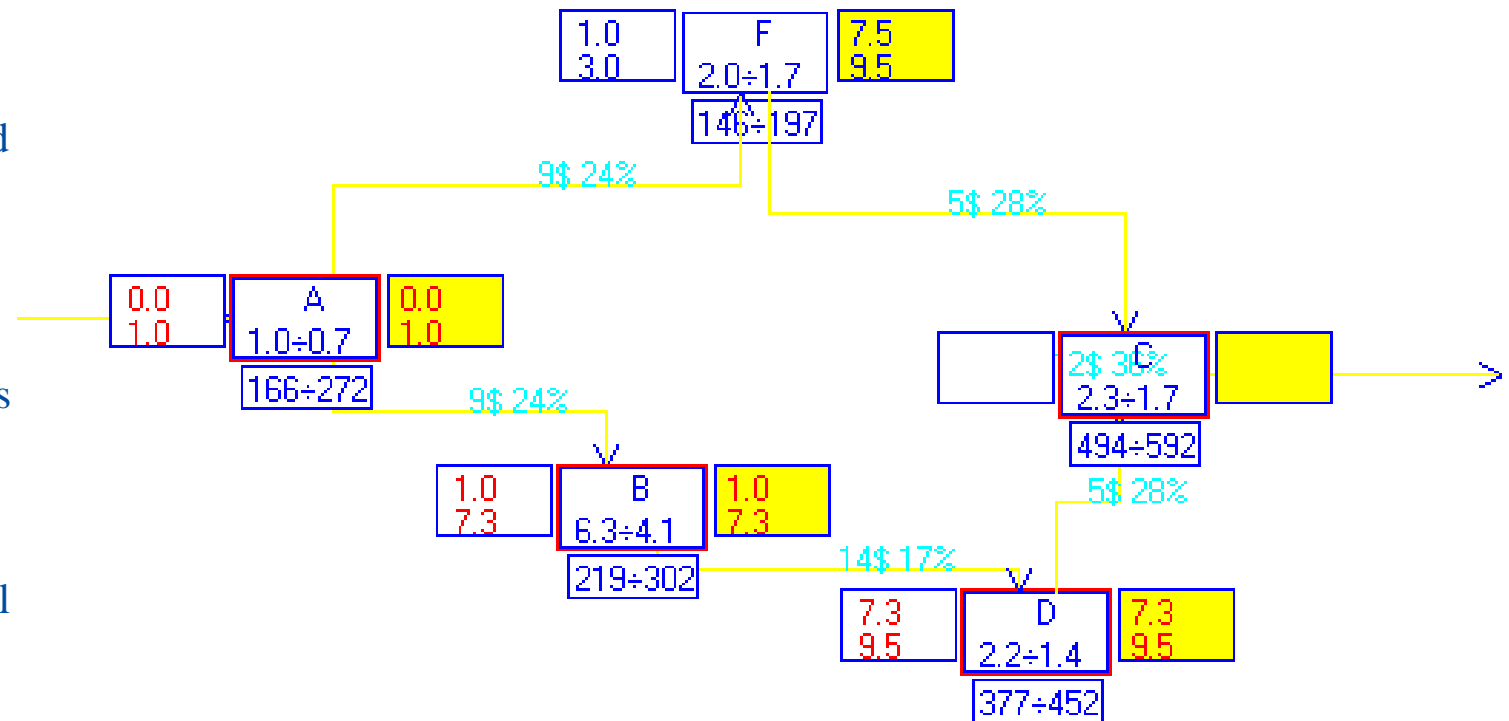


CPM/PERT to improve the Project: Crash and Parallelization

PERT/CPM | Reset | Move | Parallel | Critical | Crash | Results | SO | Help

EX6_1: CPM/PERT Concurrent Activities

The CPM and the PERT may be used in a combined mode to evaluate the combined convenience of crash and activities parallelization (by associating a risk level and an eventual additional cost).



CPM Cost:1402.0 \$ Add.Cost:1401\$

Mode: System Simulation Data

Last Time: 11.8 Avg.Time: 11.801139 **Make the Exercise**



Output from the Scheduling

Project Schedule

It includes at least the initial and ending dates list for each activity (normally it is preliminary until the Project Plan emission).

It is presented by using different formalism (Gantt, milestone diagrams, etc.)

Support Details

Include the whole documentation about criteria and hypothesis. Generally it includes data about the resources use, investments trends etc.; often it involves resources histograms over time, alternative scheduling (optimistic, pessimistic, etc.) and risks influence on the scheduling

Scheduling Management Plan

Planning to manage scheduling changes and updates

Updates on Resources specifications

During the planning often there are changes on required resources, in order to optimize times planning.

Formalisms to Present a Project

There are different formalism:

Project Network Diagram with Scheduled Dates

Include Durations and relations

Horizontal Histograms / Gantt

They show the durations, but often not the relations

Milestone Charts

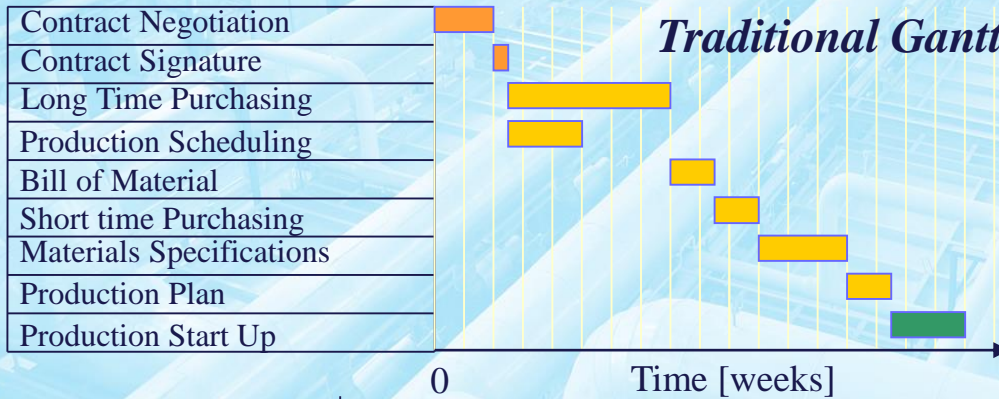
Similar to the gantt, they highlight main deliverables and keydates

Time-Scaled Network Diagrams

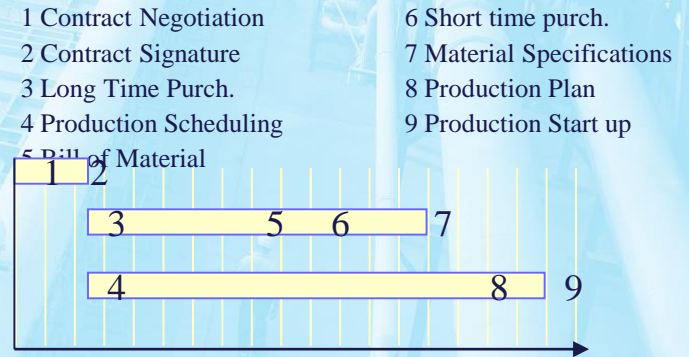
They are a mix between the project network diagrams and the Gantt and show at the same time durations and connections

Gantt Diagram

The Horizontal histograms are used to show the planned activities over time; they were introduced by Henry Gantt at the beginning of 1900; they represent a temporal scheduling and not a logic correlations network; they are the most used system for Project Schedule presentation. There are many representations

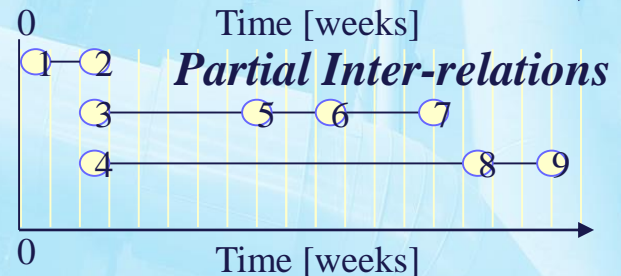
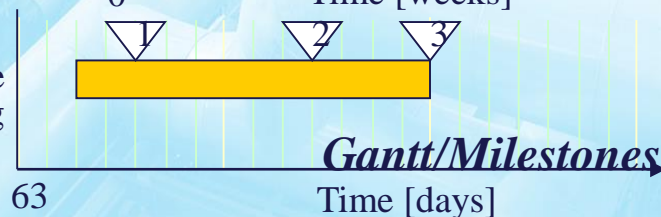


Gantt based on Combined Activities

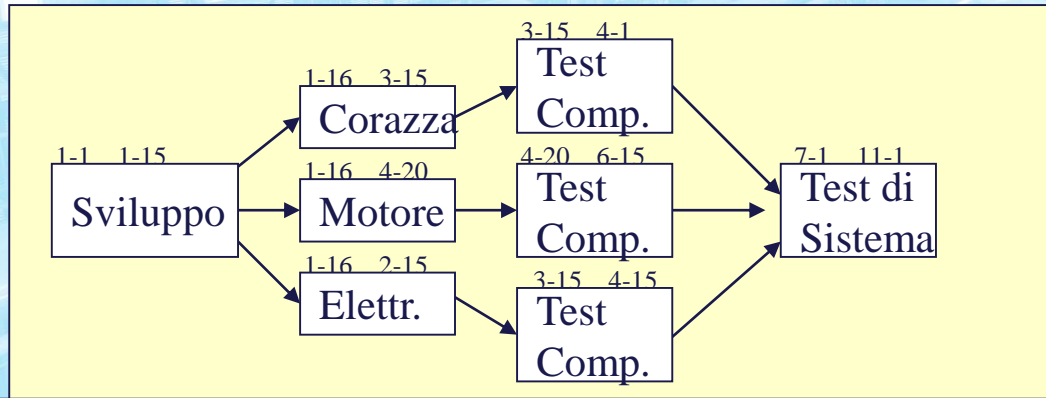


Short Time Purchasing Milestones

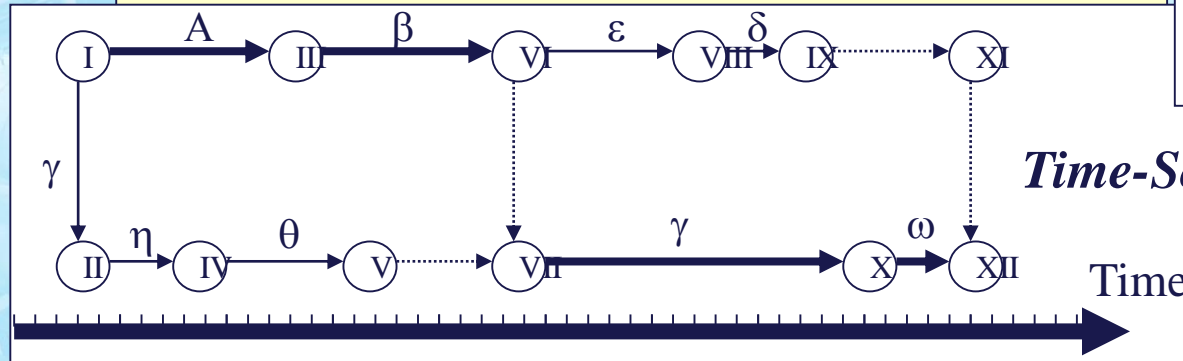
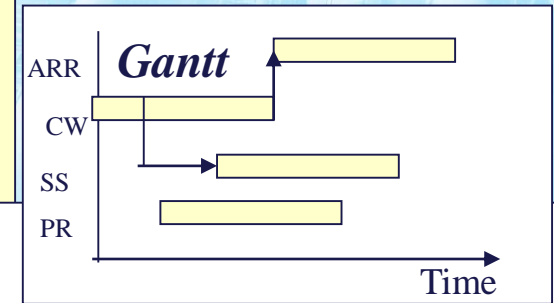
- 1 Order Emission
- 2 Invoice Rec.
- 3 Material Rec.



Examples of Project Schedule Diagrams



Project Network Diagram with Scheduled Dates



Time-Scaled Network Diagrams

Milestone Charts

Eventi / Milestones	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set
Firma con SubContractors		▲	▼						
Emissione Specifiche				▲	▼				
Revisione di Progetto					▲				
Test dei Sottosistemi						▲			
Prima Unità Consegnata							▲		
Completamento Costruzione Impianto									▲

Project Schedule Control and Input

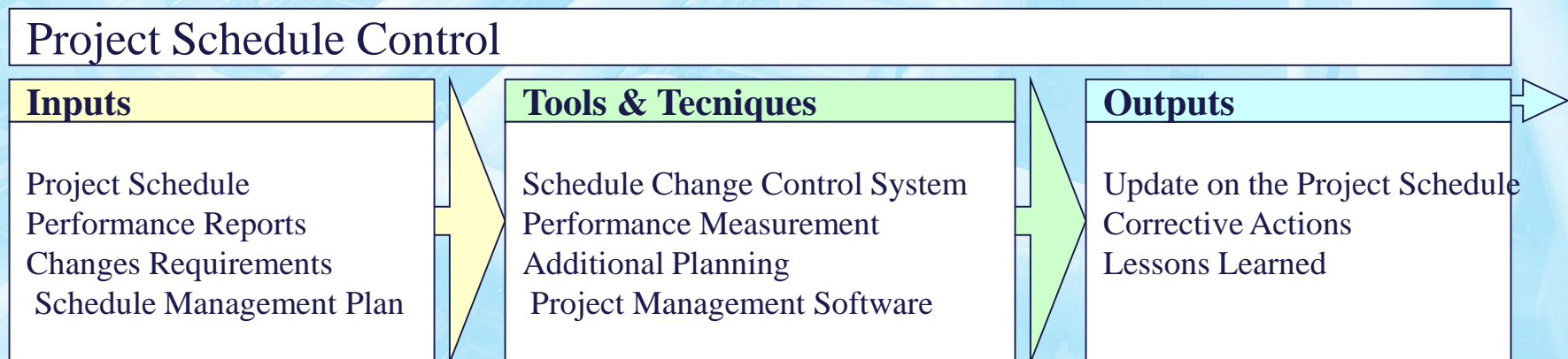
The Project Schedule control is related to:

Influence factors producing positive changes on the scheduling

Identify when the scheduling needs to be changed

Manage the on going updates on the scheduling

As Input there is obviously the Project Schedule (the one approved, often called Schedule Baseline) included into the Project Plan. In addition it is necessary to consider the change requirements and the current performance reports of the project, as well as the regulations for changes management provided during the project scheduling.



Tools for the Project Schedule Control

Project Schedule Changes Control System

It defines procedures (documents, inspections, permissions, etc..) to make changes to the schedule and it is obviously integrated with the monitoring system of Project changes

Performance Measurements

Techniques to evaluate performances and on going deviations. Often minor changes on activity do not require updates on the scheduling because the Project Schedule was robust.

Additional Planning

Necessity to re-plan the activities for important changes

Software for the Project Management

Often it is used the PM software to apply changes

Project Schedule Control: Output

Updates on the Project Schedule

Every change applied on the current scheduling and communicated immediately to all stakeholders.

They include a special category of changes:

The Reviews

They are project changes already defined in specific periods or moments in the project life and often pre-set during the planning. If the changes are very big it is necessary to redefine the baselines for performance monitoring.

Corrective Actions

All the required actions to respect deadlines; often they include the necessity to accelerate phases in order to guarantee times respect and reduce delays.

Lessons Learned

The re-scheduling phase must be documented and considered a reference basis for next evaluations.

Project Cost Management

The Objective is to guarantee that the project will be completed by respecting the costs:

- **Resources Planning**

Determine the required resources for the project in term of type, characteristics and quantities (men, means, equipments, material)

- **Costs Estimation**

Estimate costs related to all the required resources

- **Costs Budget**

Allocate the costs to the single WBS Elements

- **Costs Control**

Keep low the costs trend and regulate budget changes

For small projects these processes may coincide

Financial planning is developed often in advance outside from the PM, otherwise of course it becomes part of this activity. Since costs measures evolve over time (i.e. a new aircraft model cost: from the proposal and the order to delivery) it is necessary to use controllable references to evaluate current performances (i.e. any awards / contract terms)

Project Cost Management

Project Cost Management

4.1 Resources Planning

- .1 Inputs**
 - .1 WBS
 - .2 Historical Data
 - .3 SOW
 - .4 Available Resources
 - .5 Organizational Policy
- .2 Tools and Techniques**
 - .1 Experts Opinion
 - .2 Identification of Alternative Solutions
- .3 Outputs**
 - .1 Required Resources Specifications

4.2 Costs Estimations

- .1 Inputs**
 - .1 WBS
 - .2 Required Resources Specifications
 - .3 Resources Unit Costs
 - .4 Activities Durations Estimation
 - .5 Historical Data
 - .6 Corporate Accounting Structure
- .2 Tools and Techniques**
 - .1 Analogical Estimation
 - .2 Parametric Modelling
 - .3 Bottom-up Estimation
 - .4 Software and Informatics tool
- .3 Outputs**
 - .1 Resources Costs Estimation
 - .2 Support Details
 - .3 Costs management planning

4.3 Costs Budget

- .1 Inputs**
 - .1 Resources Costs Estimation
 - .2 WBS
 - .3 Project Schedule
- .2 Tools and Techniques**
 - .1 Techniques and Tools for Costs Evaluation
- .3 Outputs**
 - .1 Costs Reference Basis

4.4 Costs Control

- .1 Inputs**
 - .1 Costs Reference Basis
 - .2 Performance Reports
 - .3 Changes Requirements
 - .4 Costs Management Plan
- .2 Tools and Techniques**
 - .1 Control System for Costs Change
 - .2 Performance Measurement
 - .3 Additional Planning
 - .4 Software and informatics tool
- .3 Outputs**
 - .1 Costs Review
 - .2 Updates on the Budget
 - .3 Corrective Actions
 - .4 Costs Projection to the completion
 - .5 Lessons Learned

Indices		Company			
		1995	1996	1997	
Liquidity Index (Liq. + Customer Credits/Debt)		1.03	1.00	1.09	
Availabi	Standard Employee	60.000	25		
Financh	Standard Production with 40 Employees 125 in prod	460%	ML		
ROI (O	A Cover for Reference Cost Production	74400	40000	95200	52000 ML/Anno
ROE (N	Total Standard Production (Real Personnel)	460%	460%	460%	460%
ROD (C	Real Over Production Coefficient	190%	190%	190%	190%
Turnov	Minimum Elements	0	0	0	0 ML/Anno
Added Y	Direct Personnel/Staff/Personnel Reference Val	50%	50%	50%	50%
Custom	Direct Personnel/Staff/Personnel - Real Value	50%	50%	50%	50%
Stack D	Direct Personnel/Staff/Personnel - Real Value	50%	50%	50%	50%
Supplier	Real Production/Standard Production Fiat	201.6%	100.00%	103.95%	104.17%
	Foreign Production	-	45.600	57.300	55.000 ML
	Standard Italian Production in the Year	-	-	-	- ML
	Standard Foreign Production in the Year	-	60.390	-	57.885 ML
	Standard Foreign Production in the Year	-	-	-	- ML
	Italian Make or Buy	-2.00%	-2.00%	-2.00%	-2.00%
	% Margin of Production on subcontractor -> *	3.00%	3.00%	3.00%	3.00%
	% Standard margin - % Margin *	(0.18)	(0.18)	(0.18)	(0.18) ML
	Margin reduction coefficient	1.9%	0.00%	0.12%	0.12%
	Additional Costs of Subcontract to reduce		0		(4) ML
	Real Margin (Real)				
	Foreign Make or Buy	-2.00%	-2.00%	-2.00%	-2.00%
	% Margin of Production on subcontractor -> *	0.00%	0.00%	0.00%	0.00%
	% Standard margin - % Margin *	(0.22)	(0.22)	(0.22)	(0.22) ML
	Margin reduction coefficient	5.10%	0.00%	0.31%	0.33%
	Additional Costs of Service to reduce				
	Real Margin (Real)				

Resources Planning

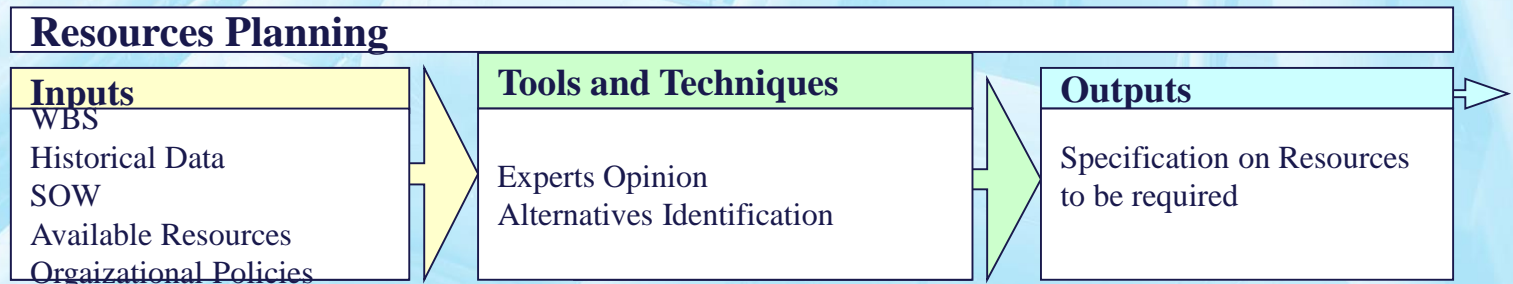
We must define the type and quantity of required resources by linking them directly to the costs (it is necessary to know the workforce cost for Construction Project and the locally available skills).

Input to this process are:

- ◆ WBS allowing the Project elements identification
- ◆ Report on Objectives and SOW
- ◆ Historical data related to resources used in similar projects
- ◆ Description of available resources and their capacity
- ◆ Organizational policies related to material, equipment rental and new specific assumptions.

As tools it is fundamental the experts opinion and general management techniques to identify new alternatives.

The result of this activity is the definition of the required resources in term of quantity and types for each element of the WBS; then they will be assigned to the project, acquired or hired.



Costs Estimation and Input

It is necessary to define approximately the resources costs for the project completion; of course for projects with a contract the cost must be distinguished from the price. The cost estimation must be made by evaluating the convenience of higher development costs in face of shorter times that may increase in costs or penalties.

Input in use:

WBS: In order to verify that each element of the WBS is estimated to cost

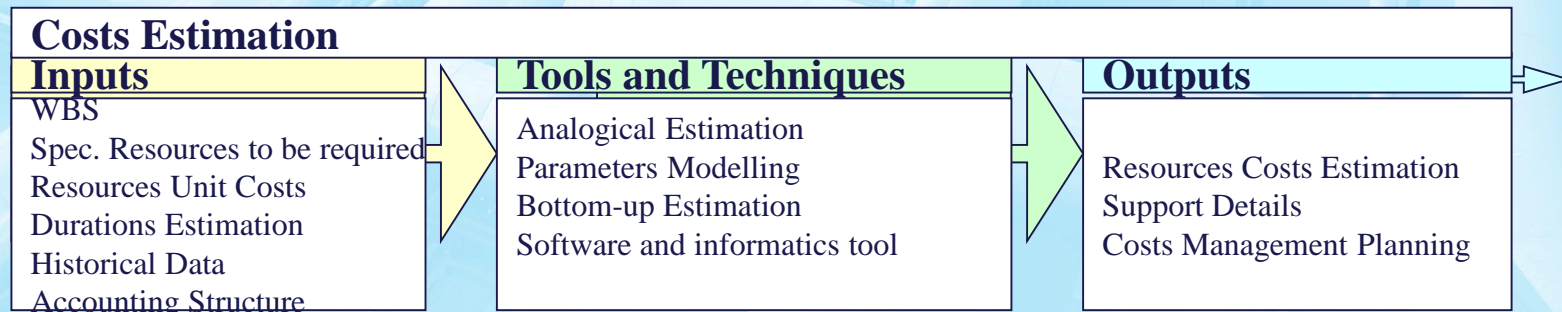
Resources to be required: list of needed resources

Resources Unitary costs: the unit costs must be known or estimated (staff cost per working hour, or of a system component)

Activities Duration: affecting the unit costs directly and through financial levers

Historical data on costs: from previous projects archives, estimates and business experience of the PMT

Corporate Accounting Structure: in order to assign costs to the classified categories and define the costs audit plan (such as cost centers, ABC etc.)



Support Tools for Costs Estimation

Analogical Assessments

Also called Top-Down Estimating, are based on deriving future activities estimations from similar past activities as already described for the estimated time; also here it is basically an extrapolation by experts from the historical data

Parameters Modeling

Simple or complex mathematical models construction to assess costs; it requires a careful data collection, VV & A and scalability (possibility of treating large and small projects)

Bottom-up Estimating

The costs are estimated based on the single elements of WBS low level to up; obviously much more detailed is the starting level most time / cost are required and better is the accuracy (it is necessary to weigh these two factors).

Software Tools

Both PM software and management tools and simulators are successfully used to improve costs estimating

Costs Estimating Results

Costs Estimation

They are more or less detailed descriptions of all costs / resources required for the project by considering both components, workforce costs as well as materials, equipment, insurance, financial costs; they are usually expressed in units money, but they may also be calculated in term of hours if the related costs are equivalent and if there may not be misunderstandings. This estimate evolves during the project and should progressively increase its accuracy; for example, the AACE (American Association of Construction Engineering) identified a progression of 5 construction costs estimating types: Order of Greatness, Conceptual, Preliminary, and Final Control.

Support Details

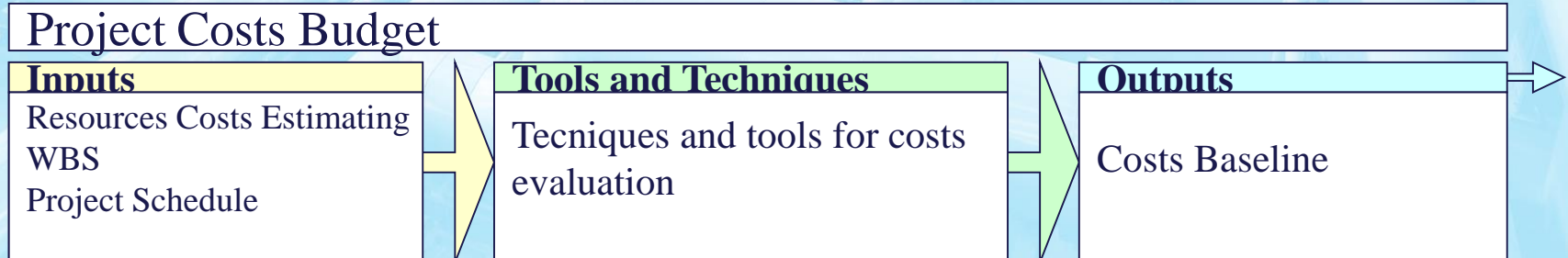
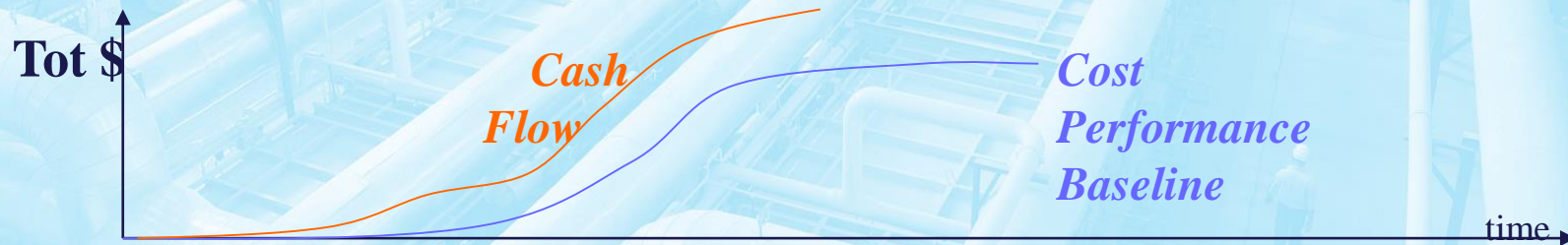
Includes WBS costs references, assumptions, used reference and variance estimating base on cost hypothesis (m,s)

Planning for costs management

This planning describes how to manage costs variability and is a component of the project general plan

Costs Budget and PMB

It means to assign each cost to a single WBS element, and thus to create the reference base for the project costs control. In input it is possible to use cost estimates that are assigned in detail to the WBS elements, taking into account their time order (Project Schedule); through the allocation techniques and costs estimating, it is possible to proceed then giving a costs baseline showing their trend over time for various items; this will be one of the main PMB to be used in project management.

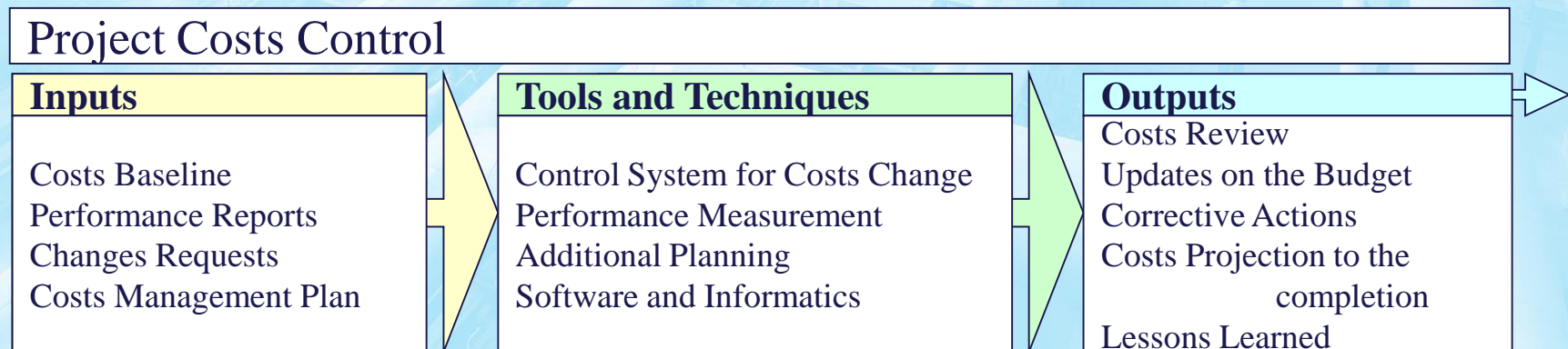


Project Costs Control

This activity aims to keep low or reduce costs during the project development, to identify immediately project costs changes and to support corrections, as well as to manage project changes.

Obviously it is necessary a careful monitoring and a proper costs allocation, a continuous correction of the costs baseline (avoiding to include unauthorized changes) and all related communications maintenance.

Obviously, in input the following elements are used: the costs baseline, performance reports together with change requests; these are evaluated based on the defined planning for project costs management



Tools for Costs Control

Control System for Costs Change

The whole system of documentation, procedures and authorization for costs changes, of course to be integrated with the integrated system for project changes control

Performance Measurement

It's very important to identify the causes of changes and check the necessity of an intervention, by using various performance evaluation techniques based on analysis of incurred costs and / or achieved earnings.

Additional Planning

Obviously it may be necessary to develop additional planning to correct the costs changes leading to expand the time or reallocate resources to other activities.

Support Software

Costs analysis is often supported by the use of general applications (i.e. SW for PM, Spreadsheets etc.) or by accountability systems or of project

Costs Control Results

Costs Estimating Review

During the project there is a continuous refining of costs estimations, to be shared with all the stakeholders.

Corrective Actions

All the required activities to guarantee the costs control by the PMT in order to achieve the prefixed objectives, by addressing the costs to the desired values or keeping low the incontestable costs increases.

Update on the Budget

It is possible to approve the changes at the budget and at the costs baseline; this generally happens when the change involves the objectives, however it is necessary to focus on the comparability and the validity respect of the baseline of old and new costs

Projection or the costs to the completion

EAC (Estimate at Completion) is a project total cost estimation based on projections starting from the baseline.

Lessons Learned

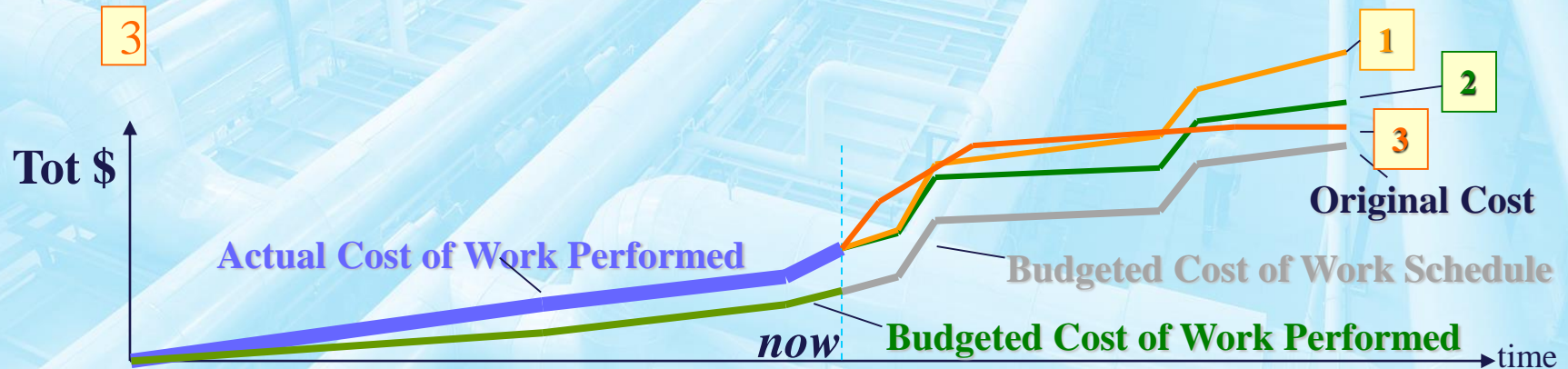
Formalization of costs change and the provided analysis to define corrective actions.

EAC: Projection to the Project Costs

The Costs Projections at completion (EAC=Estimate at Completion) are based on various hypothesis; among the most common it is possible to underline:

Current costs more remaining budget modified by a performance factor (i.e. CPI *) used when

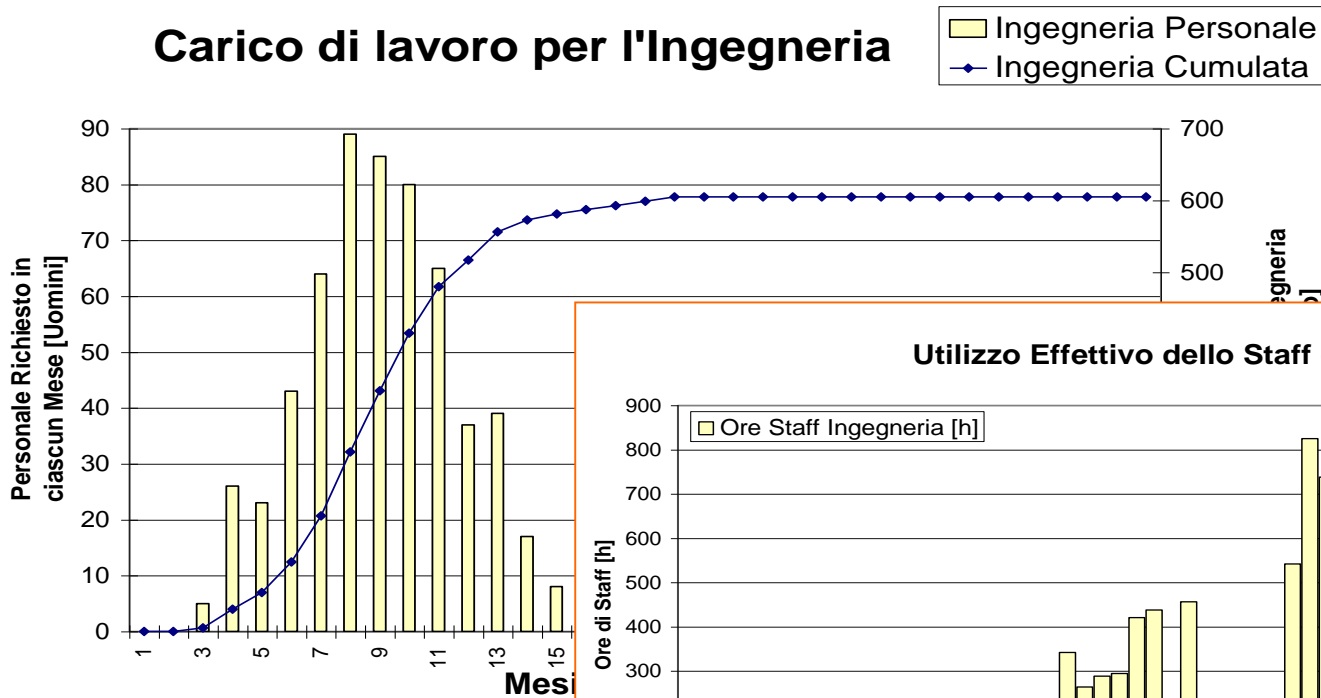
- 1 it is expected that the current changes are similar to the future
- 2 Current costs more a new estimate of all the remaining work used when it is noted that initial estimates were wrong, or are no longer valid for changes in boundary conditions
- 3 Current costs more the rest of the budget when we expect that there are more future changes



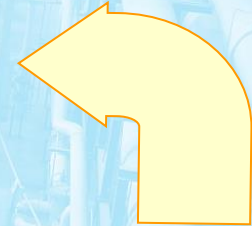
* $CPI = BCWP / ACWP$: Cost performance Index = Budgeted Cost of Work Performed / Actual Cost of Work Performed

Planning and Consumptive Histograms

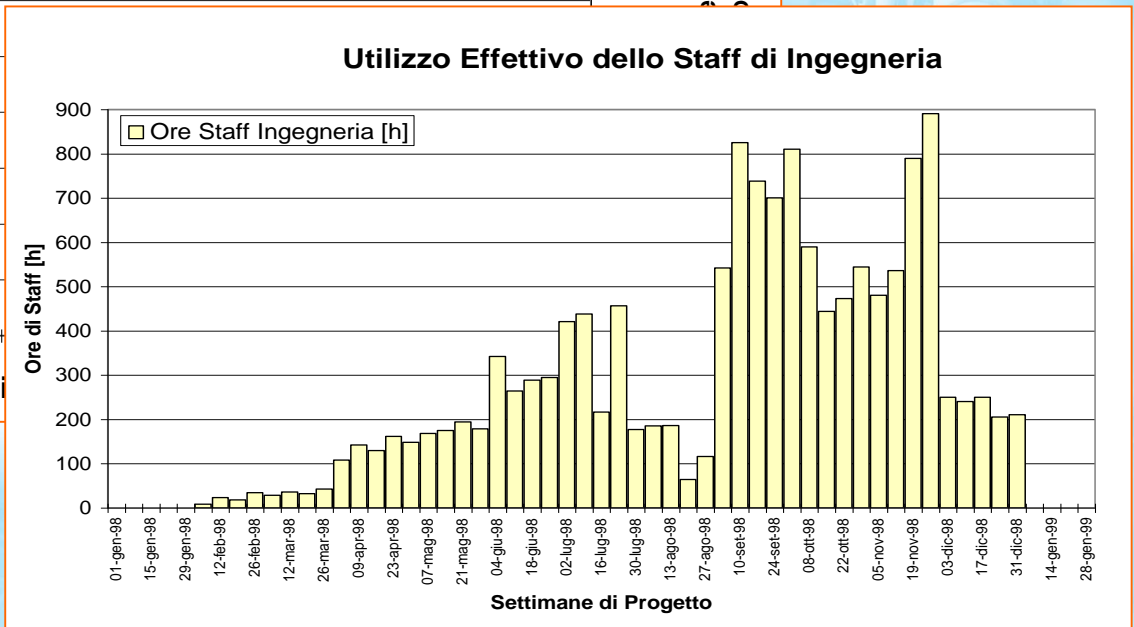
Carico di lavoro per l'Ingegneria



Replanning



Utilizzo Effettivo dello Staff di Ingegneria



Reports



Project Quality Management

All the activities of the general management functions determining quality policies, objectives and responsibilities and applying them through the quality plan, its control, certification and continuous system improvements, in the system quality

- **Quality Planning**

Significant quality standard identification for the project and determination about how to satisfy them.

- **Quality Certification**

Quality System systematic evaluation and implementation in order to control the project to guarantee the satisfaction of high quality standard.

- **Quality Control**

Quality controls to verify compliance with quality standards and to apply the corrective policies

Due to the Projects *ephemeral* nature the quality system definition must take into account that it must be paid during the project.

Quality Management in Projects

As for the Quality, in companies it is expected to apply management philosophies, controls and responsibilities to ensure the activities traceability and the continuous monitoring of ongoing processes.

It aims to apply the TQM (total quality management) teachings, which will satisfy the customer, ensuring the product and project quality and aiming to the continuous improvement process to erase cancels any faultiness.

Today, the quality system should refer to international standards, the most popular and of general order is included in the regulations for the quality certification of ISO9000.

Key Points:

**Customer Satisfaction,
Prevention with Inspections and Audit,
Responsibilities Management,
Effective planning and operational procedures**

Project Quality Management General Overview

Project Quality Management

5.1 Quality Planning

.1 Inputs

- .1 Quality Policies
- .2 Reports on Objectives & SOW
- .3 Product Description
- .4 Standards and Regulations
- .5 Other Processes Output

.2 Tools and Techniques

- .1 Costs/Benefits Analysis
- .2 Benchmarking
- .3 Flow Diagram
- .4 DOE (Design of Experiments)
- .5 Support SW

.3 Outputs

- .1 Planning for Quality Management
- .2 Operational Definition
- .3 Checklists
- .4 Input for other processes

5.2 Quality Assurance

.1 Inputs

- .1 Planning for Quality Management
- .2 Quality Control Results
- .3 Operational Definitions

.2 Tools and Techniques

- .1 Techniques and tools for quality planning
- .2 Quality Audit (Quality Control)

.3 Outputs

- .1 Improvements to the Quality System

5.3 Quality Control

.1 Inputs

- .1 Job Results
- .2 Planning for the Quality management
- .3 Operational Definitions
- .4 Checklists

.2 Tools and techniques

- .1 Inspections
- .2 Quality Map
- .3 Pareto Diagram
- .4 Statistical Sampling
- .5 Flow Diagrams
- .6 Trend Analysis

.3 Outputs

- .1 Quality Systems Improvements
- .2 Acceptance of done work
- .3 Additional Operations
- .4 Completed Checklist
- .5 Process Corrections

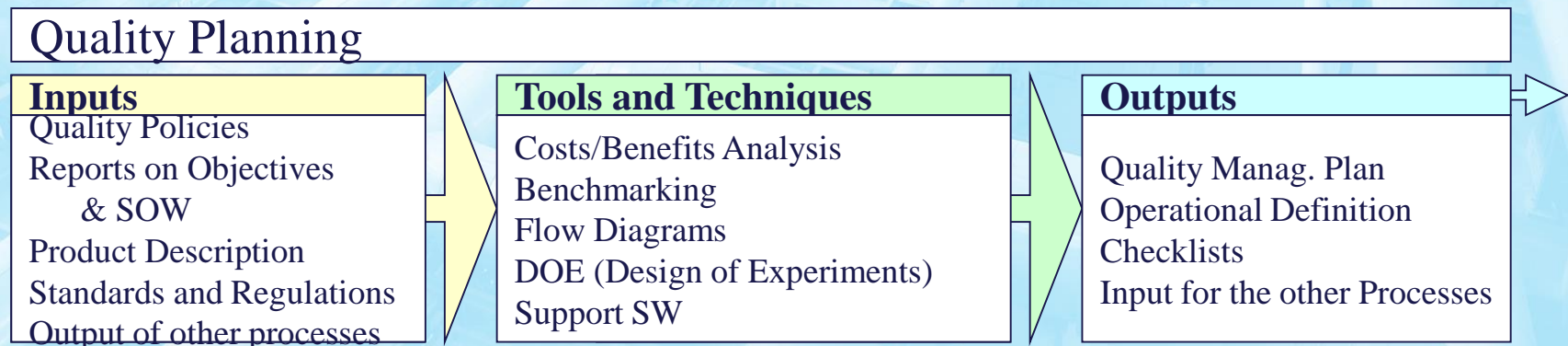
- ❖ The Quality Plan defines the Project Quality System
- ❖ The Quality Assurance applies and control the application of the Quality System
- ❖ Quality Control controls the quality of the Process and the Product

Quality Plan and Input

The goal is to identify the quality standards to be implemented, secured and controlled, as well as how to achieve these objectives; the quality system setting is faced during the planning phase

Input of this process are:

- ◆ The quality policies (management and top-management intent); for joint venture they should be defined from scratch, and the PMT is responsible to sensitize the stakeholders.
- ◆ Objectives and SOW reports provides a support to identify specific qualities of various stakeholders.
- ◆ Product descriptions similar to the SOW, it normally includes additional technical details that may be critical to quality
- ◆ Standards and Regulations: it is necessary to use the specific ones for each part of the project.
- ◆ Outputs of other processes: they provide an additional reference for Quality in some aspects
- ◆ (i.e. quality of suppliers in the procurement)



Quality Planning Tools

Costs/Benefits Analysis

Balanced analysis of the benefits of the quality system (right first time, low cost, customer satisfaction) compared to the costs (cost of quality system), it is assumed that normally the benefits of quality are dominant, however, in projects it is necessary to be careful in not investing too much, however projects must always be very careful of the quality (i.e. military)

Benchmarking

Activities involving comparative tests between known and new working practices in term of function and quality; these analysis should extrapolate innovative solutions to improve the quality

Flow Diagram

Techniques based on the use of relationships diagrams between objects and/or the activities of a project (i.e. cause and effect diagrams, process flowchart). Their use can highlight critical aspects and help prevent / schedule them.

Design of Experiments (DOE)

Analytical techniques allowing to evaluate the involved parameters influence on the test functions goal (ie S / N ratio Signal / Noise, Sensitivity Analysis; metamodelling, etc.). It allows to determine optimal conditions for project management

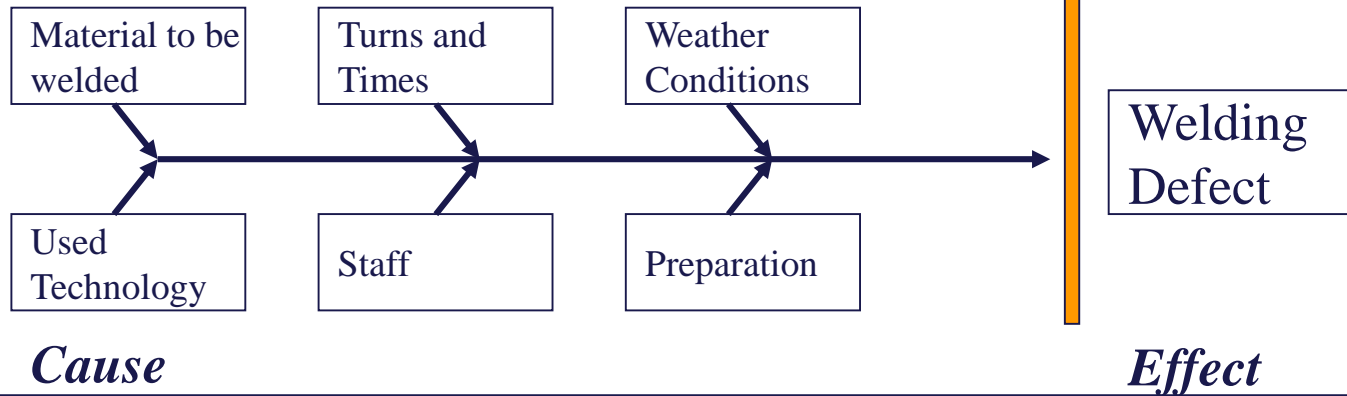
Support Software

The quality control can be supported by specific software (SW Contract control management) corresponding to the SPC (Statistical Process Control) or by using auxiliary software of analysis (i.e. SAS, Statgraf etc.)

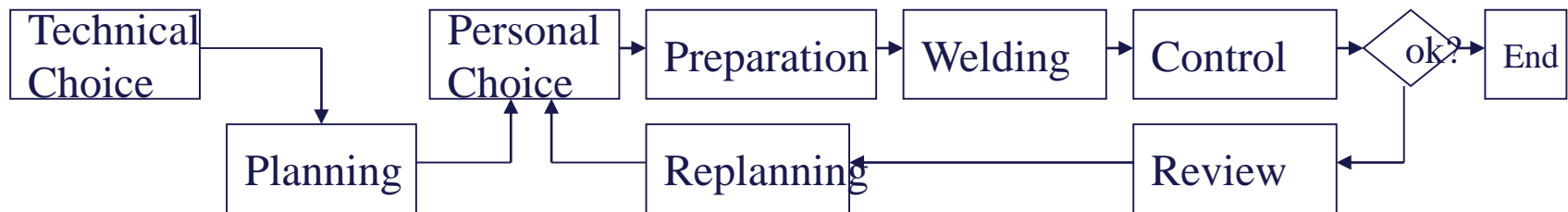
Flow Diagrams to support Quality

Among the different diagrams, the two most popular are:

Cause-Effect Diagrams, called even Ishikawa or herringbone



Process or System Flow Diagrams:



Quality Planning Output

Plan for Quality Management

It includes the description of the ways in which the PMT will implement the quality policies and then it describes the quality system organizational structure, responsibilities, procedures, processes and resources required to implement quality management' (ISO); it also often includes: quality manual, procedures, operational instructions and modules.

Operational Definition

The definition of the elements to which apply the quality and the ways in which to measure / control it; it must be specific and sufficiently detailed; in some sectors this process is called metrics.

Checklists & Modules

They are lists intended to verify step by step operational procedures, where questions are placed (i.e. two metals are in contact?) or specific operations requests (i.e. cut a pipe sample at the point where the corrosion occurred). Then it is necessary to add all the forms (paper / digital) for quality control

Input for other processes

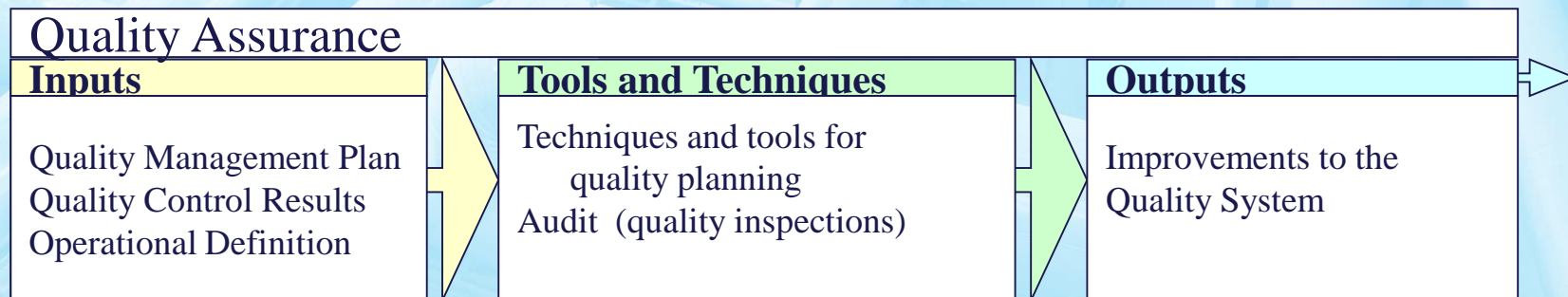
Since the quality is a crossing activity, it provides input to other processes in order to improve the project quality.

Quality Assurance and Input

The quality assurance that today is more and more related to quality certification, requires the application of the Quality Planning; often there is a business Division / Office responsible for the Quality Assurance and always a responsible for quality (in the case of ISO9001 certified company).

It can affect both the internal quality (for PMT) and external (i.e. the customer); in the project the PMT is responsible for quality policies application.

The used input are the quality system documentation, the results of quality measurements with sampled data and the possibility of Comparisons, as well as operational definitions of the elements related to the project quality.



Quality System Application: Tool and Output

Tools for quality system implementation are:

Techniques for quality planning and control

All the used techniques during the planning are used also for the implementation; so DOE, diagrams, SW etc.

Quality Audits

The quality audits are inspections that are applied in order to verify that the PMT is implementing correctly the quality system; during these audit it is verified (i.e. random) if the documentation, the operations and procedures are implemented in compliance with the quality system. All non-compliance are ranked by importance and recorded, in order to be checked again in the next audit; the audit results should lead to reorganization of work / quality system to improve the application and applicability.

Audits may be internal or external; specific audits are performed by the certifying body (i.e. ISO9000) in order to confirm the quality certificate.

The quality system implementation provides as output:

Improvements to the Quality

Actions to improve project effectiveness and efficiency

Quality Control

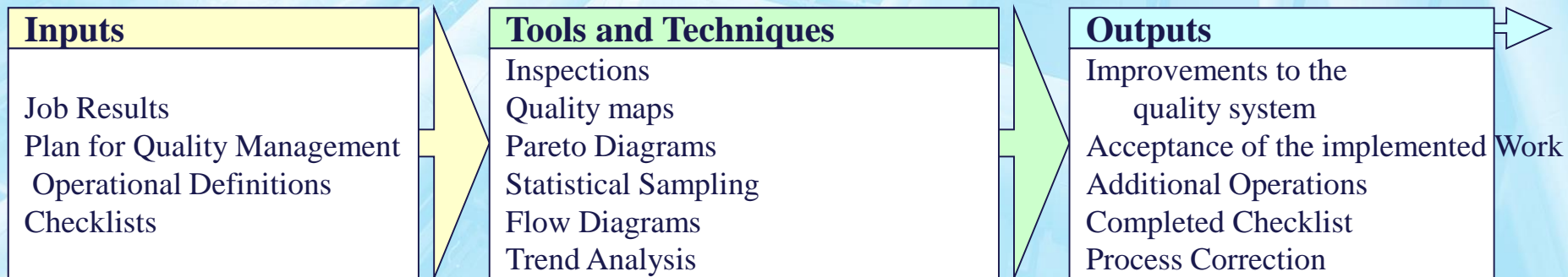
The quality control concerns with some variables monitoring in order to verify that they meet predefined quality standards.

The work results to be checked involve both results on the product (i.e. deliverables) that results on project management (i.e. cost and time).

The control is usually performed by a division or an office manager external to the project, but it may be not specifically delegated or be faced by project personnel.

To facilitate the application of quality controls and the corresponding PMT is required to have a good knowledge of statistical tools and a clear understanding of factors such as:

- ◆ Prevention (errors out of the process), inspection (before delivering to the customer),
- ◆ Attribute controls (compliant or not) and Scalar Control (degree of conformity)
- ◆ Special Cases (Special Events), Random Causes (stochasticity of the process)
- ◆ Tolerances (the result is within the tolerance limits and the product is acceptable) and control limits (the process is within the limits and is controllable)



Input for Quality Control

Work Results

The job results both on the process and on the product to be compared with planned or expected results (project plan).

Quality Management Plan

The plan to manage Quality System

Operational Definition

Definition of elements to be checked and definition of the methodology to be used to make controls

Checklist

Checklist for the inspections implementations and controls on the process and product

Tools and Techniques for Quality Control

Inspections

The measurement activity, examination, tests taken to determine whether the achieved results are in accordance with the quality specifications; they are made at every level.

Quality Map

The quality maps are graphical tools to verify the results over the time and to verify if the related processes are compliant and under control

Pareto Diagrams

The Pareto diagrams are cumulative histograms that, sorted by frequency, allow to identify causes having major influence on non-compliances.

Statistical Sampling

Statistical Data extracted from the population involved in inspections (i.e. take 5 drafts to be controlled for the quality out of 150 delivered); an effective sampling saves time and guarantees results reliability.

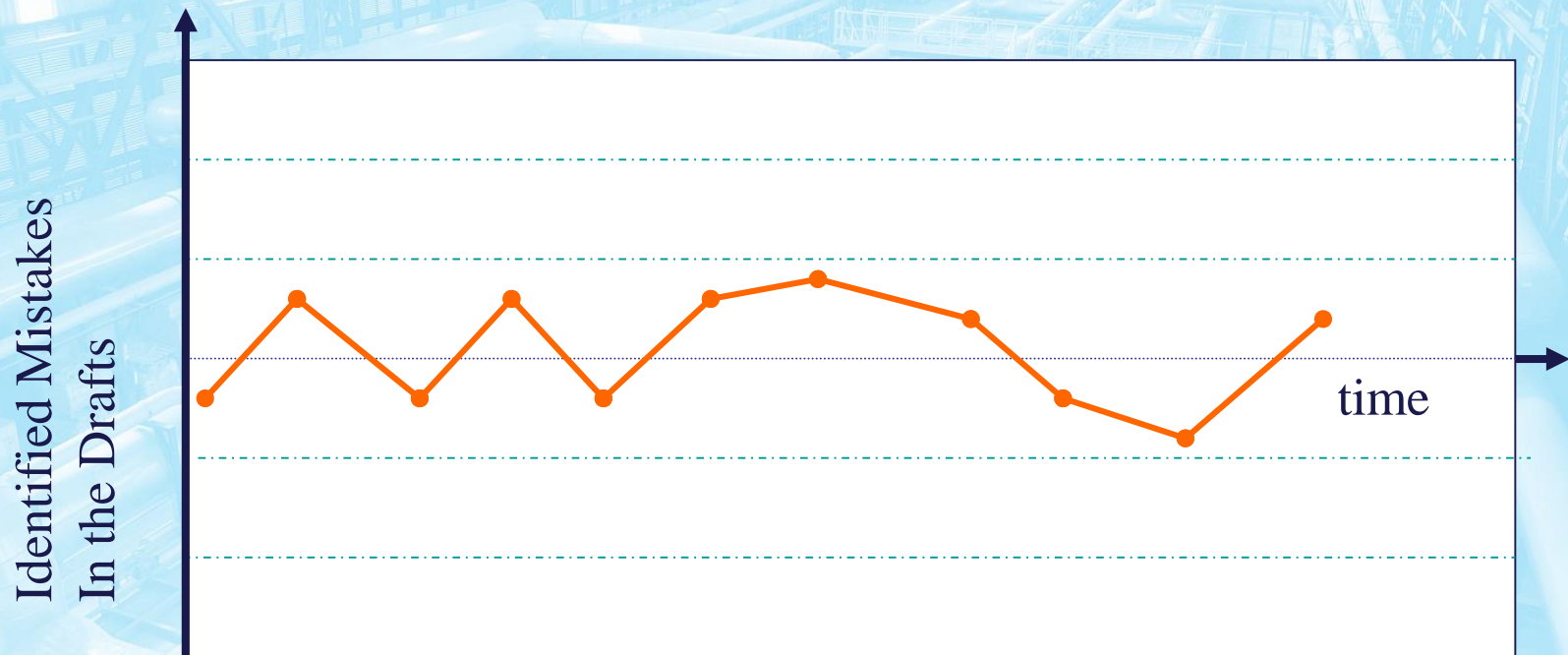
Flow Diagram

Used as already seen for the quality planning

Trend Analysis

Mathematical analysis techniques and forecasting based on historical data; they allow to control technical performances (i.e. to assess based on mistakes found in a SW how many are left), or management ones on time and cost (i.e. determine how many activities have been changed in each period)

Quality Map in the Project Management

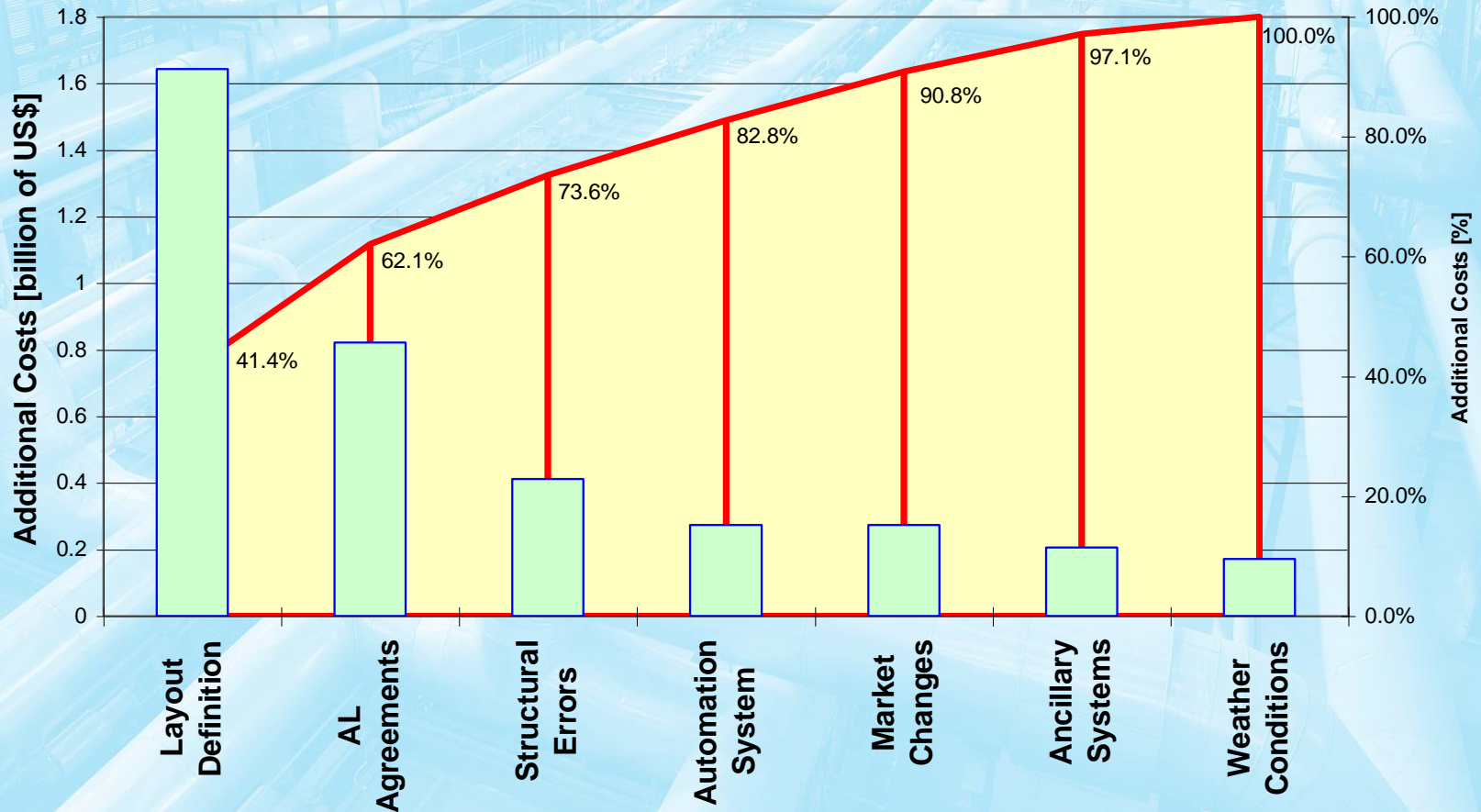


The process up to that is under control should not be changed (it could be improved, but not completely changed).

In Project Management many different types of work are measured to control the project such as: costs and time changes, objectives change in term of size, flu or frequency, mistakes in project documents, etc..

A Pareto Diagram for Project Management

DIA: Unexpected Costs
Pareto Diagram



Quality Control Results

Quality Improvements

By making controls it is possible to improve product and project quality

Approval of the performed work

Based on the results it is necessary to take decision: to accept or not the performed works

Additional Operations

In case of no. Compliance additional work is required to correct the errors; these involve often delays and costs increasing, so they have to be minimized by the PMT as much as possible.

Completed Checklist

Among the data to be included in databases there are the checklist completed during quality control.

Process Regulations

If you find that the process is out of control is required to immediately lead to corrective or preventive actions; in Project Management this involves the activation of the various control procedures integrated into the overall project control system.

Human Resource Management

This management area aims to the best use of all human resources involved in the project (stakeholders-sponsors, customers, engineers, etc..)

- **Organizations**

Roles and Responsibilities identification, documentation and assignment

- **Staff Hiring**

To acquire the human resources required to complete the Project

- **Working Groups Development**

Individual and Groups skills improvement to improve/achieve project performance

The project is carried out by Men (beyond the fact that they use pencils, computers or mathematical techniques), their correct employment is essential to achieve the objectives in time and with the hypothesized costs and the required quality level

Human Resources and Project Management

Here it is required the effective implementation of the typical skills of Human Resources Management that are shared among all the management aspects:

General Management Skills: Leadership, Communication, Negotiation etc.

Individuals Management Skills: delegating capability, Motivate, Coordinate, Guide etc.

Groups Management Skills: Team Building Capability, Conflicts Management, etc.

Human Resources Administration Skills: Evaluation capability in hiring process, Maintenance and exclusion, in working relationships management, in safety and health caring etc.

In the projects it is necessary to take care of the following specific aspects:

- ◆ The project has a limited duration and often is a new structure, it is necessary to select people and manage them by taking this fact into account
- ◆ Type and number of the stakeholders change during the project evolving, so people and techniques will be upgraded / adjusted to be effective in the project management.
- ◆ Administrative issues are often a PMT responsibility, which has to know the organization to ensure effectiveness

Project Human Resources Management: General Presentation

Project Human Resource Management

6.1 Organizational Planning

.1 Inputs

- .1 Each Project Interface
- .2 Staff Specifications
- .3 Constraints

.2 Tools and Techniques

- .1 Templates
- .2 Human Resources Policies
- .3 Organizational Theories
- .4 Stakeholders Analysis

.3 Outputs

- .1 Roles and Responsibilities Assignment
- .2 Staff Management Plan
- .3 Organization chart
- .4 Support Details

6.2 Staff Hiring

.1 Inputs

- .1 Staff Management Plan
- .2 Available Resources for the Staff
- .3 Practices for the hiring process/ attribution

.2 Tools and Techniques

- .1 Negotiation
- .2 Pre-Assignment
- .3 Acquisition

.3 Outputs

- .1 Project Staff Assignment
- .2 Project Team Members List

6.3 Project Team Development

.1 Inputs

- .1 Project Staff
- .2 Project Plan
- .3 Staff Management Plan
- .4 Performance Report
- .5 External Feed-back

.2 Tools and Techniques

- .1 Building Team Activity
- .2 General Management Skill
- .3 Awards
- .4 Collocation Analysis
- .5 Training

.3 Outputs

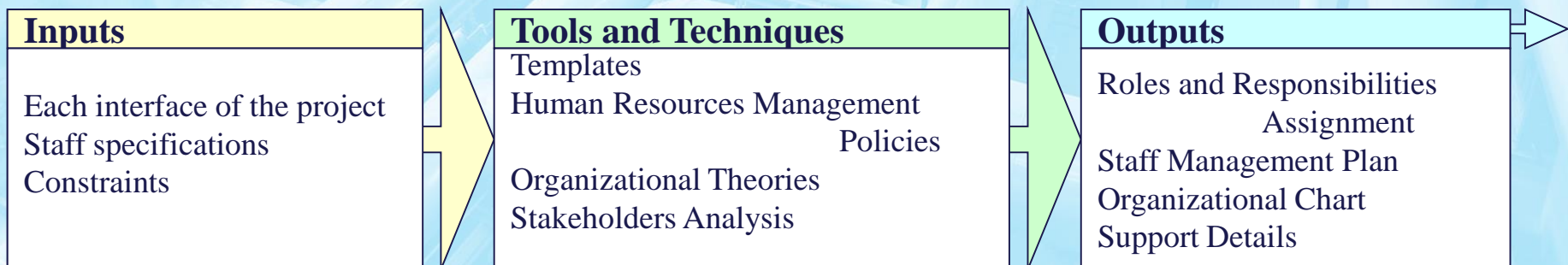
- .1 Performance Improvements
- .2 Acceptance of the Performance

Organizational Planning

It means to identify, document and assign all roles to be played in project management, all the responsibilities and relationships structure in term of reports; these may be assigned to individuals or workgroups.

These organizational entities may be either internal or external; internal groups are often associated to functional departments (engineering, sales, administration).

Organizational planning is often one of the first steps, but it is necessary a continuous review to verify the effective applicability. As the organization is closely linked to communication these two processes must be planned together.



Input for Organizational Planning

Each interface of the Project

They are many and often run in parallel. They can be divided into three main categories:

- **Organizational Interactions:** formal and/or informal communications among organizational units; they may have various complexity levels (links between a Power Plant engineering and commissioning; alert to the customer of a not expected check, etc..)
- **Technical Interactions:** formal and/or informal communications covering different technical disciplines; they occur both between the various phases of the project (a new computer product design and design of the lines needed to produce it), and between stages within the project (the civilian foundations must be related to the mechanical design of the plant structures)
- **Interpersonal interactions:** Relationships among different individuals operating on the project.

Staff Specifications

Skills required to the individuals and to the project team (they are identified during the resources planning).

Constraints

All constraints on the staff organization: the contractor organizational structure (binding on the PM authority); Contractual or unions agreements; PMT preferences; default assignments based on individual company characteristics.

Tools for the Organizational Planning

Templates

Even if each project is different, it is possible to reuse similar cases as reference templates for the project staff organization development.

Human Resources Management Policies

Company guidelines, Practices and regulations for human resources management.

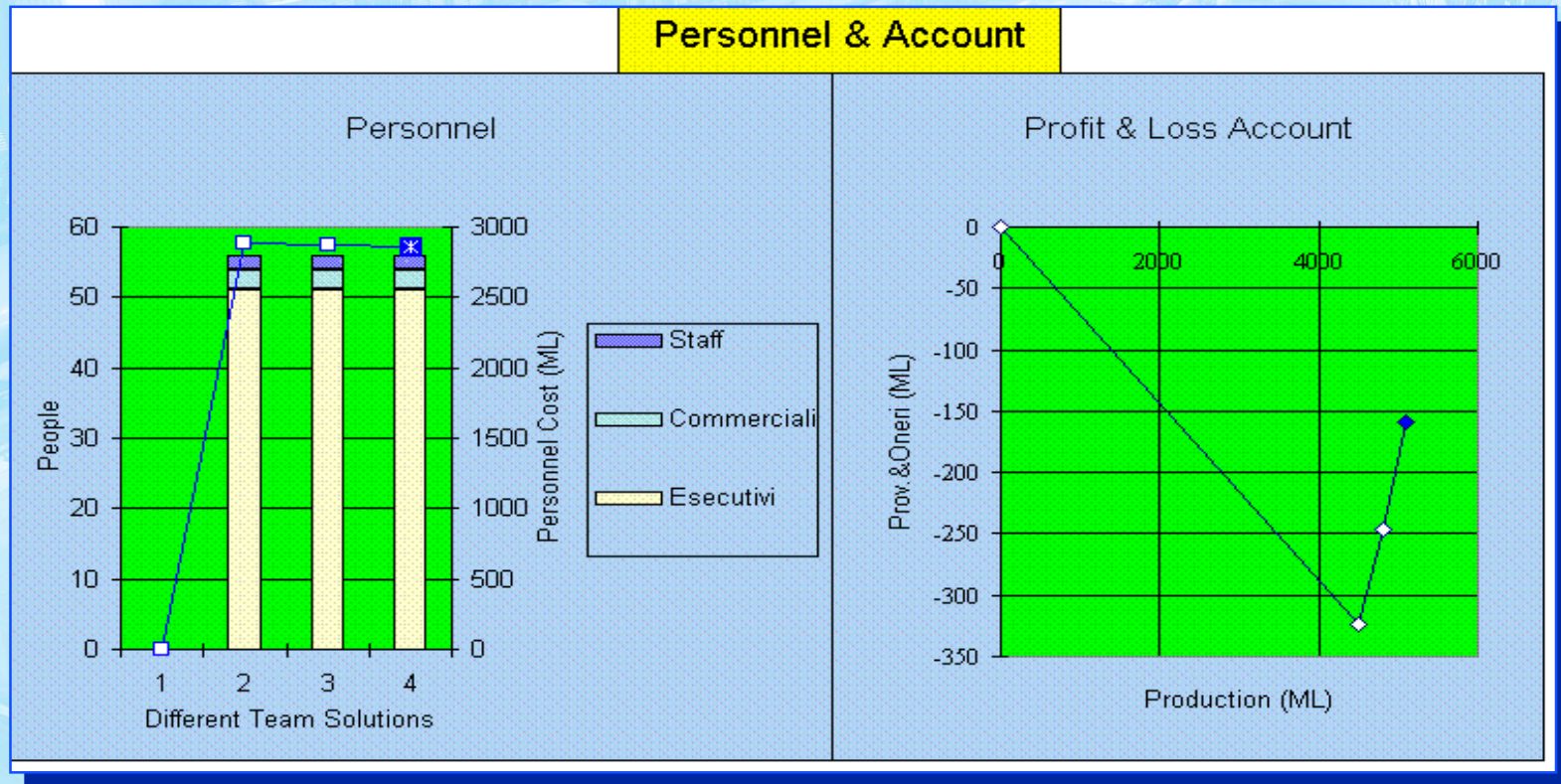
Organizational Theories

All the literature referring to how to organize a structure and to historical documented cases. It is necessary to pay attention to the fact that this literature is only minimally related to the project management case that has very different and important from cases and general management cases.

Stakeholders Analysis

Evaluation of all the stakeholders and their needs in order to satisfy them.

Personnel Structure

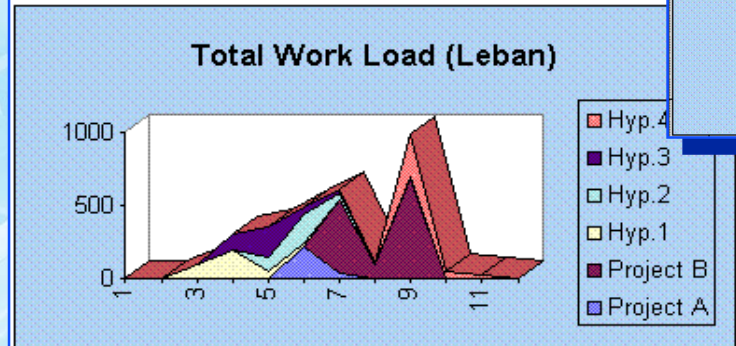
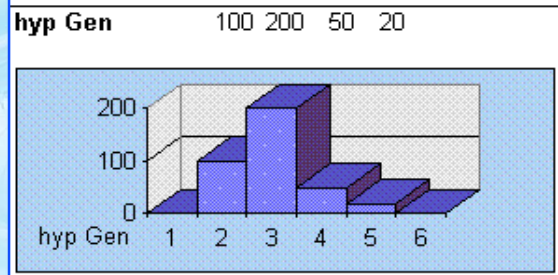


The project personnel structure is a constraint for the project planning and execution, for this reason it needs to be controlled and must evolve according to the project needs.

Assignment & Work Load Procedure

There are Tools to support Roles assignment

Work Load (Leban)	Months 1994									
	1	2	3	4	5	6	7	8	9	10
Project A						220	40			
Project B							500	100	680	
Hyp.1		100	200	50	20					
Hyp.2				100	200	50	2	18		
Hyp.3			100	200	50	20				
Hyp.4							10	290	50	



TEAM

A	Design	Team A1	Team A2
B	Manuals Development	Team B1	Team B2 External M1
C	Technical Translations	Team C1	External T1 External T2 External T3
D	International and Military certifications	Team D1	Team D2 Team D3 External E1
E	ISO 9000 quality certifications	Team E1	Team E2 Team E3 External E2
F	Real Estate Activity	Team F1	

Team **Team D1** ↓

Team D1	No	Skill Requ.
Designers	1	B
Technicians	2	A
Engineers	1	A
Name Directory	Directory	

LEBAN

PALIS	Project A	Project B
LEBAN	07/06/94	12/07/94
Acquisitions	11/07/94	30/09/94
157080 ML		
Project A	26520 ML	
Translation	ASME Rules	Admin.
150 h	100 h	10 h

PROJECT

Project A

PALIS LEBAN

ASME Rules

Cost 105 kL/h

Time 100 h

Skill Requ. B

Team **Team D1** ↓

Relations Project_A[translation][100%]

Sometimes it must cross more projects to evaluate correctly the workload

Organizational Planning Output

Roles and Responsibilities Assignment

Complete definition of all roles (who does what), and Responsibilities (who decides what); it is based on staff requests arising from the resources allocation (that is derived from the WBS). The roles are usually assigned to stakeholders, obviously the PM is often critical in this structure; responsibilities allocation matrices are often used (RAM Responsibility Assignment Matrix).

Plan for Project Staff Management

This plan describes how and when to use the project personnel; it belongs then to the General Plan Project and often includes histograms about resources; it is necessary to pay attention to the personnel reassignment when it leaves the project: i.e. reduce costs if people don't work between a project and another one or improve morale by reducing uncertainty about future activities to be executed.

Organizational Chart

It is a graphical representation allowing to show the project organizational relationships; the OBS (organizational breakdown structure) is a type of organizational chart highlighting responsibilities of staff in relation to WBS

Support Details

All the needed details of support; and often they include a report on the implemented organization, a job description including here technical/management skills / characteristics requirements and job features (job description); requests for specific training.

RAM: Responsibility Assignment Matrix

Structures highlighting task and activities of each group

Project ASCI-SW	Workgroups				
	R&D	Marketing	Engineers	SW	PM
<i>Specifications Definition</i>	E	P	P	I	R
<i>Project</i>	P		E	V	R
<i>Development</i>	P	V	P	E	R
<i>Preliminary Check</i>	R	P	R	E	
<i>Test</i>			V	E	R

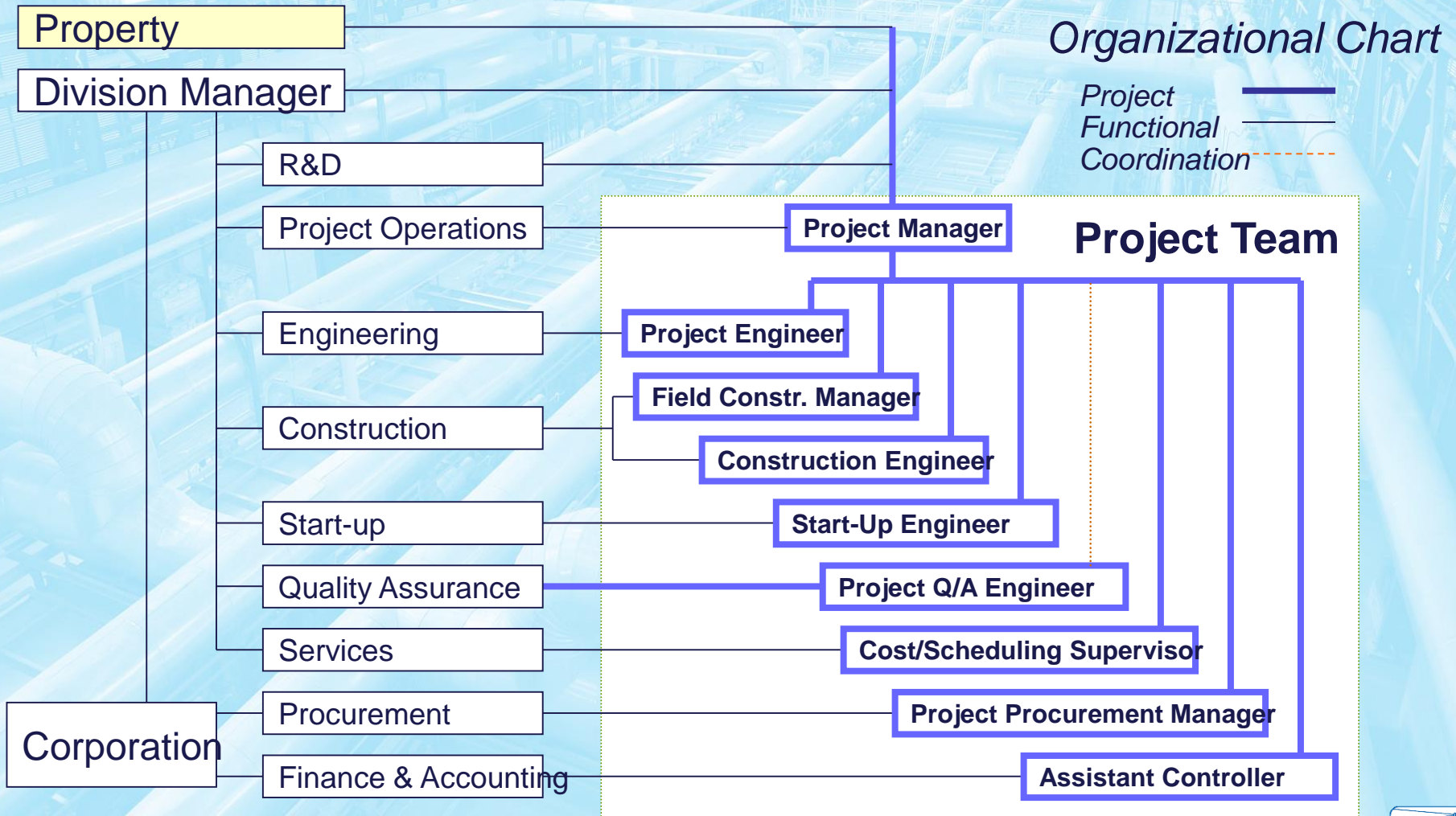
Staff Acquisition

They may be hierarchically structured by covering all the WBS phases

Project ASCI-SW	Personnel R&D					
	Francy	David	Sandrosky	Sonny	Laitanasi	Nehislin
<i>Specifications Definition</i>	S	P	P	P	A/V	R
<i>Project</i>	A	P	A/V	P		A/V
<i>Development</i>	A	P		P		A
<i>Preliminary Check</i>	R	A/V		A/V		
<i>Test</i>						

E Emission - P Participation - I Input Supplier - R Review
S Signature - A Attributable - V Observer

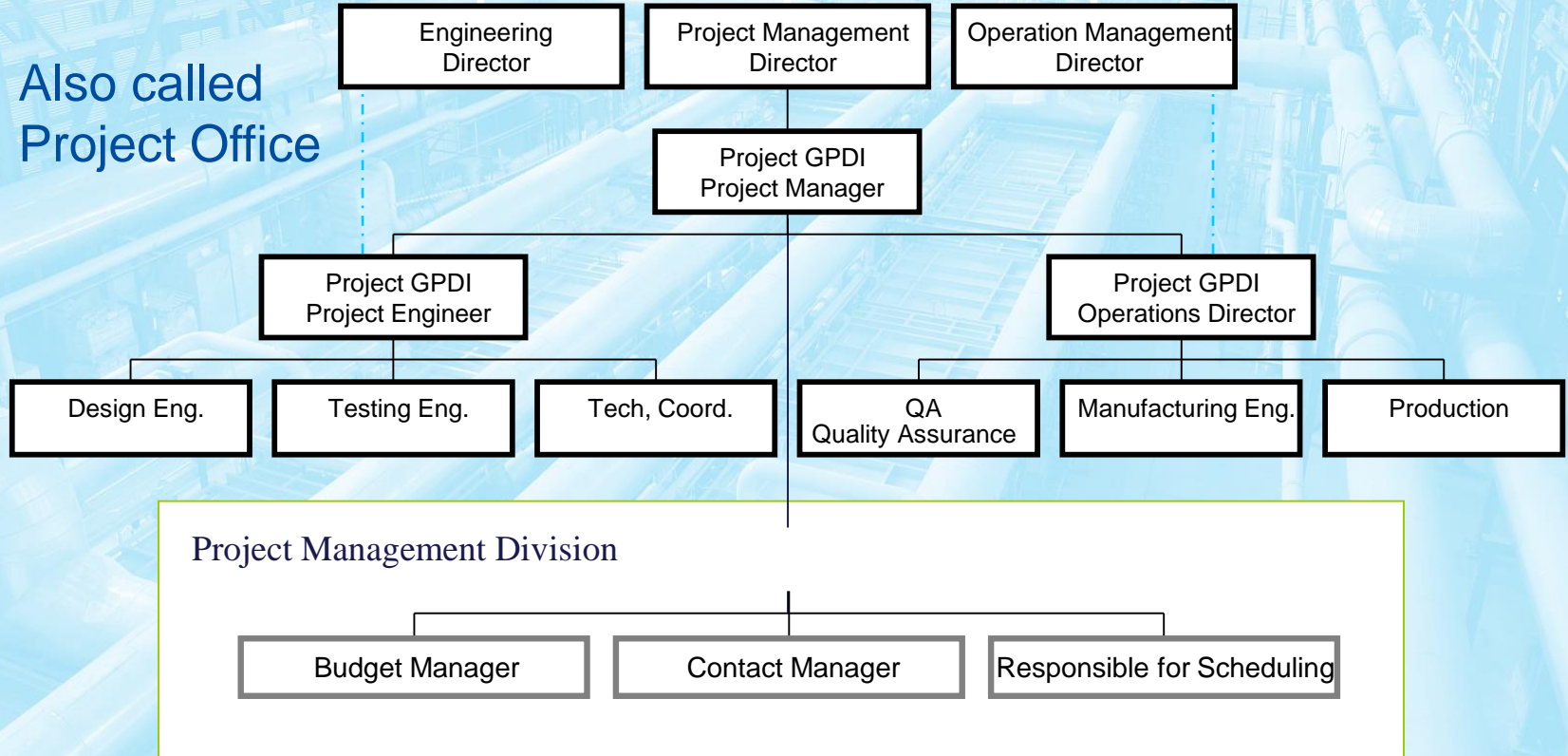
Typical Organization of a Project for Constructions



Project Organizational Chart

Organization Project Office GPDI

Also called
Project Office



It allows to visualize all the Project functions grouped by team or individuals

Staff Hiring and Input

It refers to the staff allocation to the different project activities; often these are not already available and the PMT must find the necessary resources; the recruitment may be effective in the company or simply recruitment in the project staff.

Sometimes the PMT has not the ability to define the staff, however he must try influencing the staff composition.

The used standards are those established during the planning for the project personnel management, and it is necessary to assess the available resources characteristics (previous experience, personal interests, personal characteristics and time availability); obviously all the regulations and practices used in the company for human resources hiring and allocation are used as a reference.



Tools and Techniques for Staff Hiring

Negotiation

It is often important for the PMT to negotiate with functional managers in order to ensure that the project employs personnel with appropriate skills, sufficient time and appropriate priorities; of course it is necessary also to negotiate with other PMT in order to effectively share specific specialized resources. Often the assessment criteria of functional managers may not get benefits to the project (i.e. awards for high productivity may encourage inappropriate staff for increasing hours of engineering).

Pre - Assignment

Sometimes the staff is pre-assigned to the project; this often happens when the project is a proposal in competition with others (internal / external), or when the project is an internal service that has already defined some people in the definition phase.

Acquisitions

It is possible to decide to hire, recruit or use individuals or groups with special skills; that may be necessary for the internal lack in the corporate structure, for economic convenience or for special technical / professional skills.

Results provided by the Staff Hiring

Project Staff Assignment

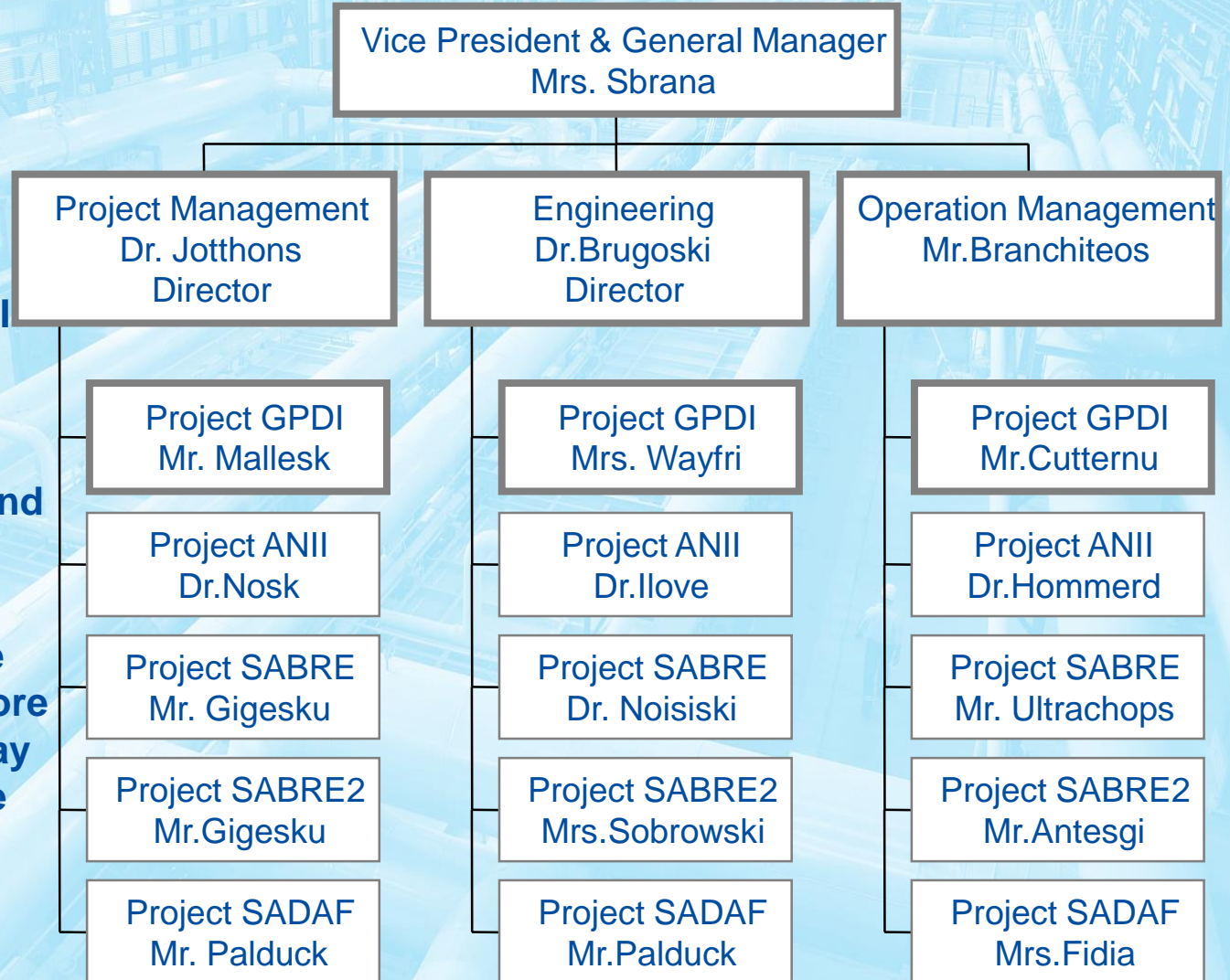
The list of persons assigned to the project and the corresponding location; they are structured in organizational diagrams with nominal identification. The staff can be assigned full-time, part-time or in different ways depending on the need

Project Team Directory

List of PMT members and all the stakeholders; this may be formal or informal, often it is issued with contacts, roles and references to facilitate communications

Organizational Chart: First Step

UGELOFI Cooperation



The Project GPDI even if not fundamental for the company is presented first and in bold at the customer.

Some people are able to follow more projects or to play more roles in the same project.

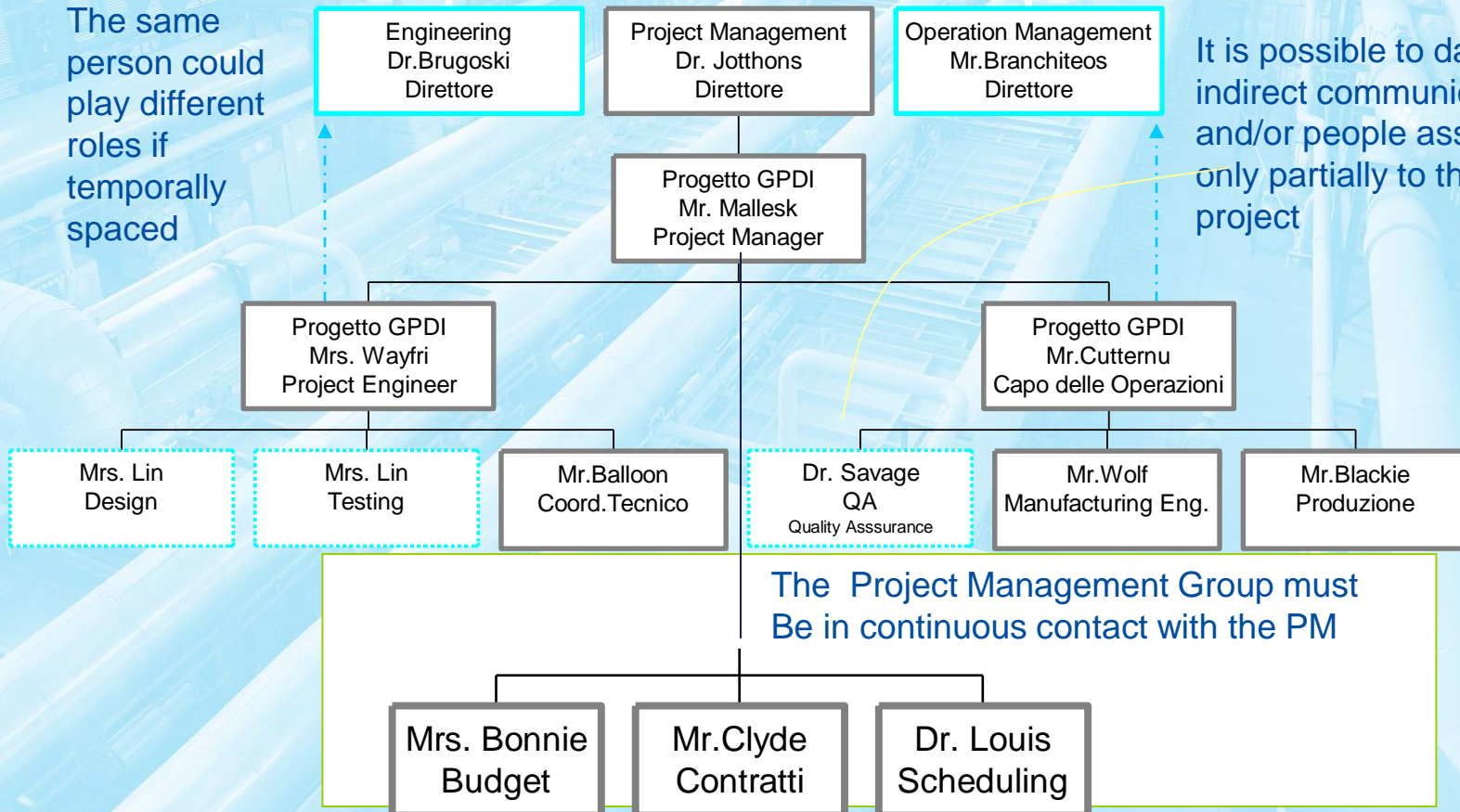
Organizational Charts Step Two: Project Structure

Also this diagram could be addressed to the customer as well as to the internal organization

The same person could play different roles if temporally spaced

It is possible to dash indirect communications and/or people assigned only partially to the project

Organizzazione Ufficio Progetto GPDI



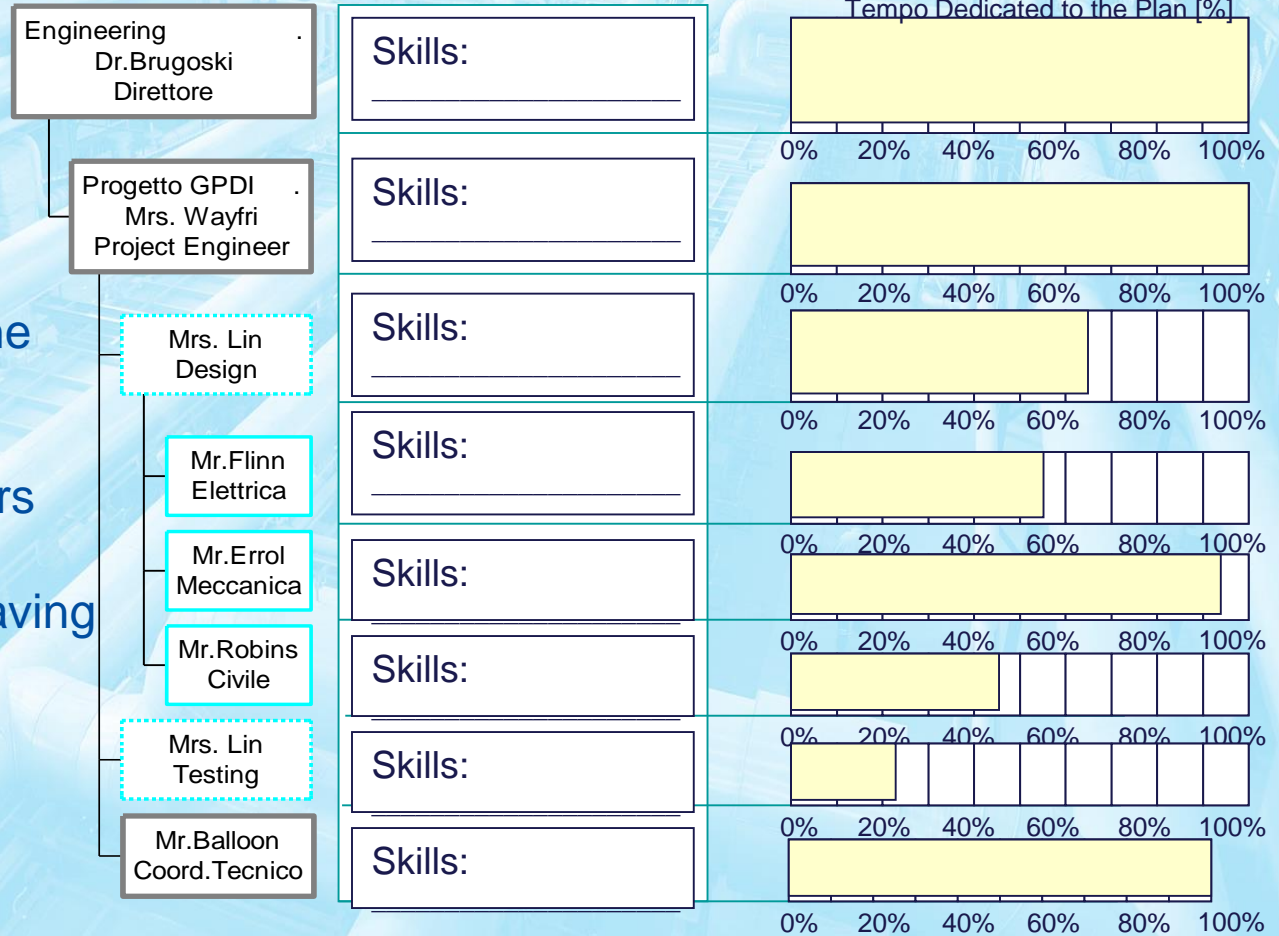
The Project Management Group must Be in continuous contact with the PM

Sharing Top-Quality Personnel

Project Engineering Department Manning

The Project Manning Chart allow To highlight The personnel attribution to the project

Many customers Understand The utility of having part-time Top-quality personnel in the project



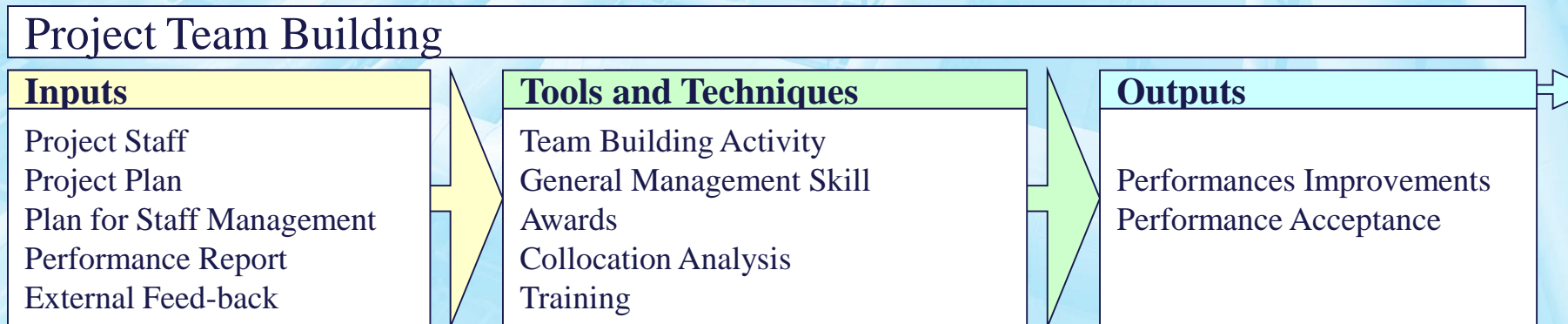
Project Team Building and Input

The goal is to improve both the individual capabilities of the stakeholders that their capacity of working in teams (note: sometimes it is possible to define a team or group as a stakeholder).

This becomes complicated when Project Team members are delegated to operate both as functions manager and project manager (PM must ensure its effectiveness).

Even if it is an executive process evidently it is developed throughout the whole project.

It uses as input: the assigned staff for the project, the Project Plan, the plan for personnel management, performance measurement and reports and it is recommended to request periodically opinions (feedback) by anyone out of the project itself.



Tools and Techniques for Team Development

Team Building Activity

They vary from techniques and activities to solve individual conflicts or technical ones during ordinary meetings to specific activities devoted to interpersonal relationships improvement.

General Management Skills

They refer to the typical management skills already mentioned (i.e. leadership)

Awards System

They aim to improve the teams and individuals behaviors; usually the company's system of rewards does not fit the project, so it is appropriate to define a specific one; key factors are the system clarity, its objectivity, the feasibility and measurability of the objectives. Goals must be corrected: i.e. not reward extraordinary due to poor scheduling, but to reward extraordinary related to aggressive scheduling. The awards to individuals or teams must be related to their cultural setting (i.e. unloved team award in competitive individual cultures).

Collocation Analysis

Even with modern communications systems human rapport and personal contact are key factors: it is necessary to plan the staff placement by taking into account these factors (ie war room, overseas offices etc..)

Training

The training includes all the activities increasing skills, knowledge and project team capability; the training cost is often charged on the structure for technical/management reasons.

Results of Team Development

Performances Improvements

After team development they are more efficient and improve their performance in term of

Individual Improvements

increasing their individual effectiveness

Team Improvements (i.e. surfacing/dealing conflicts)

increasing the technical effectiveness of the team

Individual and Team Improvements,

increasing the capability of identifying and developing better solutions for the project

Acceptance of the Performance

The Project Staff should provide an assessment of the work provided by other project members at each significant interaction and its acceptance; this may be formal or informal (typically formal in negative cases).

Note: The union law could avoid the evaluation of human performance based on on-line quantitative controls on productivity

Project Communication Management

This activity includes all processes devoted to spread and store in time all necessary information to the project; it allows to communicate in the project language.

- **Communications Planning**

Determine information and communications required by stakeholders; what, when, how and who is provided with information

- **Information Distribution**

Make required information available in time to the stakeholders

- **Report on project performances**

Acquire and distribute information about project evolution: current status, progress and projections evaluation

- **Administrative Closure of Documentation**

Generate, distribute and elaborate all the required documentation for formalizing the project phases conclusion

It is necessary to evaluate both procedures (communication models) communication supports, communication style, presentation techniques as well as meeting management

Project Communication Management Layout

Project Communication Management

7.1 Communication Planning

.1 Inputs

- .1 Communications Requests
- .2 Technology for Communications
- .3 Constraints
- .4 Hypothesis

.2 Tools and Techniques

- .1 Stakeholders Analysis

.3 Outputs

- .1 Plan for communications management

7.2 Information Distribution

.1 Inputs

- .1 Work Results
- .2 Plan for communications management
- .3 Project Plan

.2 Tools and Techniques

- .1 Communication Skill
- .2 Information Research systems
- .3 Information Distribution System

.3 Outputs

- .1 Project Record

7.3 Performances Report

.1 Inputs

- .1 Project Plan
- .2 Work Results
- .3 Other Project Record

.2 Tools and Techniques

- .1 Performance Review
- .2 Variance Analysis
- .3 Trend Analysis
- .4 Earned Value Analysis (EAV)
- .5 Techniques and tools for information distribution

.3 Outputs

- .1 Performance Report
- .2 Change Requests

7.4 Administrative Closures of the Documentation

.1 Inputs

- .1 Measured Performance Documentation
- .2 Documentation on the Project Product
- .3 Other Data of the project

.2 Tools and Techniques

- .1 Techniques and Tools for Performance Report

.3 Outputs

- .1 Project Archives
- .2 Formal Acceptance
- .3 Lessons learned

Communications Planning and Input

The project organization is closely related to the communications planning: they must continuously adapt to the project evolution.

Input are:

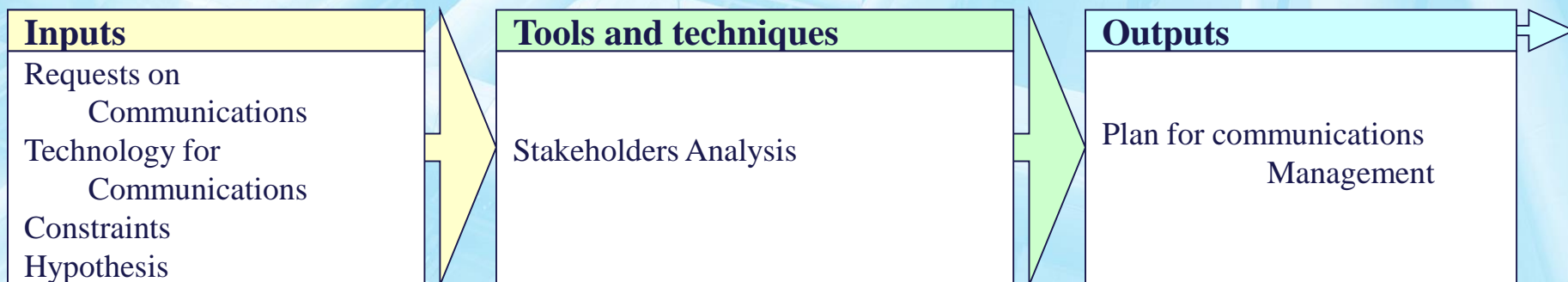
specifications on communications of Project that are related to the responsibilities and project structure, to the individual skills, to the logistics and people location and external need (i.e. communications with mass media)

Technologies for communications: identify which tools/ techniques to use, verification of the technology importance for the project, the technologies reliability, the users capability to use it and the technology durability for through the whole project

Constraints, such as confidentiality and available resources

Hypothesis on the communication system working

Communications Planning



Tools and Techniques to Plan Communications and Process Output

Stakeholder Analysis

This phase allows to indentify characteristics and needs of each stakeholder/group.

Output are:

Plan for Communication Management

It is a document including all the procedures and systems to collect, store, distribute information, a structure for distribution of information (what to whom), a description of information that is distributed (formats, content, level of detail), a scheduling for the distribution and methods for accessing the recorded data plan also includes practices to upgrade the information management system

Information Distribution: Input, Output and Tools

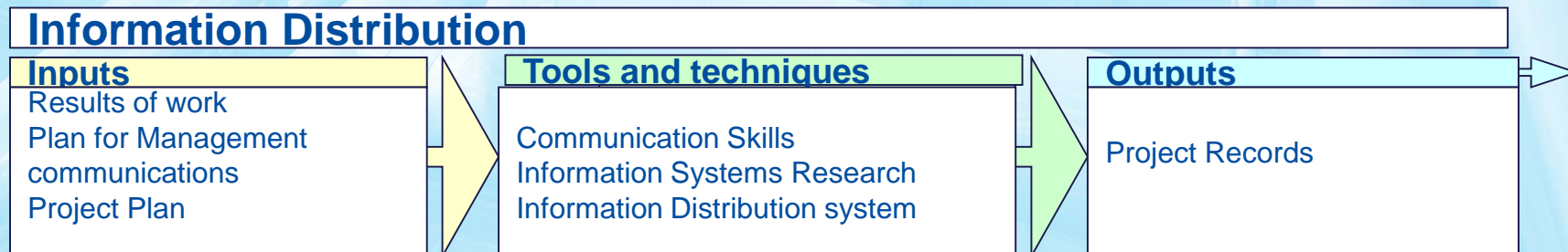
This is the process that will disseminate to all stakeholders the information required on the project.

It is based in fact on the results of project work, the plan for the management of communications and the general plan of the Project.

What techniques for the distribution is important to enhance the communications skills at all levels (internal to the project, external customers or the public) and all types (oral, written), formal (reports) and informal (conversations), vertical and horizontal.

Obviously there must be a system to search for information and one for the automatic distribution, these tools often rely on computer tools and software such as Dbase central and SW linked to the network.

What results do you get all the records of the project (memos, notes, correspondence, reports and documents), all these data may be kept as a personal basis by stakeholders.



Report on the Performance of the Project and its input

The Performance Report involves all activities to capture data on the performance of the project and distribute; this process involves:

Status Reporting

Progress Reporting

Forecasting

Current Status of Project

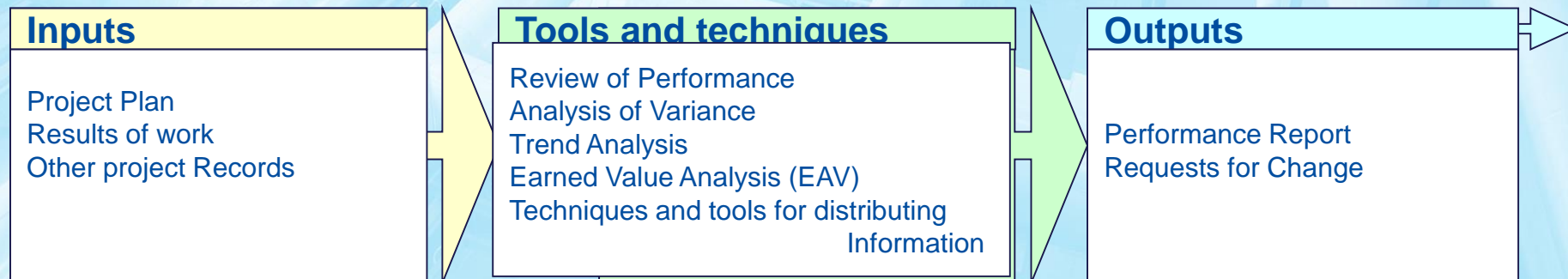
What targets has the project achieved

Forecasts on Project development

This information is usually related to schedules, timing, cost, resources, the quality and purpose of the project; they can be to prepare anyway, or only on the basis of specific conditions.

Input is Used in the project plan, the data on the deliverables already delivered more additional and auxiliary data on the project.

Report on Project Performance



Tools for Project Performances Report

Performance Reviews

They are meetings devoted to determine the project progress, in this phase all the different techniques for analyzing the project are applied

Variations Analysis

It is a comparison between the results of the current project in term of expected value / actual value; it is often about the cost and time, but it could be developed on objectives, risks, and quality

Trend Analysis

Trend analysis to project the performances to the future, it is possible to use simple tools (regressions) or complex (i.e. considering seasonality and variations)

Earned Value Analysis EVA

It is one of the most popular technique to analyze the variance

Tools and Techniques for Information Distribution

All the used techniques to define the Communication Management Plan.

EVA: Earned Value Analysis

The EVA is a very popular technique based on the computation of three key values for each activity:

BCWS

Budget

Budgeted Cost of Work Scheduling

ACWP

Costo Attuale

Actual Cost of Work Performed

BCWP

Earned Value

Budgeted Cost of Work performed

It is also possible to work on discrete values of the completion to evaluate the Earned Value (i.e. 10 % - 20% ..., or only 0% or 100%)

The combined use of these terms provide the assessment parameters:

CV = BCWP - ACWP

Cost Variance

SV = BCWP - BCWS

Schedule Variance

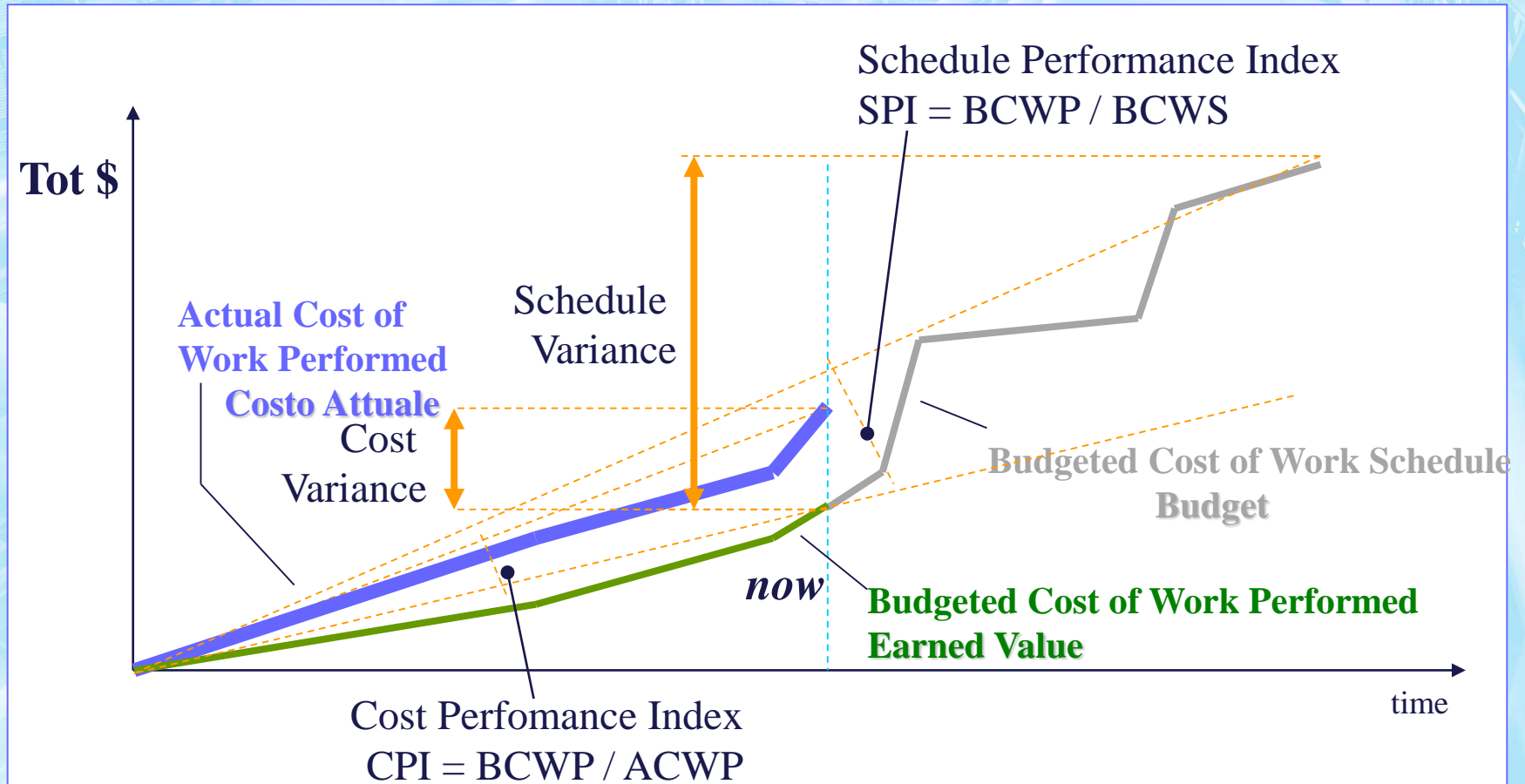
CPI= BCWP/ACWP

Cost Performance Index

Often it is used the total **CPI** to make previsions on Project Costs at the completion; while often it is used the **SPI = BCWP/BCWS** (**Schedule Performance Index**) to estimate the completion date.

EVA : Interpretation of Different Terms

EVA parameters are often the reference for estimations and future previsions of both times (SPI) and costs (CPI)



EVA a Cumulative Parameter

It is necessary to think to the EVA as a set of parameters to be detailed for each activity WBS and to be cumulated in order to make estimates for the whole project.

WBS Elements		Budget	Earned Value	Actual Cost	Costs Variance		Variance on Project Schedule	
		BCWS	BCWP	ACWP	BCWP-ACWP	BCWP/ACWP	BCWP-BCWS	BCWP/BCWS
		[USD]	[USD]	[USD]	[USD]	[%]	[USD]	[%]
1	Pilot Planning	56000	52000	55000	-3000	-5.5%	-4000	-7.1%
2	Checklists Draft	48000	46000	42000	4000	9.5%	-2000	-4.2%
3	Life Cycle Project	39000	35000	40000	-5000	-12.5%	-4000	-10.3%
4	Medium Term Evaluation	84000	84000	86000	-2000	-2.3%	0	0.0%
5	Supports Implementation	11000	7000	6000	1000	16.7%	-4000	-36.4%
6	User Manual	6000	5000	4800	200	4.2%	-1000	-16.7%
7	Development Plan	32000	18000	23000	-5000	-21.7%	-14000	-43.8%
Total		276000	247000	256800	-9800	96.2%	-29000	89.5%

By using a such kind of estimation it is easy to reprogram the timing and project costs having at each moment the control of detailed complete and checked internal parameters.

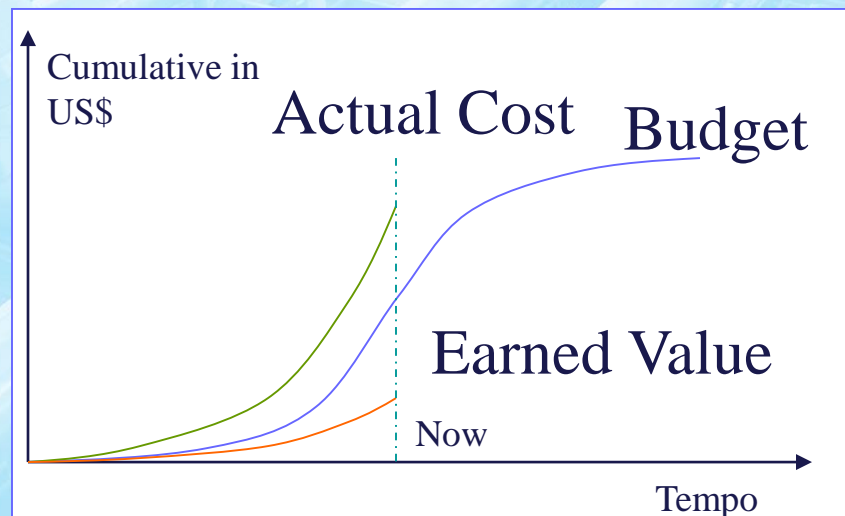
Output del Performance Reporting

Performance Reports

Summaries including detailed results of performance analysis for the related stakeholders. Often Bar Chart (Gantt), S Curves, Histograms tables are used.

Change Requests

The project performance analysis often generates requests to change some components; such requests must be managed as described by the various control systems (ie scope change control).



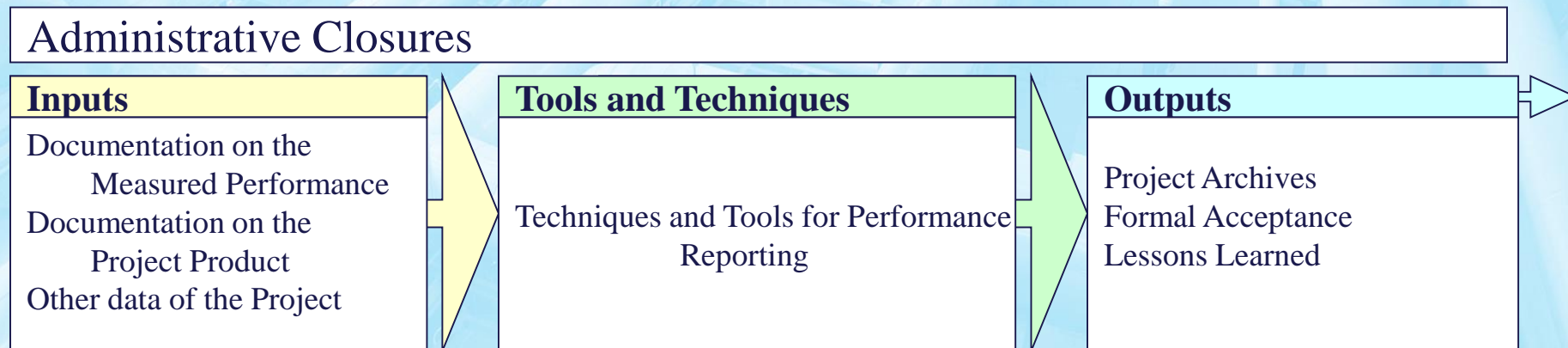
Often it is common to use EAV as reference for the different key elements

Administrative Closures : In, Out Tools

Each phase of the project requires its administrative closure after the objectives achievement or elimination; this means to verify and document the project results and their formal acceptance; so all project data and estimates about the on going activity success are included; it should not be delayed at the completion of the project, but managed during its natural evolution.

As input we have the documentation on the achieved performance, the project product documentation all other related data; as tools are used the techniques to evaluate performance; at this point all is sent to the archives, keeping them updated with particular attention to economic and financial aspects.

All documentation requiring formal approval (the sponsor or client) must be prepared and distributed



Project Risk Management

The Projects are stochastic activities so they are connected to direct and indirect risks so it is necessary to manage:

- **Risks Identification**

Identify risks that could affect the project and document it

- **Risks Quantification**

Evaluate risks and their interactions to estimate the influence on the project

- **Development of Plans for Risks Management**

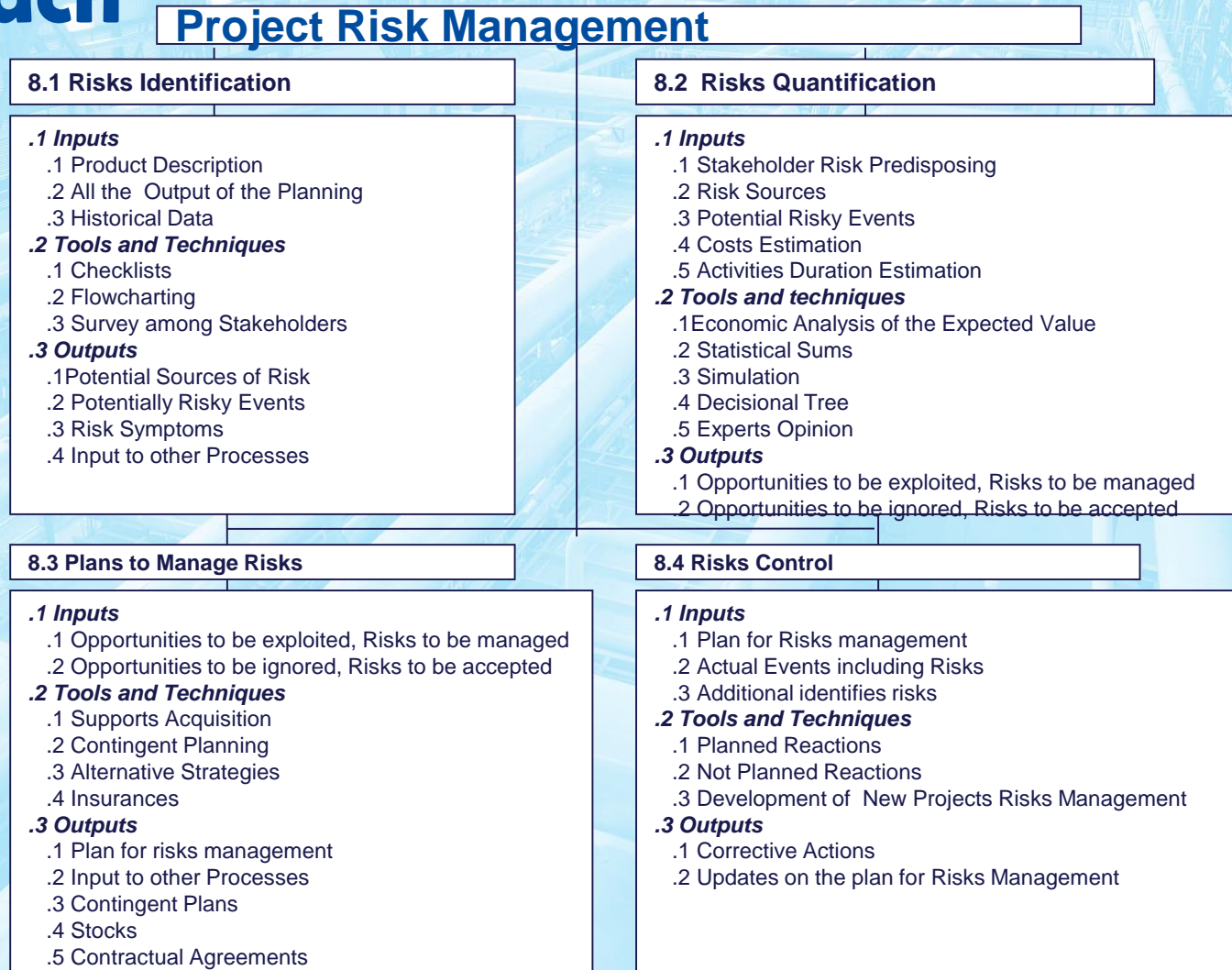
Define steps and procedures to react effectively to the different conditions

- **Applied Countermeasures Control**

Reply to the risks evolution during the project life

In the Industrial Plant management there are some common risks related to environmental evaluations in addition to traditional economic and financial risks.

Project Risk Management: General Approach



Techniques and Tools for Risks Identification

Checklists

The checklist (widely used by the American people) are generally structured by sources of risk and may cover both the SOW that the product, the technology, the team etc.

Flowcharting

As already seen in the analysis of the quality it is possible to build diagrams highlighting the possible cause-effect relations; similar analysis of the time and costs diagrams may identify critical aspects.

Survey among stakeholders

Interviews and questionnaires allow to identify the sources of risk not yet highlighted by the planning; the opinions and feedbacks during the feasibility study could be precious.

Sources of Risk

These are the categories of risk that may affect the project for good or evil, both types need to be considered in project management.

These categories are usually characterized by:

Magnitude (Potential effect)

Probability of Occurance

Normally they include:

Specifications Changes

Mistakes, Omissions and Misunderstanding of Design

Mistakes in the allocation/ comprehension of roles and responsibilities

Wrong Estimates

Poor Performance of the Staff

The sources of risk change in the life of the project (decreasing uncertainty) and may be either discrete (i.e., a license that is or not assigned) or continuous (a time that may be more or less long).

Risks in Plants Contracts

Among the principal risks in a industrial plant project management there are:

***Deadlines Respect
Project Goal Achievement***

Obviously it is possible to highlight the related risks related to the contract definition both technical and economic

***Contractual Exclusion
Payment Conditions
Civil Responsibilities
Taxes
Subcontracts Assignment
Insurance Needs
Starting Date
Penalties
Political Situation***

***Customer Obligations
Guarantees and Warranties
Delayed Delivery and Installation
Variations and Extra-Work
Force Majeure
Arbitration
Ending Date
Changes
Bureaucratic Iter at Public Bodies***

Risks Identification Results

Sources of Risk

A complete definition of all potential risks regardless of their magnitude (influence) and frequency / probability of occurrence.

Any estimation must include: an assessment of the probability of occurrence if there are potential causes, the range of the event variability probability data (i.e. it can happen multiple times?)

Potential Event of Risk

Discrete events that including implicitly or explicitly the risk factors (i.e. natural disaster, explosion); they should be highlighted in addition to the sources of risk when magnitude & probability of occurrence are high (with respect to the project requirement).

Risk Symptoms

The symptoms are indirect manifestations of potential current (i.e., low morale, mistakes in initial forecasts, etc..)

Input to the other Processes

If risks are easily identified it is necessary that other activities lead further analysis to identify solutions and / or alternative

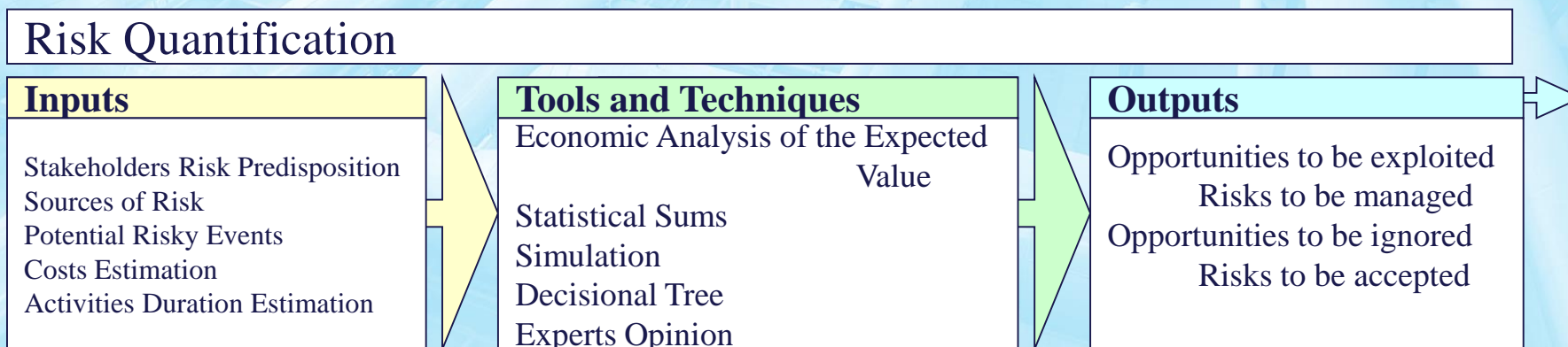
Risk Quantification and Input

Once identified the potential sources of risk, they should be quantified to support decisions and project choices.

It is necessary to consider that risks may interact in unexpected ways, that a single event can generate the so-called "domino" effect generating a series of linked events, that the risks can be considered as opportunities by some and threats by others (i.e. reduced costs vs. reduced profits).

The mathematical analysis in this field may create incorrect illusions about the precision and accuracy of the on going estimations.

As input are used the estimates related to risk sources and potential risk events, as well as all the time and cost estimates on the project; also the stakeholders predisposition to the risk is important to assess the tolerance related to project risk.



Techniques and Tools for Risks Evaluation

Economic Analysis of the Expected Value

The expected value (*Expected Monetary Value*) is one of the most popular parameter to evaluate the risk and it is obtained as the product of two terms, the probability of risk event and its value; it is typically the parameter used by decision-making tools (decision trees).

Statistical Sum

Allow to evaluate the total cost of the project starting from the single work/activity by considering to operate in a probabilistic environment.

Simulation

The simulation (often of a simple Monte Carlo type) is used to assess the risks on times and costs; and it is common to use it when the project is complex and mathematical methods are limited, or there are complex phenomena of *path convergence* which can not be analyzed.

Decisional Tree

They are a technique used to evaluate different alternatives; in these diagrams the branches represent the decisions or events associated with a probability and a cost / gain.

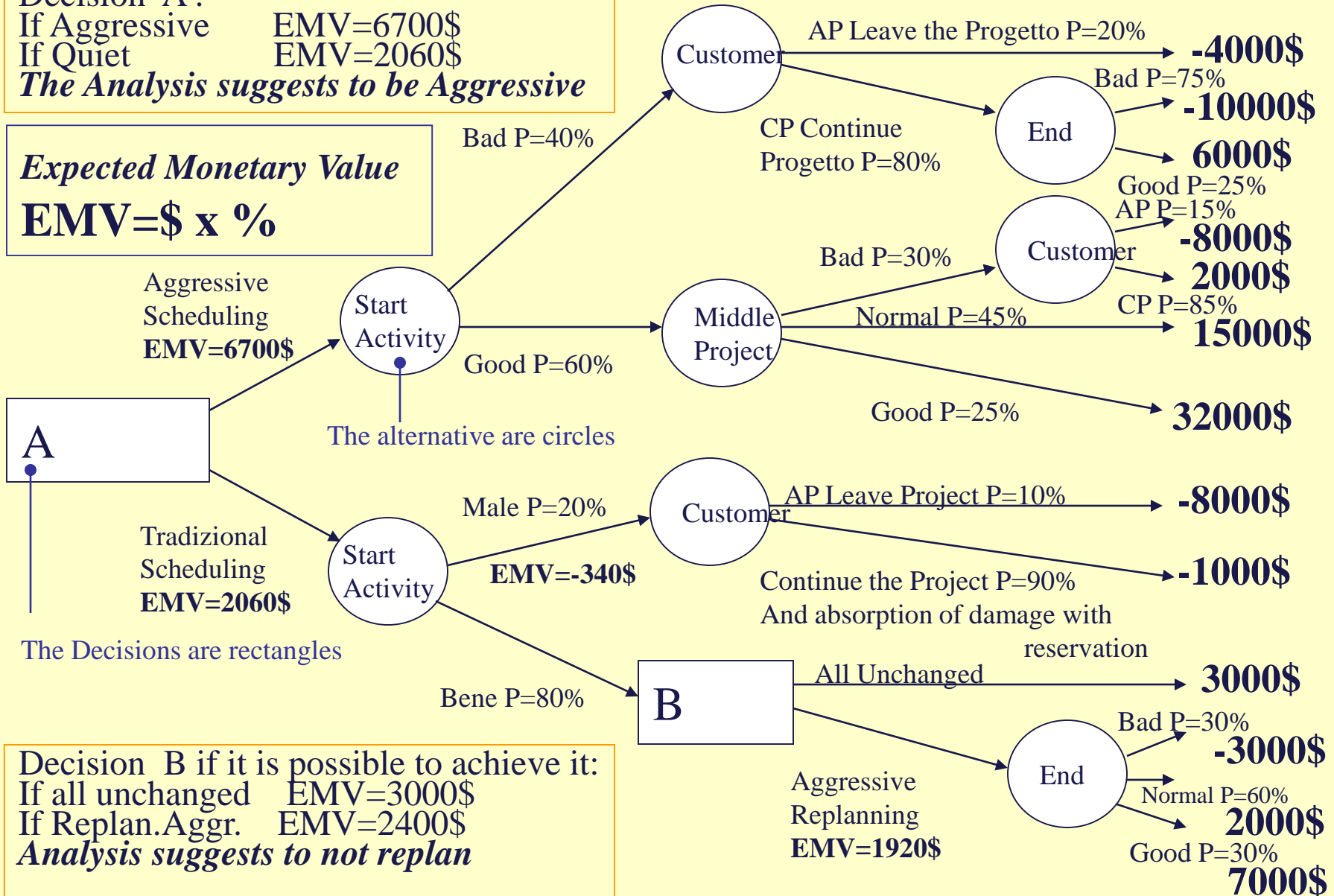
Experts Opinion

It is often used instead of or in addition to the aforementioned techniques, obtaining quantitative assessments: these can lead at least to the definition of a ranking list of risk sources

Decisional Tree for EMV Evaluation

Decision A :
 If Aggressive EMV=6700\$
 If Quiet EMV=2060\$
The Analysis suggests to be Aggressive

Expected Monetary Value
EMV=\$ x %



Decision B if it is possible to achieve it:
 If all unchanged EMV=3000\$
 If Replan.Aggr. EMV=2400\$
Analysis suggests to not replan

Check for Errors

Tangible and Intangible Risks

In the risk assessing there are two types of factors: tangible and intangible; the first type is quantifiable, while the second not (i.e. effects on future activities external to the project, favorable or detrimental conditions to future developments, factors of image etc..).

It is necessary however to consider in the risk assessment also intangible factors; to neglect intangible risks (not normally detectable by quantitative analysis) leads to dangerous distortions of the evaluation, moreover aggravated by the stakeholders trust on quantitative estimates generating high risk of wrong decisions and underestimation of losses in adverse circumstances and overestimation of earnings in case of opportunity.

I.e.: two engineering solutions have the same EMV, but the second involves the risk of making a terrible image with the customer; that could affect future relationships => so they are not equivalent

Statistical Sum: Combinations in Sequence

Progetto di:	Acquisto tre nuovi Computers					
Attività	Durate Stimate (giorni)			Valori Calcolati		
	Ottimistica a	Piu' Probabile m	Pessimistica b	Media μ	Scarto σ	Varianza $\exp(2 \ln(\sigma))$
Preliminari						
Acquisizione Offerte	2	7	15	7.50	2.17	4.69
Confronto Preliminare	1	3	6	3.17	0.83	0.69
Selezione Iniziale	1	2	3	2.00	0.33	0.11
Effettive						
Negoziazioni	1	3	10	3.83	1.50	2.25
Offerte Definitive	4	7	21	8.83	2.83	8.03
Valutazione Offerte	2	3	5	3.17	0.50	0.25
Selezione Definitiva	4	5	10	5.67	1.00	1.00
Ipotesi di distribuzione Beta di Probabilità per le durate						
Totale Durata del Progetto	30			34	4.13	17.03

If you make different hypothesis about the distributions, different values are obtained (they can be combined as desired).

It is always valid for activities in sequence:

The total average duration is equal to the sum of mean values

The **total variance** is equal to the variances sum

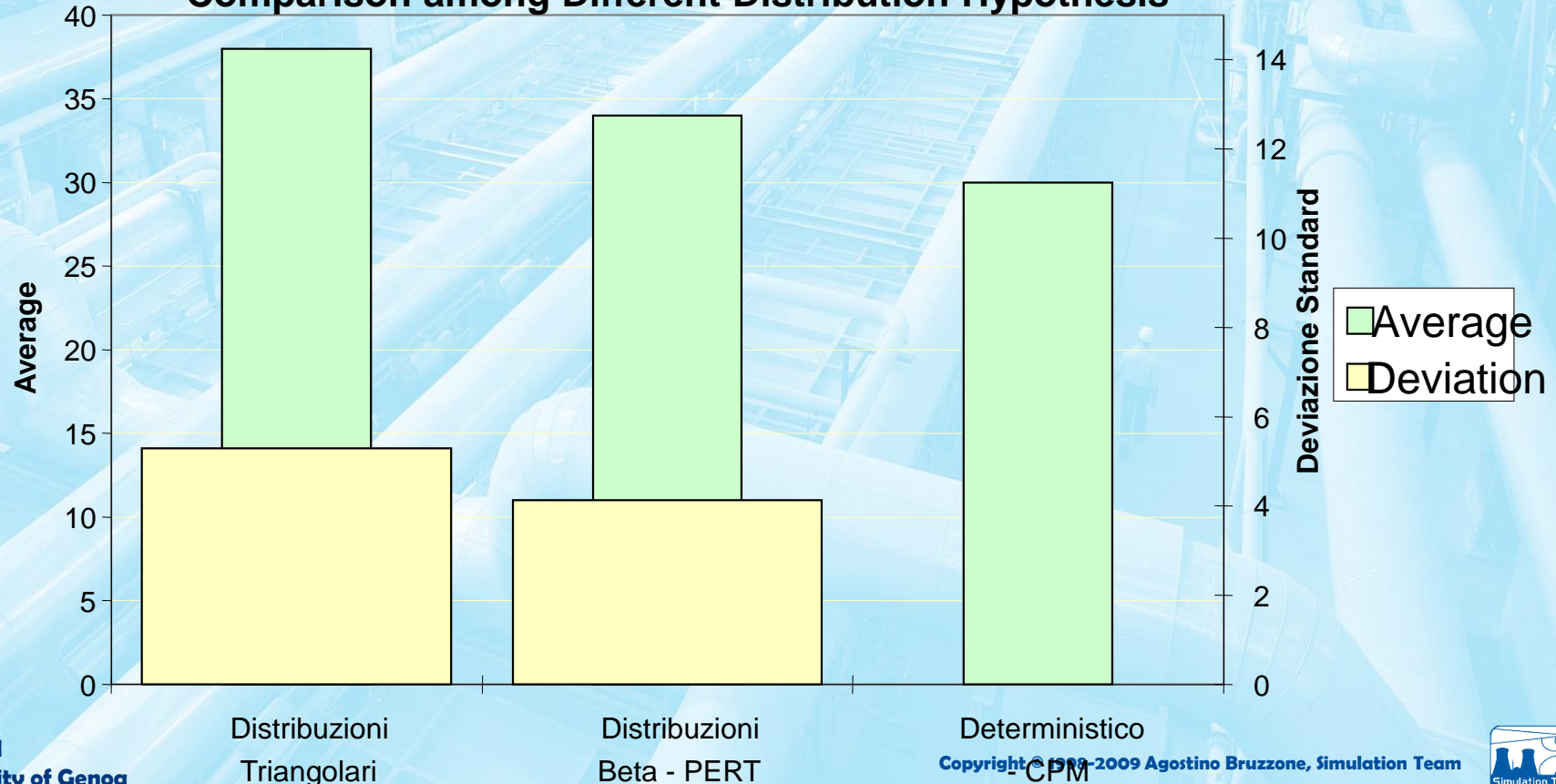
The **standard deviation** is the square root of the total variance

Progetto di:	Acquisto tre nuovi Computers					
Attività	Durate Stimate (giorni)			Valori Calcolati		
	Ottimistica a	Piu' Probabile m	Pessimistica b	Media μ	Scarto σ	Varianza $\exp(2 \ln(\sigma))$
Preliminari						
Acquisizione Offerte	2	7	15	8.00	2.68	7.17
Confronto Preliminare	1	3	6	3.33	1.03	1.06
Selezione Iniziale	1	2	3	2.00	0.41	0.17
Effettive						
Negoziazioni	1	3	10	4.67	1.93	3.72
Offerte Definitive	4	7	21	10.67	3.70	13.72
Valutazione Offerte	2	3	5	3.33	0.62	0.39
Selezione Definitiva	4	5	10	6.33	1.31	1.72
Ipotesi di distribuzione Triangolare di Probabilità per le durate						
Totale Durata del Progetto	30			38	5.29	27.94

Combine the statistical Distribution based on $a, m & b$

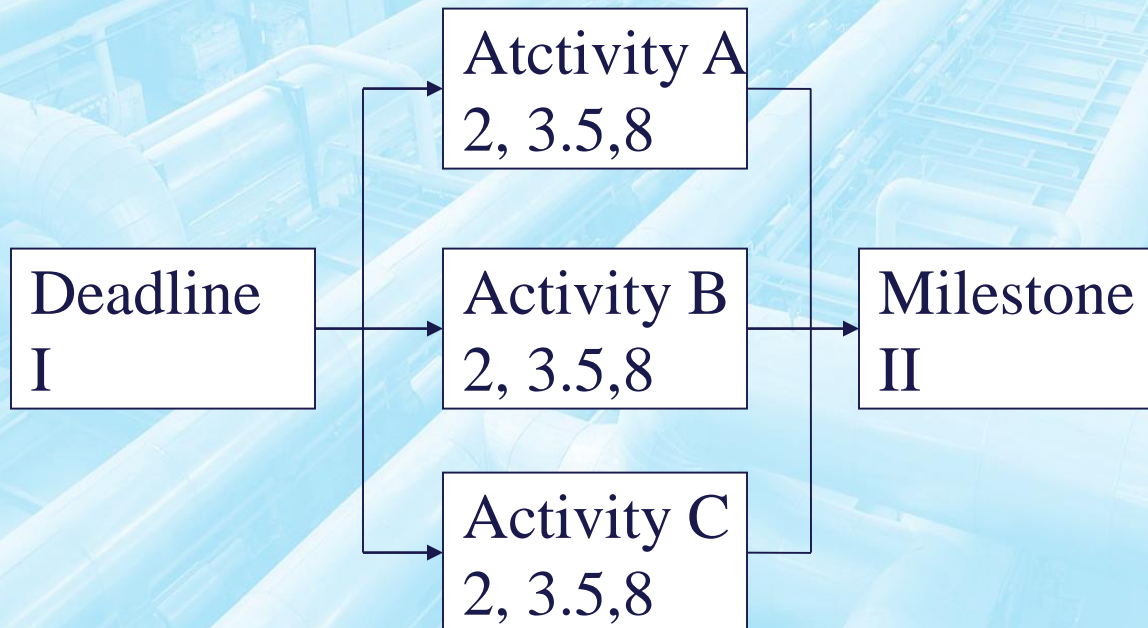
By using the distributions with three references (beta, triangular); if m values approach the left worst estimations are achieved respect of the CPM value

Comparison among Different Distribution Hypothesis



Path Convergence and Risk Assessment

In an assessment provided by a CPM are not considered risk factors, by using a PERT if the chart is complex and / or beta are replaced with other distributions specific of the activities, it is not easy to estimate the phenomenon of delay between parallel branches.



In the case of convergence Path the estimate of the PERT would use an average time of 4 and evaluates the duration to 4, however, if any of the activities should be delayed, the Milestone II would delay

The Monte Carlo Simulation and Risk Analysis

Replicazioni	Attività 1 Uniforme 3 - 8 Continua	Attività 2 Exp.Neg 3 Continua	Attività 3 Gaussiana 6, 1 Continua	Attività 4 Uniforme 5,11,14,17 Discreta	Attività 2 Deterministica 5 Continua	Singolo Run Durata Totale
1	5.5	2.9	4.8	5.0	5.0	23.24
2	3.6	1.9	6.1	11.0	5.0	27.59
3	3.4	0.6	7.2	14.0	5.0	30.22
4	5.2	5.4	7.0	17.0	5.0	39.57
5	7.3	2.7	6.3	11.0	5.0	32.34
6	3.4	2.1	7.3	17.0	5.0	34.78
7	7.6	7.0	5.9	14.0	5.0	39.42
8	7.7	12.5	6.3	14.0	5.0	45.59
9	5.6	7.9	4.9	5.0	5.0	28.39
10	4.2	0.2	6.1	17.0	5.0	32.45
11	3.8	2.3	7.1	17.0	5.0	35.14
12	6.4	0.3	5.4	11.0	5.0	27.96
13	7.8	0.1	4.9	5.0	5.0	22.77
14	5.7	3.5	5.8	5.0	5.0	25.03
15	3.2	0.2	6.1	17.0	5.0	31.50
16	5.4	0.3	4.2	5.0	5.0	19.85
17	6.6	2.1	4.0	17.0	5.0	34.63
18	4.2	0.8	8.0	14.0	5.0	32.06
19	6.3	6.2	6.4	14.0	5.0	37.85
20	6.4	0.3	7.2	14.0	5.0	32.92
21	6.6	0.2	7.4	5.0	5.0	24.13
22	7.0	0.9	6.0	17.0	5.0	35.86
23	4.2	4.6	5.1	5.0	5.0	23.88
24	3.1	5.5	6.4	17.0	5.0	37.09
25	6.8	0.2	9.1	17.0	5.0	38.07
26	4.1	1.3	5.8	11.0	5.0	27.20
27	5.1	10.6	6.3	11.0	5.0	37.98
28	3.0	2.5	6.3	17.0	5.0	33.91
29	3.9	3.3	6.6	5.0	5.0	23.77
30	5.1	13.0	6.3	14.0	5.0	43.44
31	5.7	5.3	6.6	11.0	5.0	33.65
32	4.4	0.1	4.6	5.0	5.0	19.04
33	6.4	1.7	6.0	11.0	5.0	30.06
34	5.1	5.5	5.6	5.0	5.0	26.23
35	5.3	2.1	6.4	11.0	5.0	29.81
36	6.9	0.8	5.6	14.0	5.0	32.22
37	5.2	0.2	5.7	11.0	5.0	27.11
38	4.2	2.4	6.6	5.0	5.0	23.13
39	4.9	2.0	5.0	14.0	5.0	30.85
40	4.5	0.5	6.5	11.0	5.0	27.47
41	4.2	4.4	7.4	14.0	5.0	34.96
42	4.3	0.1	5.5	14.0	5.0	28.89

CONSUNTIVO PROGETTO	Media	31.0
42 Replicazioni	Scarto	6.1

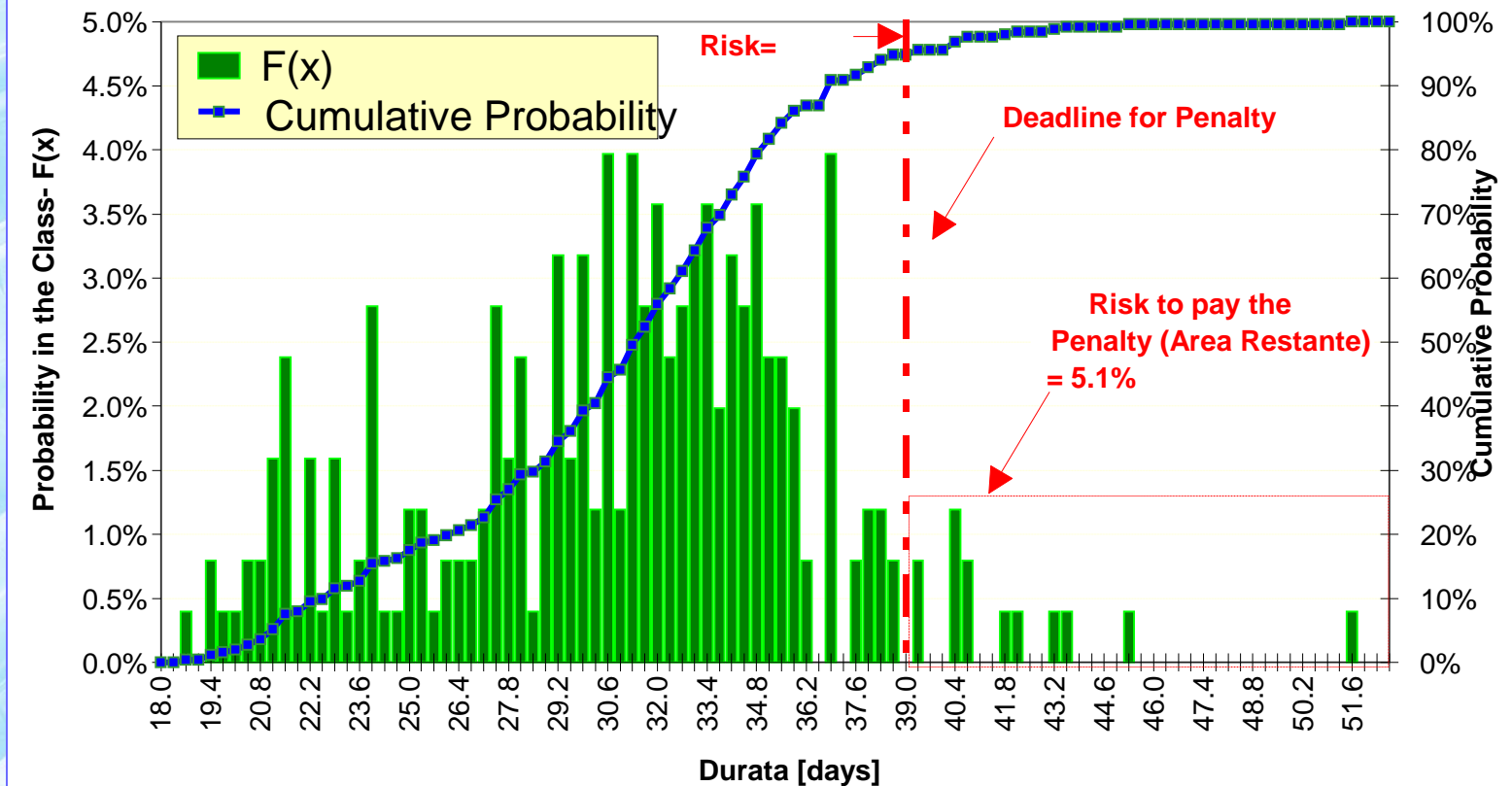
The Monte Carlo method is among stochastic simulation types one of the most simple and traditional more common in the PM.

Start by defining each variable (i.e. duration or cost) in term of statistical distributions (continuous, discrete - beta, normal, exp neg., etc.). Then proceed carrying out n replications by extracting each time values of the corresponding distributions; at the end of n run replicated an overall assessment is made (average, standard deviation, maximum, min, probability distribution, etc..)

Total Risk Determination

Using the simulation it is possible to estimate the overall risk (i.e. a total duration of the project). The key result is the determination of the cumulative probability curve of the problem.

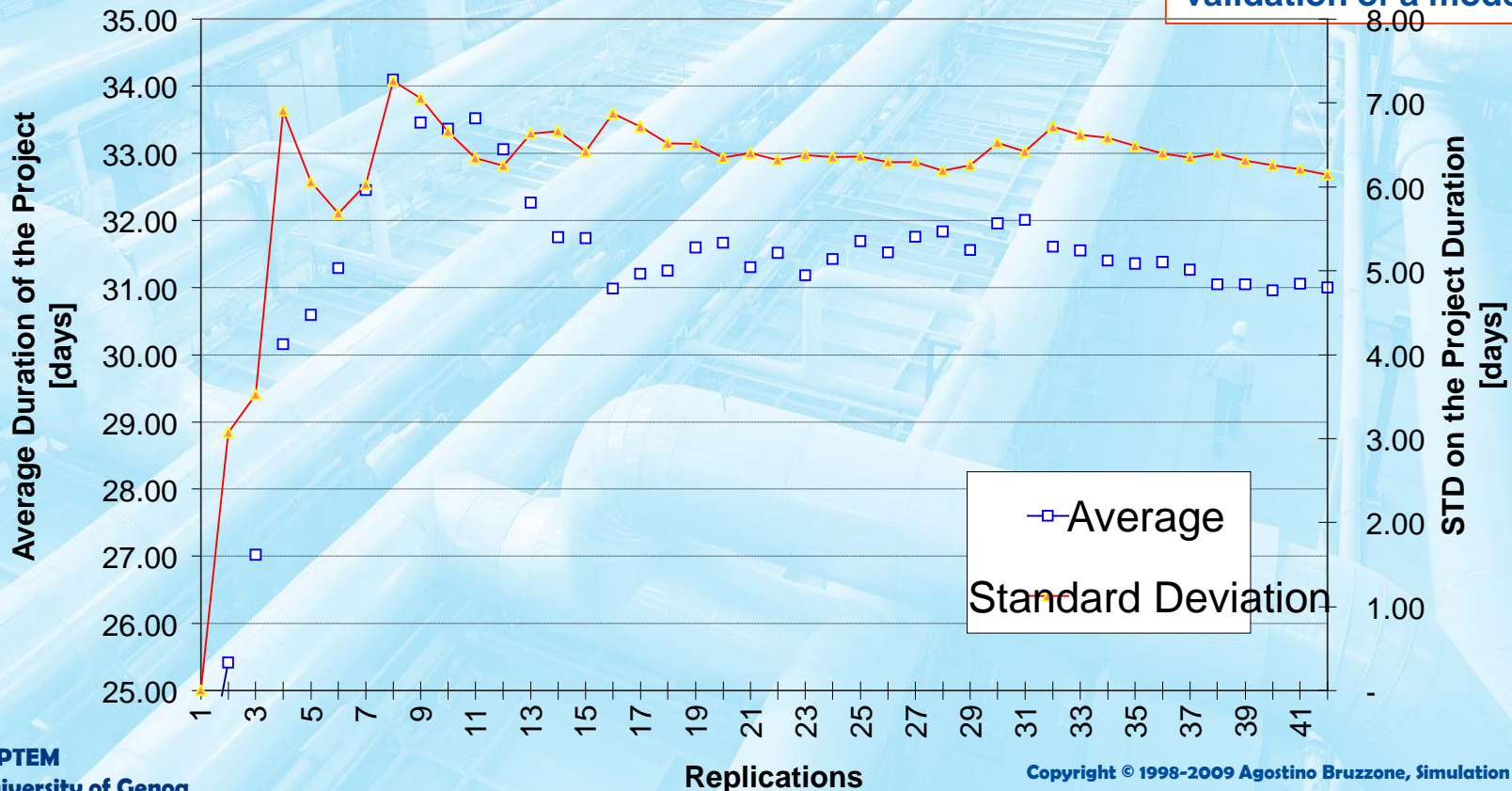
Probability Distribution by Simulator



Monte Carlo Simulation and Replications

The use of the Monte Carlo method requires a careful calibration of the number of replications for the verification and complete validation of a model.

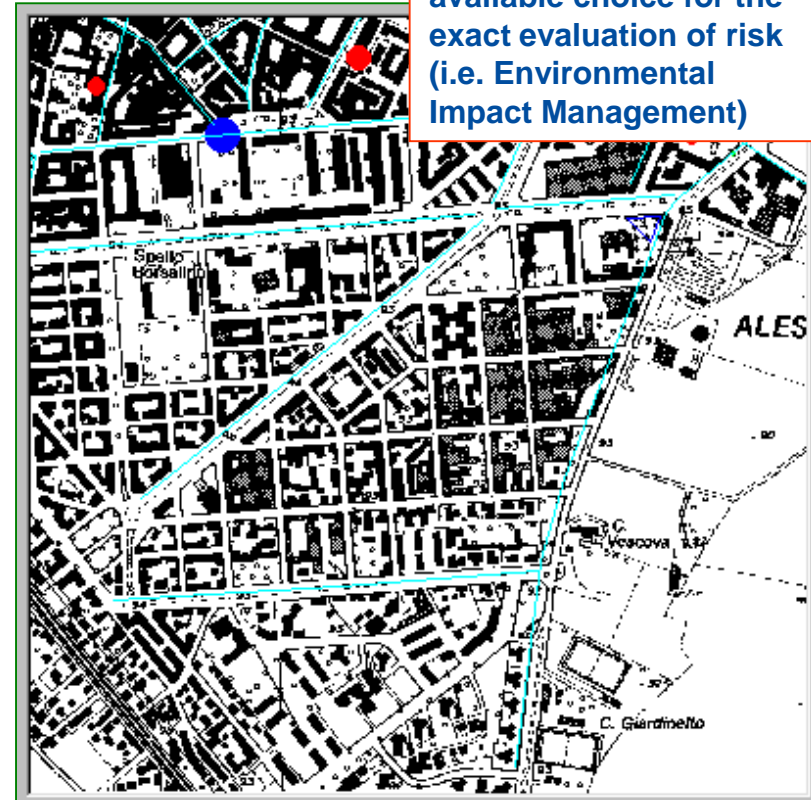
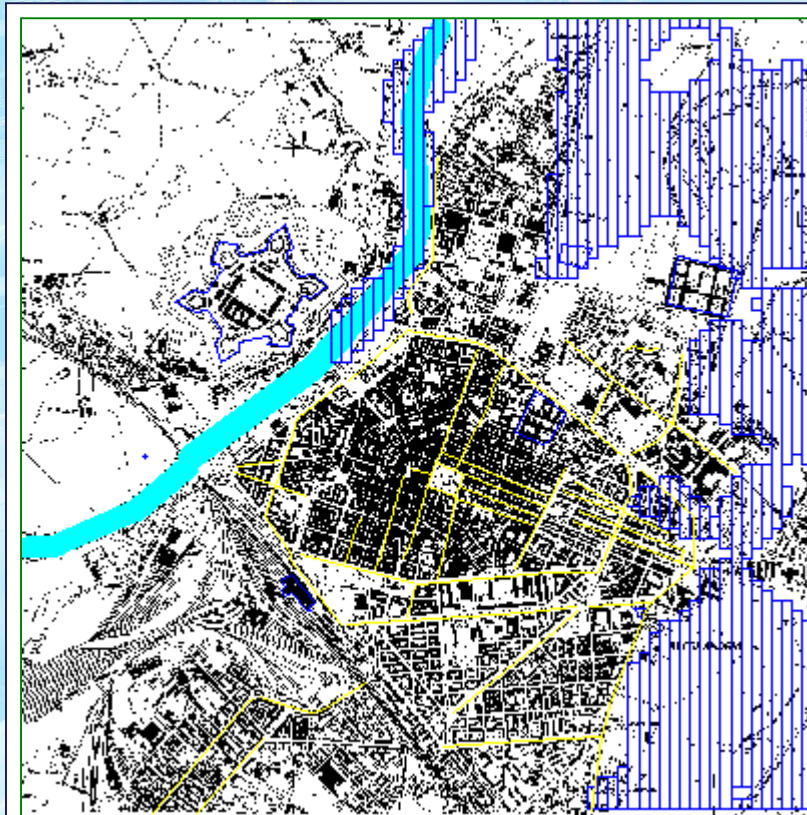
**Replication Number Influence
On estimations by Montecarlo Methods**



□ Average
△ Standard Deviation

The Simulation for Environmental Risks

Often the simulation models are the only available choice for the exact evaluation of risk (i.e. Environmental Impact Management)



CIPROS

Simulation Models detailed for risk assessment and consequences: i.e. emergency and incidents in industrial plants (Hazardous Material Spills, Fires, Explosions)

Ranking List of the Risks

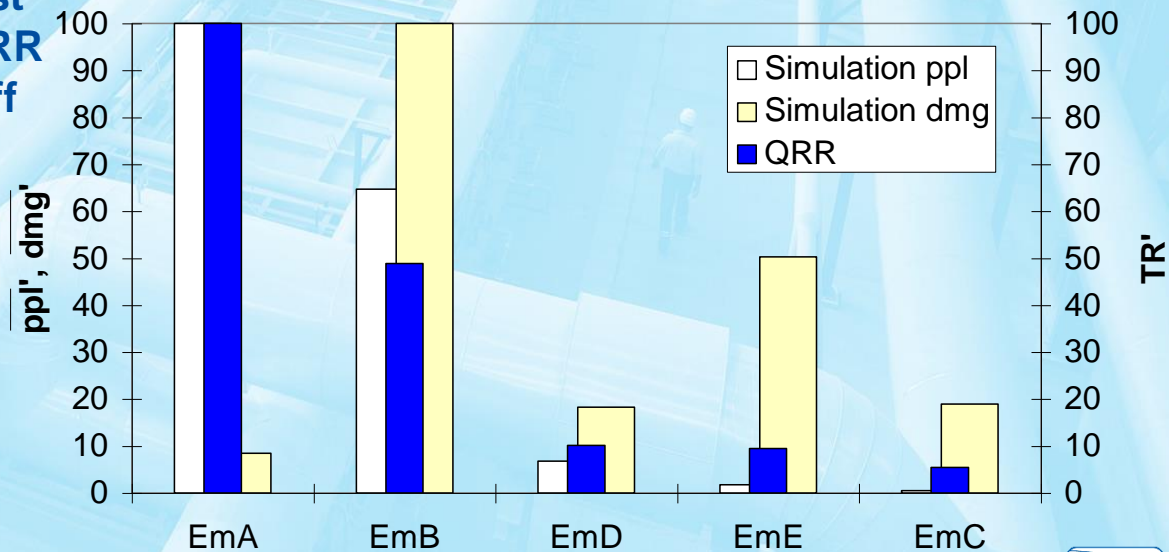
Create a ranking list of risks is very important specially for the Risks related to security; In fact safety regulations requires it even if there are not techniques for its preparation

Below an innovative technique (QRR) which is achieving good results. The comparison by disasters is compared through the simulation considering both the physical damages (dmg) that people (ppl)

We note that the ranking list of the simulator and the QRR are consistent with the staff (same order).

- Em_A *Spill from a Chemical Plant*
- Em *Fires in a Chemical Plant:*
- B *Hazardous Material Area*
- C *Administrative Buildings*
- D *Loading/unloading area*
- Em_E *River Flooding in Chemical Plant*

Comparison QRR & Simulation



Fuzzy Techniques for the QRR

Qualitative Risk Ranking is a technique using Fuzzy Logic to create the ranking list of the sources of risk

In order to evaluate the frequency, the exposition to a risk is defined as:

$Ex_i = FAM_{ex} (Nex_i, Dex_i)$	
Ex_i	Exposure to i-th risk
FAM_{ex}	Fuzzy Allocation Matrix (FAM) for Exposure
Nex_i	Number of exposures in one year
Dex_i	Average Duration of the exposures

It is necessary to consider the possibility that a risk is combined to other situations :

$DE_{ij} = FAM_{de} (Tr_j, NO_{ij})$	
DE_{ij}	Concurrency of i and j
FAM_{de}	FAM for correlations evaluation
Tr_j	Total stand-alone risk of j-th
NO_{ij}	Correlations between i and j

For each source of Risk, Ex represents the probability to generate the required boundary conditions.

The probability of the event occurrence is:

$$Pr_i = Fpr (Hda_i)$$

Pr_i	Historical Experience on i-th accident
Fpr	Fuzzy Function for evaluating Historical Data
Hda_i	Number of Historical accidents for the i-th risk [accidents/year]

The possibility to stop an event if it happens is:

$$Ss_i = FAM_{ss} (Ps_i, Sp_i)$$

Ss_i	Possibility to stop the i-th accident
FAM_{ss}	FAM for stop danger situation
Ps_i	Protection system effectiveness against the i-th risk [percentage of success]
Sp_i	Speed of the accident [s]

The possibility to prevent an incident by staff is evaluated as combination of experience/training and alerts/notices:

$$Rc_i = TABrc(Oex_i, Sex_i)$$

Rc_i	Risk Perception for i-th risk
$TABrc$	Correlation Table (TAB) for perception
Oex_i	Operator Experience for i-th risk
Sex_i	Advice and Signals for i-th risk

Fuzzy Allocation Matrix & Risk

The Risks Components are expressed as:

Magnitude
Frequency/Probability

These factors could be estimated as combination of fuzzy variables.



Fuzzy Set:

- Triangular Membership Funct.
- 25% Overlapping
- 7 Membership Grades

Fuzzy Allocation Matrix

$x_2 \backslash x_1$	NL	NM	NS	ZE	PS	PM	PL
NL	PL	PL	PL	PL	PM	PS	ZE
NM	PL	PL	PM	PM	PS	ZE	NS
NS	PL	PM	PS	PS	NS	NM	NL
ZE	PL	PM	PS	ZE	NS	NM	NL
PS	PL	PM	PS	NS	NS	NM	NM
PM	PM	ZE	NS	NM	NM	NL	NL
PL	ZE	NS	NM	NL	NL	NL	NL

Y

Center of Sums Method

$$z = \frac{\sum_{i=1}^l \left\{ u_i \cdot \sum_{k=1}^n [\mu_{clu}(k)] \cdot (\mu_i) \right\}}{\sum_{i=1}^l \sum_{k=1}^n [\mu_{clu}(k)] \cdot (\mu_i)}$$

l: Number of Elements with a positive value

u_i: i-th proposed Solution

clu: membership grade of k-th rule

QRR: Combination of Results

Risk evaluation is computed as:

Dm_i	= $FAM_{dm} (Np_i, Sk_i)$
Dm_i	Consequences of the i-th accident
FAM_{dm}	FAM for consequence estimation
Np_i	Average number of people that may be involved in the accident
Sk_i	Vulnerability to the i-th accident (i.e. shock, injuries, death)

This procedure provides a ranking list based on *Tri* values that however should be analyzed in a relative sense.

The QRR technique is A technique to give a method for the qualitative analysis of risks by using measurable data

$$Fr_i = \frac{\left(Ex_i + \frac{kp}{Rc_i} + Pr_i \right)}{Ss_i}$$

kp Coefficient for perception inverse proportionality to accident frequency

$$Tr_i = Fr_i Dm_i$$

$$Mr_i = Dm_i + \sum_{j=1,n} DE_{ij}$$

$$TR_i = Fr_i Mr_i$$

TR_i Total Risk connected with the i-th potential accident

Risks Evaluation Results

Opportunities to be exploited, Risks to be managed

The list of all potential opportunities to be exploited and all risks to be monitored with the related qualitative assessments and performed calculations

Opportunities to be ignored, risks to be accepted

It is necessary also to document the sources of risks and / or risk events that the PMT decides to accept and / or ignore consciously as well as the criteria that led to this decision and the decision responsible.

Risk Management Planning

The risk management includes both good opportunities and risks; in this case we can assume three kinds of reactions

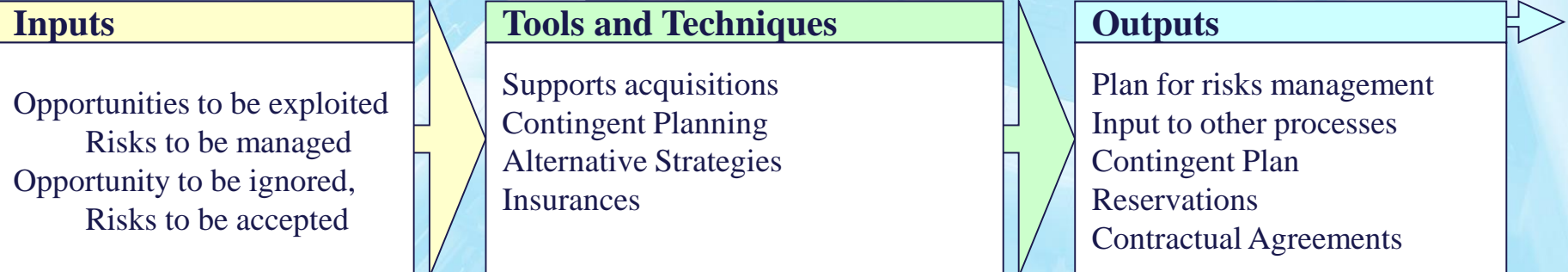
Avoid the risk: normally by deleting the causes (it is not possible to eliminate all the risks).

Mitigate Damages: Plan in order to reduce damages (i.e. EMV) in case of negative event by acting on its probability (i.e. using more known technology respect of completely innovative) or on its entity (i.e. insurances)

Risk Acceptance: Acceptance of risk consequences may be active (planning to face it) o passive (accept losses).

Input are the results of the quantitative analysis of the risks.

Risk Management Planning



Techniques and Tools for Risks Management

Acquisitions

Usually it is possible to reduce risks by acquiring skills, resources, materials, know how (i.e. for instance to buy burner insert instead that producing them directly considering that it is an not common product for the company)
Obviously this introduce a shift from internal to external risk in term of delivery time and costs.

Contingency Planning

The definition of all procedures and activities to be done in case the risk become real, these plans are sometime defined as SOP (Standing Operative Procedures).

Alternative Strategies

by changing approach and Project Plan it becomes possible to reduce, or cancel, some kind of risk (i.e. sequential engineering program instead vs. concurrent engineering)

Insurance

Insurance agreements are common techniques devoted to reduce specific kind of risk; these change in term of costs and capabilities case by case

Risk Management Output

Risk Management Plan

It includes a summary of everything discussed, including the name of responsible to manage the different areas of risk.

Inputs to Other Processes

Notices to all processes with the procedures and activities to be implemented in case of risk

Contingency Plans

Procedural steps to be implemented for each risk; they are often part of risk management plan, but are also normally included in parts of the project Plan.

Contingencies

Margins have held up in order to mitigate damages, they are normally economic (cost per action), the temporal nature (to act on program).

Contractual Agreements

These involve services, insurance, contract terms that ensure to reduce the overall risk of the project

Risk Control: In, Out e Tools

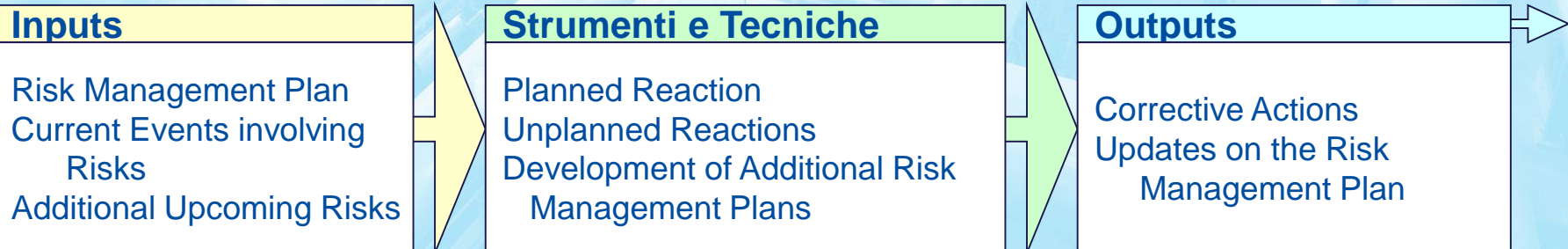
The control of the response to risk is the executive management of risks devoted to react to events in an effective way.

Risk Control is based on the risk management plan, on current events and on any new risks that are identified during project execution.

It is necessary to proceed through planned and unplanned reactions by operating on events immediately and through the development of new systems devoted to manage the risks.

In the output we get the corrective actions to implement and any changes and additions plan to manage risks, and these often involve a continuous evaluation of the level of risk of events refined along the course of the project in order to support strategic and operational decision making.

Plans to Control Risk Evolution



Project Procurement Management

This Management Activity involves all the procurement procedures for goods, materials or services from actors different from the contractor

- **Procurement Planning**

To identify and define what to buy from suppliers and when to do it

- **Solicitation Planning**

To Define the Procedures for Soliciting and Selecting the Providers

- **Solicitation**

To obtain quotations, estimations and proposals

- **Supplier Selection**

To select suppliers among the potential providers

- **Contract Administration**

To manage the relationship with Supplier and Sub Contractors

- **Contract Closure**

To close the contract by achieving formal completion

In this phase a customer of the project is identified, a supplier of components and a contractor devoted to manage the project; often it is possible to have several contractors operating concurrently and/or subcontractors that are directly involved in the contract

Project Procurement Management

9.1 Pianificazione Forniture

.1 Inputs

- .1 Definizioni Obiettivi
- .2 Descrizione Prodotto
- .3 I Fornitori Disponibili
- .4 La situazione di mercato
- .5 Altri Output dal Planning
- .6 Vincoli ed Ipotesi

.2 Strumenti e Tecniche

- .1 Analisi Make-or-Buy
- .2 Giudizi di Esperti
- .3 Tipologie di Contratto

.3 Outputs

- .1 Piano Gestione Forniture
- .2 SOW per le forniture

9.2 Pianificazione Richieste di Offerta

.1 Inputs

- .1 Piano Gestione Forniture
- .2 SOW Componente
- .3 Altri Output dal Planning

.2 Strumenti e Tecniche

- .1 Modulistica Standard
- .2 Giudizio di Esperti

.3 Outputs

- .1 Documenti per la richiesta di Forniture
- .2 Criteri Valutativi
- .3 SOW Updates

9.3 Acquisizione Offerte/Proposte

.1 Inputs

- .1 Documenti per la richiesta delle Offerte
- .2 Liste di Fornitori Qualificati

.2 Strumenti e Tecniche

- .1 Meeting con i Fornitori
- .2 Pubblicità' alla richiesta di Fornitura

.3 Outputs

- .1 Proposte dai Fornitori

9.4 Selezione dei Fornitori

.1 Inputs

- .1 Proposte dai Fornitori
- .2 Criteri di valutazione
- .3 Politiche della Struttura Organizzativa

.2 Strumenti e Tecniche

- .1 Negoziazione dei Contratti
- .2 Weighting System
- .3 Screening System
- .4 Stime Indipendenti

.3 Outputs

- .1 Contratti di Fornitura

9.5 Gestione dei Contratti Fornitori

.1 Inputs

- .1 Contratti di Fornitura
- .2 Risultati dei Lavori
- .3 Evoluzione nelle Richieste
- .3 Fatture del Fornitore

.2 Strumenti e Tecniche

- .1 Sistema di Controllo Cambi del Contratto
- .2 Performance Reporting
- .3 Sistema di pagamento

.3 Outputs

- .1 Corrispondenza
- .2 Cambi al Contratto di Fornitura
- .3 Richieste di pagamento

9.6 Chiusura dei Contratti

.1 Inputs

- .1 Documentazione del Contratto

.2 Strumenti e Tecniche

- .1 Controlli sulle Forniture

.3 Outputs

- .1 Archiviazione Contratti
- .2 Accettazione Formale e chiusura della Fornitura

Procurement Planning: Input, Out and Tools

The procurement planning is devoted to identify the components and services that it is convenient to acquire externally.

Often we tend to keep the know-how (knowledge) valuable in-house (ie the turbine design and give out the piping in power plants).

If the customer wants to influence directly the decisions of potential suppliers, or if you want to involve more directly the suppliers may be convenient to use subcontracting systems and have sub-contractors.

The assessment is based on the product description and objectives combined with a broad analysis of potential suppliers available (taking into account the market place and time of delivery) as well as any constraints on the choice of suppliers and assumptions about time and costs, together with any assessments of the phases of planning.



Techniques and Tools for Procurement Planning

Make-or-Buy Analysis

It is necessary to evaluate the convenience (economic, image, quality, etc) of external purchasing services/goods/materials/components
This is very common in projects due to the fact that time constraints that requires big attention in investing on new skills/equipment

Expert Evaluation

It is often very useful to use expert to evaluate possible suppliers and related benefits in outsourcing

Contract Solution Selection

There are many contractual solutions; usually these could be summarized in the following three types:

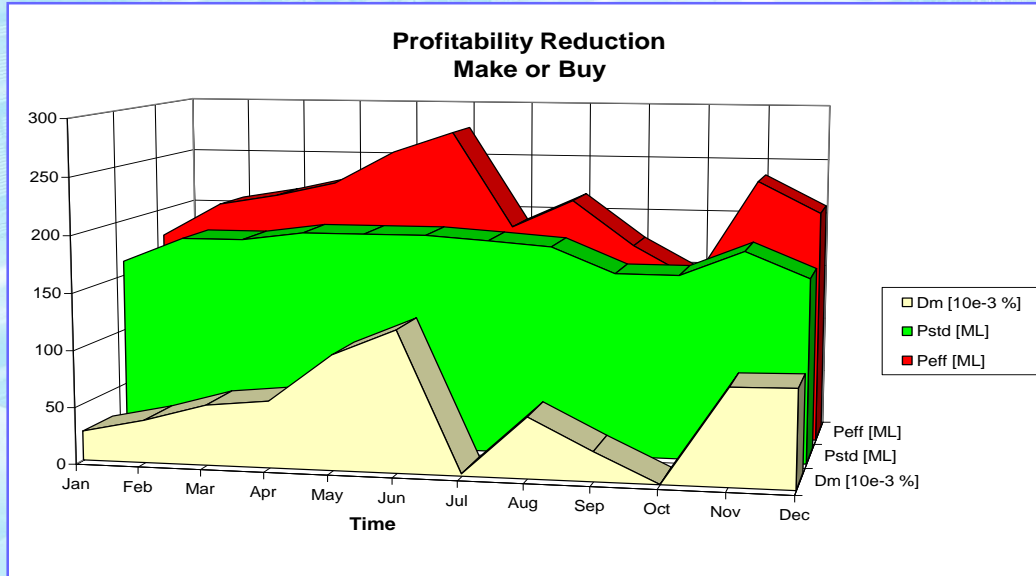
Fixed Price: fixed price for a well defined product/service; if the service is not well defined a risk could emerge for both supplier and contractor

Reimbursable: supplier is repaid while the costs are sustained; direct costs (i.e. working hours) are refunded while indirect costs (i.e. overheads) are estimated usually as percentage of the overall direct costs.

Unit Cost: it is defined an unitary cost and the total is estimated based on this references; for instance 300 Euro/h for consulting or 1 kEuro/kg for carpentry

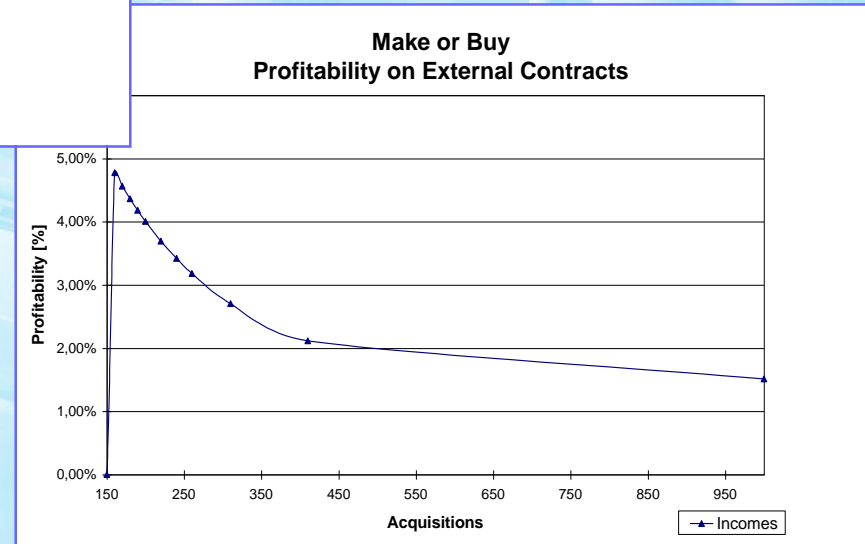
There is always the possibility to define incentives for overpassing the basic requirements

Losing Profits by Excessive Sub-Contracting



Increasing the subcontracts it becomes possible to acquire and manage more projects, by this involve often the necessity to give out a part of profits

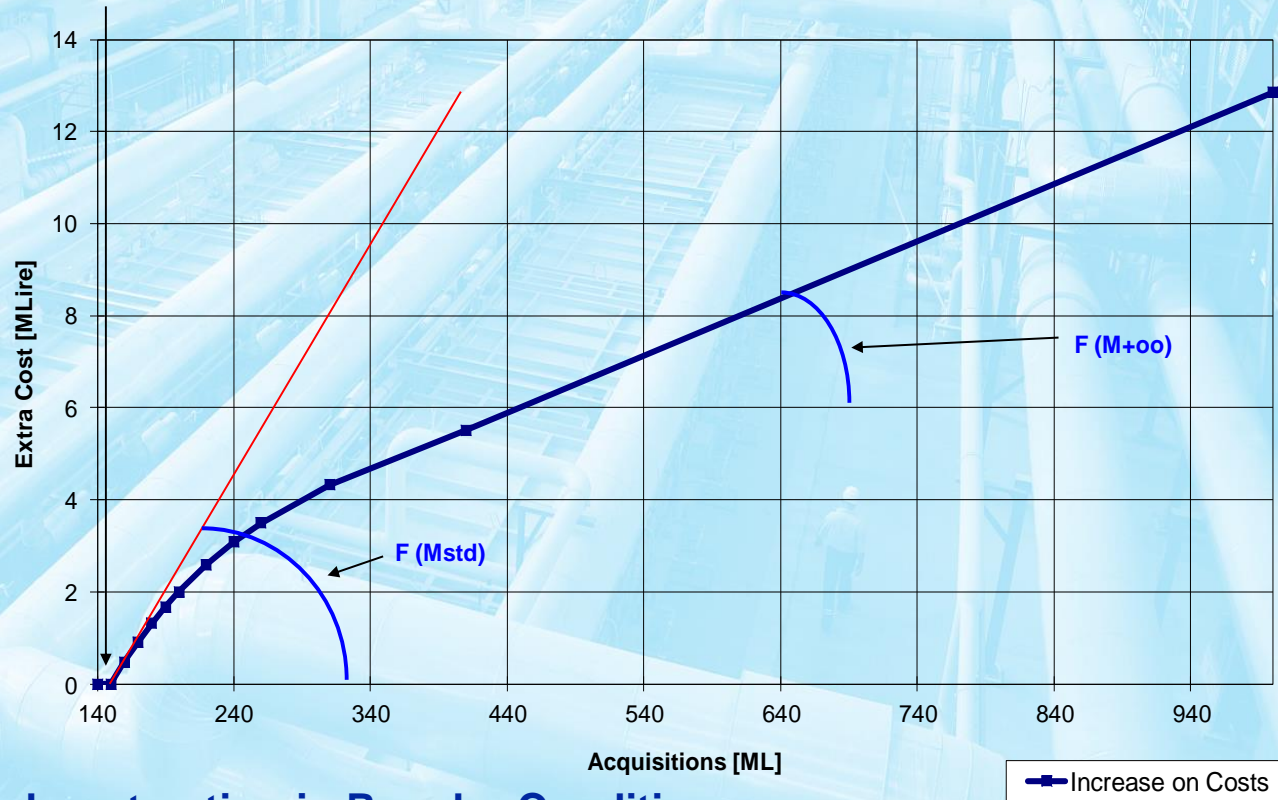
If a company is well structured for its activities, the margin on projects tends to decrease asymptotically to a trading value as outsourcing increases



Margins on Subcontracts

Balanced Situation

Make or Buy
Total Extra Costs



It is evident that by operating on different markets, the preventive coefficients M_{std} and M^* are different and it is required eventually and additional computation

M_{std}
 M^*

Margins on Subcontracting in Regular Conditions.
Limit Margin for Sub-Contracts in case of total Outsource

Output of Purchasing Planning

Purchasing Plan

It describes the elements of the project that require outsourcing (request for quotation, request for proposal, proposal selection, contract solutions etc.) For instance it is defined the type of contract for the different kind of outsourcing and it is identified who is in charge to prepare the proposal, the activities to be attributed to PMT and that one for the contractor administration

Statement of Work (SOW) for each Outsourcing

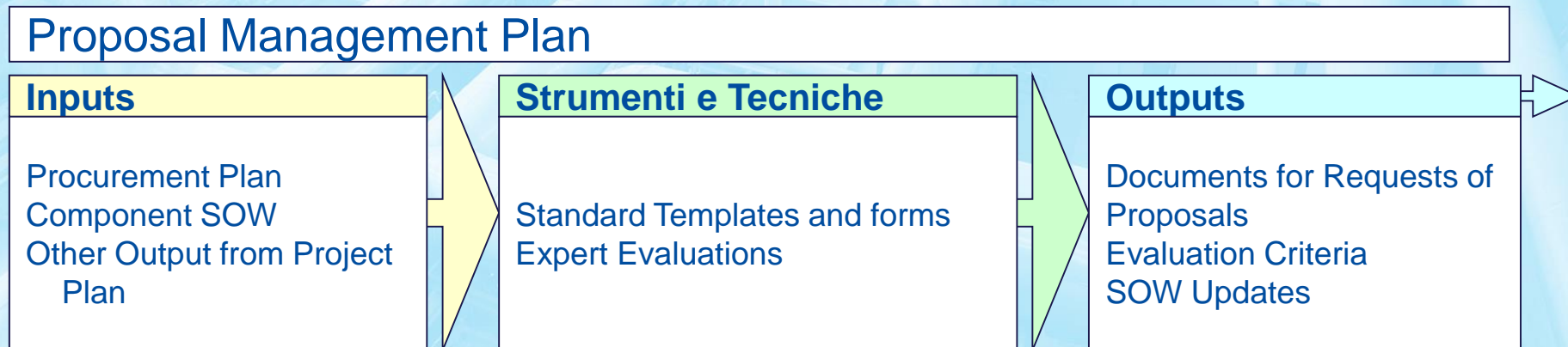
All the outsourcing need to be finalized by a statement of work clear and detailed; sometime the difference in this framework it is between SOW and SOR (Statement of Requirements) the first describes a component the second a problem to be solved (*i.e. Project Mk.46 SOW data on the torpedo body vs. SOR requirements for guidance system in term of precision and capability to engage targets etc.*)

It is critical to define it clearly and to involve the suppliers in the process to be sure that the purchasing results to be convenient and reliable in term of costs, risks, quality and etc.

Proposal Management Plan: *In, Out & Tools*

This is to prepare documents and procedures to manage bids and proposals from suppliers; the plan is based obviously on purchasing plan and on the defined SOW for all components, as well as on all estimates of cost and time obtained from the planning to ensure that the requests include deadlines on time delivery, cost and contractual constraints appropriate for the project.

It uses all the basic forms if available: ie request for standard offer, standard contracts, standard descriptions of components, framework agreements with suppliers, in addition it is possible to require additional estimates from experts as evaluation criteria and verification of the completeness of the applications.



Results of the Proposal Planning for Outsourcing

Documents for Offer Application

All documents necessary to request a quotation, including of course the SOW. In English we use the term sometimes Bid or Quotation if the request is in nature economic (ie cost of plumbing standards) and Proposal if it involves also involves not economic factors (ie feasibility of a new control system); in Italian bid and proposal have these meanings, however, the terms are often understood as equivalent; acronyms includes IFB (invitation for Bid), RFP (request for Proposal), RFQ (Request for Quotation), Invitation for Negotiation, and Contractor Initial response.

Evaluative criteria

To evaluate and compare the proposals by an objective process (ie the PM must be a certified project manager, the provider must be ISO9000) or subjective (the proposal must come from a company with experience in the field). You can only use the acquisition cost (complete with ancillary expenses: ie transportation) for these estimates, if this is a component available and simple; therefore it is possible to relate to factors such as: understanding of the project goals by the supplier, the life cycle cost of the component, technical capacity, managerial capacity, financial capacity etc.

SOW Updates

Updates to the SOW based on the examination made in bidder documentation preparation

Collecting Proposals and Quotations from Suppliers

This process leads to get offers from potential suppliers. With documentation and prepared lists of qualified suppliers (ie managed by the company's quality system, or investigations in industry associations and scientific societies) it is possible to require formal bids. Often it is useful to adopt so-called Bidder's Conference (Conference Contractor, Vendor Conference, Pre-Bid Conference) who are meeting with potential suppliers before finalizing the proposal; these ensure that the supplier properly understand the expectations of the contractor, and often reports on these meetings are reported as additions to the tender documentation. If a goal is to extend the list of potential suppliers, it is possible to request additional supplies through advertisements (ie often required by government contracts for subcontracting). At the end of this phase the proposals of suppliers are collected

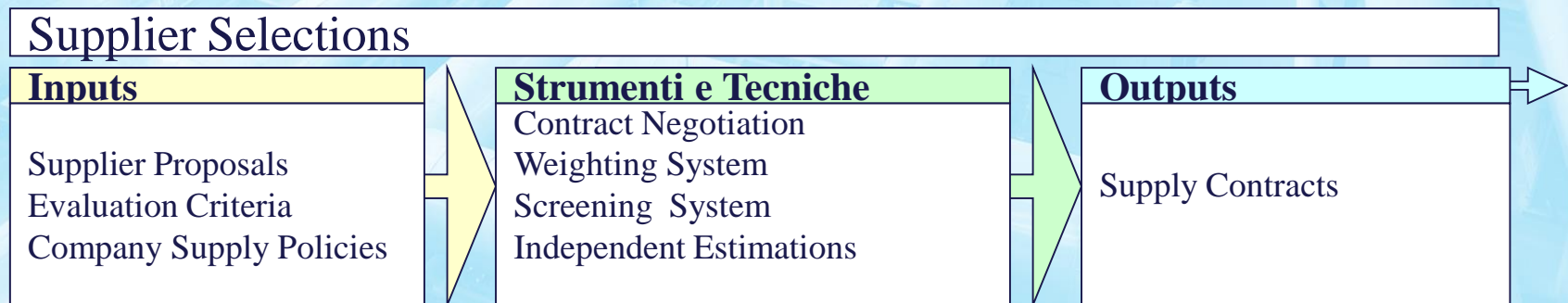


Supplier Selection

The vendor selection involves the receipt of proposals and the selection based on predefined criteria and logic schemes; it is necessary to consider among other things:

- The lower price may not be the least cost (ie delays in delivery resulting in increased costs)
- Initially, the technical part of tenders must be evaluated separately from the commercial elements
- Products may require more critical suppliers to ensure the project success

Usually, it shall be useful to make an initial selection and to proceed through review of remaining potential suppliers. Input are obtained using proposals, evaluation criteria and organizational policies for supply contract management; sometimes these policies are binding the project management (i.e. you buy only from suppliers accredited unless they



Techniques and Tools for Supplier Selection

Negotiations

Mutual agreements, clarifications and details for refining the contract before the signature based on bilateral agreements between supplier and main contractor. For complex contracts, this could become an autonomous process.

Weighting System

This is a method for quantifying qualitative information and it allows to minimize the influence of personal bias, most of these systems are expected to assign a weight to each evaluation element and to evaluate each bid based on a score obtained by a weighted sum

Screening System

This is a system based on determining the minimum specifications in terms of performance proposed by the supplier in order to select just one part tender (ie we exclude all those who come from companies with less than 10 employees, or do not plan to provide drawings on CD).

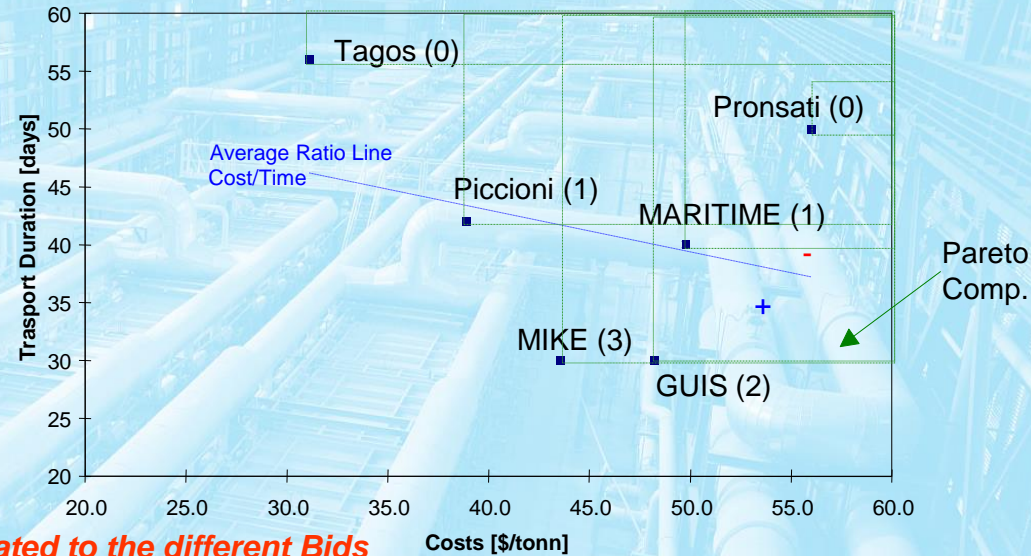
Independent estimates (how much it should cost)

For many supplies you need to make an independent assessment by internal company resources to prepare a cost estimate and compare it with that of suppliers in order to highlight errors or misunderstandings in the SOW and risks.

Example

In this case it is proposed an example of analysis of suppliers for the transport service of a boiler from Civitavecchia to Yalta, as shown by the method without weights the winner result to be a company that would be eliminated if screening had initial required previous experiences.

Supplier Comparison



Initial Data related to the different Bids

	Costo [\$/ton]	Durata Op. [days]	Mezzi Propri	Fatturato [m\$]	Esperienze Precedenti
Piccioni	38.9	42	No	150	Si
Pronsati	56.0	50	No	non noto	Si
MIKE	48.2	30	No	70	No
Targos	31.1	56	Si	65	No
MARITIME	49.8	40	Si	~400	Si
GUI5	43.6	30	Si	>200	No

	Solo Costo	Solo Tempi	Linea Media	Costi x Tempi	Lavori Precenti	Navi Proprie	Pareto Comp.	Fatturato	TOTALE
Weight	16%	16%	32%	8%	8%	4%	12%	4%	100%
Piccioni	0.32	0.64	0.32	0.32	0.08	0.16	0.36	0.12	2.32
Pronsati	0.96	0.8	1.28	0.48	0.08	0.16	0.6	0.24	4.6
MIKE	0.48	0.16	0.32	0.24	0.32	0.16	0.12	0.16	1.96
Targos	0.16	0.96	1.28	0.16	0.32	0.04	0.6	0.2	3.72
MARITIME	0.8	0.48	1.28	0.4	0.08	0.04	0.36	0.04	3.48
GUI5	0.64	0.16	0.32	0.08	0.32	0.04	0.24	0.04	1.84



Ranking list for Suppliers based on different Criteria

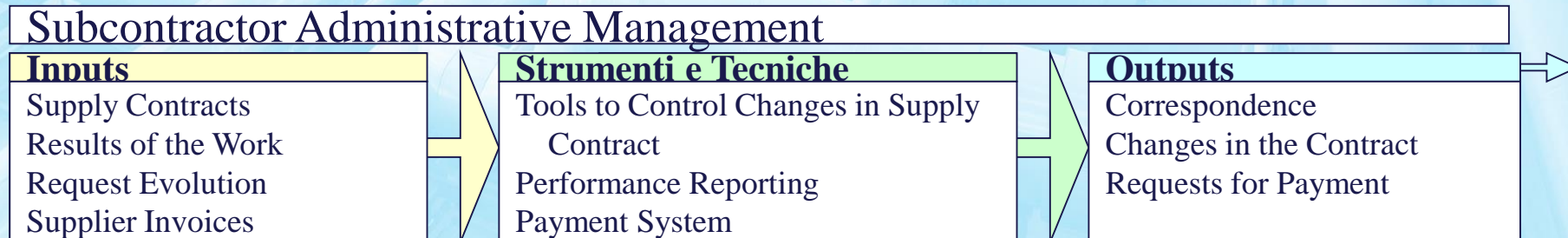
Results on Supplier Selection: Supply Contracts

Contracts of Supply

These are the bilateral agreements which obligate the supplier to provide a defined product and the buyer to purchase it by paying an established fee . The contracts are legal agreements, they are subject to be evaluated in the court, it is critical to clarify exactly who is authorized to sign and to be aware of the related implications. Once signed the contract, future claims could be solved on the basis of direct negotiations or in judgment, with additional costs, time and related consequences. The Contract for a project can be very large (ie contract of a plant in 24 volumes) or very simple (ie the contract Buying a PC on page 1 on the offer received).

Supply Administration

The objective of this process is to ensure that the performance of the supplier meets the customer. For large projects, there being many suppliers have to organize an effective system to manage and maintain communications and controls. Since the contracts are legal agreements is imperative that the PMT is always thoroughly aware of the legal implications of the agreements made. Management of Contracts Suppliers includes the application of PM processes for the integration of output (ie Project Execution Plan to authorize the supplier to perform the work when necessary, performance reporting, cost control and the timing of the provider relative to controls quality on the supply, control of changes to alert suppliers on time). It is based on the terms of contract of course, the results of the work, of any request for change (ie any decision to cancel a supply for poor quality), the complaints are usually referred as claims. The vendor sends invoices to be paid periodically, usually according to arrangements defined in the contract.



Results and Tools for SubContract Management

Results of Supplu Management

Management Tools

Control System for Changes on Supply Contract

These are all the processes, documents and authorizations required to manage change in contracts, to be integrated into the general management changes

Performance Reporting

The service provider must be continually monitored and provided the PMT to coordinate the relationship between supplier and check the project, similar control of internal performance

Payments System

Payments are normally managed by the provider of main contractor, if the project is very complex can be managed a project structure, but in any case, the PMT should handle the approvals on the basis of an effective and efficient.

Correspondence

All communications between supplier and purchaser, to be used as warnings of dissatisfaction, clarifications etc.

Changes to Contract

The changes may be approved or not approved, but must still be documented and known to the PMT

Requests for Payment

If approved the work and the payment is made by the administration of the main contractor, the PMT emits requests for payment to suppliers

Certification of Project Managers

Nowadays there are several possibilities for the Project Manager to obtain an international certification, there are two associations, one American and one English that provide certificates on the basis of tests that must be renewed periodically (2 years).

The American approach provides a generic certificate of PM while the European / English is specific kind of activity '(ie construction rather than manufacturing.)

The certificate requires an internal company certifying experience in the field of Project Manager, requested training courses and passing the exam.

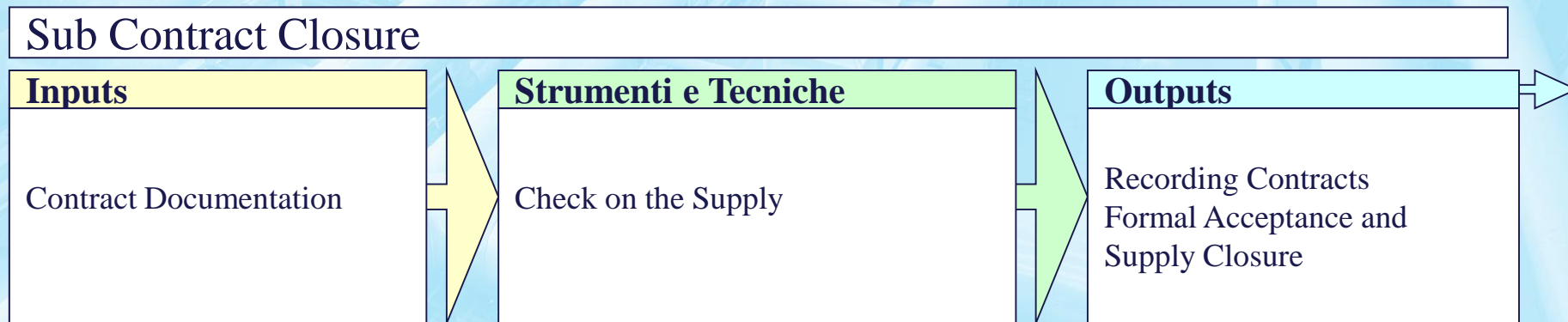
Italy in Europe has not yet adopted extensively this process in contrast to France, UK, Germany and Holland

SubContract Closure

Likewise the internal closure activities, the subcontracting must be carried out at the end of the supply, of course it is critical to make sure that this has been done properly and in the time in respect of all requirements; so closure includes a supply review and an administrative closure, often in the contract it is even possible to proceed in early closure of supply by a specific procedure. As Input all documentation of the subContract is used (scheduling, Technical documents etc.)

Usually it is planned to implement a control and review process by both technical and administrative checks to verify the success of the subcontract.

As results the administration proceeds to record contracts in order to add the project files, as well as to finalize the formal acceptance of deliveries by the manager through written notice of completion of delivery (as is often required by the contract).



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