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IPPA

INVESTMENT PROJECT PREPARATION AND APPRAISAL

TEACHING MATERIALS

Module 3

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Developed by
Industrial Promotion and Technology Branch (UNIDO)
in cooperation with the Inter-Regional Centre for Entrepreneurship
and Investment Training (EDII, Ahmedabad)

Technical Analysis

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IPPA Teaching Materials

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2005

MODULE 3 – TECHNICAL ANALYSIS

CONTENTS

Related Documents

INTRODUCTION

TECHNICAL ANALYSIS

Engineering and other technical aspects of the project development should begin during the planning stages. A production process must be designed; a technology and the related machinery and equipment selected; a site selected and developed; estimates of capital and operating costs provided for financial analysis. Consultation with technical experts may be appropriate. In the appraisal process technical aspects are compared with criteria of interested parties.

If the project is approved for investment detailed engineering is required. An implementation plan must be developed and then the actual construction and installations managed. Technical expertise may be required to manage the production process, to deal with plant maintenance and for product development. If the plant is to be decommissioned, there is a need for a plan and its management.

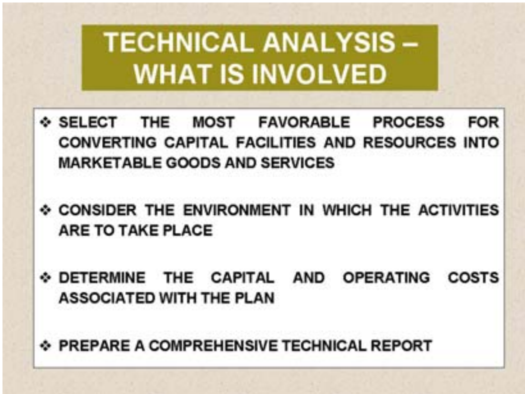
Although the costs are usually significant, risk is reduced when project sponsors secure appropriate technical expertise to deal with the major design and implementation aspects. If at all possible, engineers and technicians commissioned to design the physical plant and operating systems and to manage the implementation (and decommissioning if applicable) should be experienced in the project's industrial sub-sector.

The engineering and technical analysis answers the following questions:

- What is the most appropriate technology?
- Are required materials and other inputs reliably available?
- Is the available labour pool adequate for the project; if not, is it possible to train workers as required?
- Where should the plant be located?
- What is the implementation plan and how much time is required?
- What are the costs of investment, implementation and operation?

What should be the extent of technical analysis? It should be sufficiently extensive to provide reliable information concerning project feasibility and sufficiently detailed to obtain desirable accuracy in project cost estimates.

WHAT IS TO BE DONE?



In conjunction with identifying markets and planning a production and sales programme, designing the means of producing and delivering the goods and services is required for an industrial investment project. The design analysis covers the implementation and operations phases (and decommissioning when applicable). A general outline of the work to be accomplished is as follows:

Select the most favorable process for converting capital facilities and resources into the required marketable goods and services: The major task of the technical analysis is to select the most appropriate technology for the application and to determine the most favourable method for its acquisition; to design the plant, to select the machinery and equipment to carry out the planned production and to develop a plan for implementation and operations.

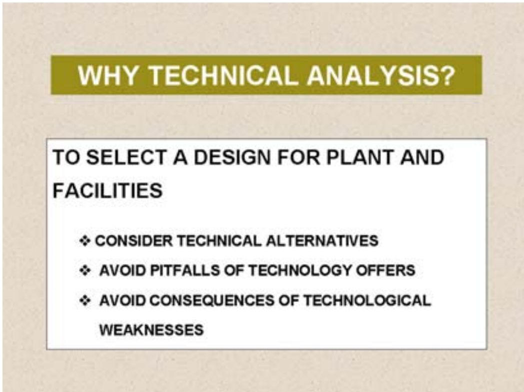
Consider the environment in which the activities are to take place: There are two aspects to this issue. (1) the effect of the environment (ambient climatic, cultural, social, economic conditions) on technology performance; and (2) the need for environmental controls and mitigation measures to comply with regulations, statutes and good practice.

Determine the capital and operating costs associated with the plan: Provide estimates of investment costs and production costs, which are used for financial analysis.

Prepare a comprehensive technical report: An adequate technical study has the following features:

- All technical aspects covered in accordance with UNIDO methodology or equivalent
- Essential points of analysis and results of study presented in a compact manner.
- Annexes appended with extensive discussions of analyses and results.
- All technological alternatives and trends
- All assumptions and bases
- Accuracy and precision of data
- Criteria for technology selection
- Sources of cost information
- Supporting documentation of investment cost estimates
- References to comparable projects

WHY TECHNICAL ANALYSIS?



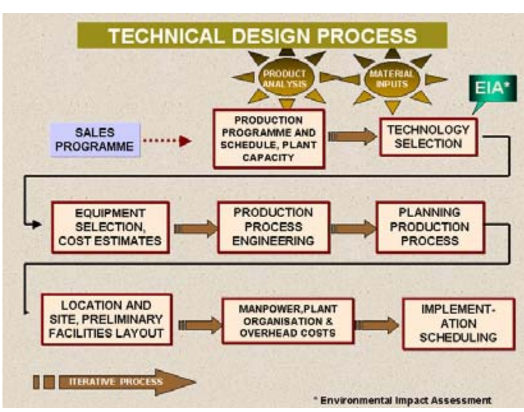
Technical analysis is needed to select the optimal plant design. For any project there are technical parameters to be selected e.g. plant capacity, material quantities and qualities and production sequence. A variety of configurations involving these parameters should be considered in deciding the actual plant design.

Consider technical alternatives: Once the product specifications and production program have been estimated, at least on a preliminary level, there are usually a number of alternative technologies that can be selected to meet these requirements. Alternative approaches to virtually all installation and operation features can usually be considered, and those that appear to be most favourable in terms of operating features and costs selected. Another factor is the selection of plant capacity; often there are capacity limits for certain technologies, particularly those that are capital-intensive. Plant capacity should be selected to optimize operational characteristics.

Avoid pitfalls of technology offers: Prudence demands that the project sponsors conduct an independent assessment of technology, the means of acquisition and its implementation rather than simply accepting an offer for equipment or process from a supplier or agent. The most prudent policy is to examine all reasonable alternatives and then to select the one with the most favourable characteristics.

Avoid consequences of technological weakness: The entire system of organization and technology must operate in synchronization and harmony to meet the project objectives. Technical analysis should attempt to identify and correct weaknesses that could jeopardize the project. Even a technical feature such as a material standard can represent a serious technical weakness. In one case the unavailability of the proper steel alloy for nozzles in a caustic spray operation became an important impediment to success as a result of frequent plant shutdowns.

TECHNICAL DESIGN PROCESS



The approximate relationships between the components of technical analysis are shown. The process of technical analysis is not linear. Although it starts from a projected sales programme for a specified product, feedback from technical analysis may affect the final configuration of the product and the sales programme. The activities indicated in the diagram are linked so that any number and types of iterations are possible. All of the elements must ultimately comprise a comprehensive and workable plan. Some consideration should be given, formally or informally, to seeking an optimal solution to technical issues. As an example, the relationship between the plant capacity, the production program and inventory policy can be adjusted for cost minimisation (investment and operations).

The analysis should be comprehensive. Any project can be considered as a chain of activities, with weakness in any one link potentially resulting in adverse consequences. With obvious exceptions, such as preliminary definition of the sales programme as an input to the capacity decision, there is no prescribed sequence to carry out the various elements of the analysis. However, at the end, the technical components should perform effectively as a system and mesh well with other aspects of the project:

Product analysis - materials standards, production methods, performance specifications and measurements.

Production programme and schedule, plant capacity - an outgrowth of the planned sales programme and other technical factors (see Production Programme and Plant Capacity in Market module)

Production process engineering - design of necessary unit operations and interfaces.

Technology selection - choosing the most appropriate means of conversion of production factors to goods and services as required, means and cost of acquisition.

Planning production process - integrating technology selection and unit operations in the most effective manner.

Equipment selection, costs estimates - finding the best sources of machinery and equipment and methods of procurement.

Material inputs: Decide quantities, specifications, sources and costs of all physical inputs.

Human resources, plant organization and overhead costs: Specify qualifications of key personnel, numbers of workers in each category, training requirements and programmes, enterprise organizational structure and non-direct costs in each area of operations (overheads).

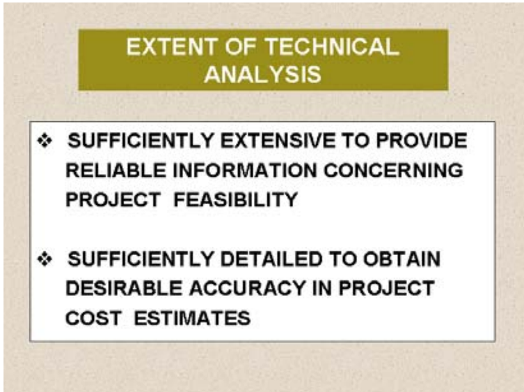
Location and site: Determine the best location for the plant on the basis of well conceived criteria, specify site requirements and identify the best site, estimate costs of civil works and other installations.

Facilities layout: Provide a layout for the site, showing infrastructure interfaces, costs of site preparation and civil works.

Implementation schedule: Develop a plan for the activities and events necessary to implement the project, the implementation organization (engineering and construction) and costs of implementation (other than costs covered elsewhere).

Environmental Impact Assessment (EIA): A study of the existing habitats of humans, flora and fauna, the impacts of the project and mitigation measures to meet acceptable environmental standards.

EXTENT OF TECHNICAL ANALYSIS



A decision on the extent of the technical analysis must be taken early so that either terms of reference can be prepared for technical consultants or the work can otherwise proceed in an orderly manner. Breadth and depth of the investigation both are determinants of cost.

The investigation and design work should be:

Sufficiently extensive to provide reliable information concerning project feasibility: The scope of issues to be addressed and the depth to which they are investigated are a function of the project configuration and the risks associated with each component. How much attention is directed toward the product, supplies, the process, plant design, infrastructure interfaces, environmental impacts - depend upon their complexities, how much is not known to the sponsors and the degree of risk associated with each.

In the final analysis a product and a programme for its production are specified. A plan for locating, siting and constructing the plant with its equipment and other facilities is presented. The manner and timing of production is explained, including any consequences this may have on the external environment. The costs of implementation, operations and decommissioning are estimated. Only when answers to all of these questions have been answered with some degree of confidence is the technical analysis essentially completed. When this information is integrated with other aspects of the project it may be subject to change.

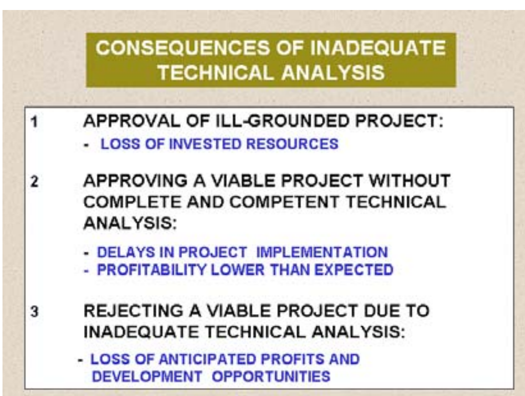
Sufficiently detailed to obtain desirable accuracy in project cost estimates: At the planning stage financial issues are of utmost concern to sponsors. What will be the necessary investment and operating costs, when will these costs be incurred? In the early stages, when data is derived primarily from available secondary sources the numbers may be subject to error of 30% or so. As the project nears the decision stage, much better accuracy is required, perhaps to the 5-10% level. More than a +10% deviation in the actual investment or in operating costs over estimates can have serious consequences for investors.

SCOPE OF TECHNICAL ANALYSIS

The technical analysis should cover all important issues to assure a high degree of confidence in the plan and in sufficient detail to reliably estimate investment and operating costs. The important issues to be addressed in the technical study are:

- What should be produced, when should it be produced and to what quality standards?
- What is the most appropriate technology in terms of product quality, reliability and operating conditions?
- What is the cost of technology?
- Is the project and its technology environmentally and socially acceptable?
- Are required materials and other inputs reliably available? How should they be provided?
- What is the most appropriate organizational structure?
- Is the available labor pool adequate for the project; if not, is it possible to train workers as required?
- What facilities are needed to implement the technology and how should they be obtained?
- Is the existing infrastructure adequate; if not, how can it be upgraded and what costs are involved?
- Where should the plant be located?
- How should the project be implemented and how much time is required?
- What are the costs of project implementation and operations?

CONSEQUENCES OF INADEQUATE TECHNICAL ANALYSIS



"To err is human" is a particularly apt observation in the context of preparing an industrial project, with all its complexities. The usual failures of the human psyche and intellect loom as imposing possibilities and should be conscientiously avoided by the project analyst - misjudgment, oversight, miscalculation, excessive optimism, inaccuracies. Some of the particular manifestations of these failures, observed from long experience in the field are the following:

Inadequate technical analysis can have consequences similar to shortcomings in other areas of project analysis. The objective of project analysis is to accept viable projects and to reject non-viable projects as investment possibilities. The consequences of failing to attain this level of discretion fall into the following categories:

Approval of an ill-grounded project resulting in loss of invested resources.

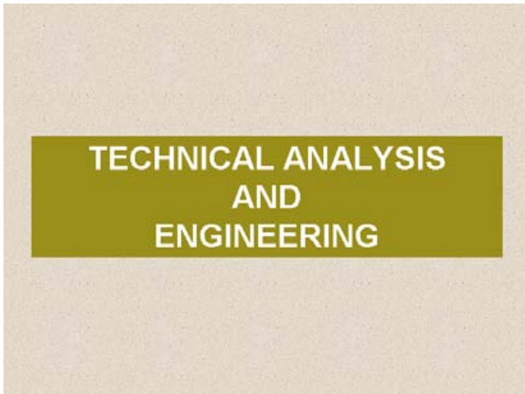
Approving a viable project without complete and competent technical analysis with consequent delays in project implementation and lower than expected profitability.

Rejecting a viable project due to inadequate technical analysis with resulting loss of anticipated profits and development opportunities.

The best way to avoid these pitfalls is to assure that the study is performed by a trained and experienced analyst, preferably someone with extensive background in the industry. An anecdote may illuminate the point: A wizened consultant was called upon to repair a mega-plant that had ceased to function for some obscure reason, unfathomable to the company's technical staff. After scanning the scene, he climbed up a ladder to the furthest reaches of the myriad of pipes that constituted the plant's arteries, pulled out a small hammer and tapped on a pipe, whereupon the entire factory commenced flawless operation.

The invoice for services presented to management was as follows: (1) Tapping on pipe - USD 5; (2) Knowing where to tap - USD 50,000.

TECHNICAL ANALYSIS AND ENGINEERING



Technical analysis: During the planning phase the process and plant are designed and an implementation plan prepared. Production plans and operating costs must be determined for the production phase. If the facilities are to be dismantled at the end of the project a decommissioning plan and related costs must be prepared.

Engineering activities: Detailed The technical study covers design features and technical plans for all project phases.

Engineering activities during each project phase are as follows:

- Planning phase: Process and plant design, capital and operating cost estimates
- Investment phase: Implementation and commissioning plan
- Operating phase: Production operations plan
- Decommissioning: Plan for decommissioning the plant (if applicable) and related cost estimates.

Engineering and technical analysis form a large portion of the effort involved in planning and executing a project. These activities commence in the planning stage and continue up to the point where the project is dismantled. Although for some engineering aspects of the project it is not legally necessary to employ the services of licensed engineers, it is prudent to do so. If site work or buildings or civil installations are involved, the employment of licensed engineering firms is usually mandatory. In any case, it is prudent to employ the best available engineering talent, and to seek the services of a firm with experience in similar projects.

TECHNICAL ANALYSIS AND DESIGN DURING THE PLANNING PHASE

Technical analysis and design during the planning phase covers a wide variety of inter-dependent activities. Final decisions and design configurations for each of these areas is determined in an iterative manner, always with reference to other project features to assure compatibility.

Product analysis: The production of the good or service is related to design. Products are designed for the market, usually independent of production considerations. However, there is an inevitable interplay between the design features and production processes. Sometimes product specifications must be adjusted to production capabilities and costs. Aluminium engine blocks for automobiles were a response to the need for compact engines with sufficient heat transfer capacity to operate in the reduced size of the engine compartment. The specifications of product standards in terms of materials and tolerances are related to production process decisions.

Process design: The production process and assembly sequences are designed. The technology is selected and means for its acquisition determined. A production programmed based upon the process is planned.

Plant design: The plant capacity is determined in consideration of the sales and production programmes. The plant layout is determined to deal with issues of space requirements for production, inventory storage, materials handling and office space. Plans for securing materials and other inputs are developed. A location is selected and a site chosen. Machinery and equipment are selected to comply with process requirements. Civil works and other installations are designed. An environmental impact assessment provides information on compliance with regulations and statutes and identifies mitigation measures required.

Organization structure: An organization structure is designed to manage operations and to staff the production facilities and marketing and distribution functions. Plans are included for recruiting and training personnel. Overhead costs are estimated.

Implementation and decommissioning plans: A plan for implementing the project - the organization, procurement of materials, machinery and equipment, construction of all facilities, personnel recruitment, setting up the organization and training personnel is prepared.

One type of analysis often overlooked, or at least under-estimated, is the complexity of decommissioning. This is particularly true for projects that leave in their wake undesirable residuals (e.g. an atomic power plant or incineration project). Projects that create undesirable residuals can be subject to extensive litigation costs and unforeseen cleanup costs if decommissioning is not carefully planned from the start. In some cases the decommissioning problems may be so complex as to render the project infeasible.

Project cost estimates: The financial analyst needs information from technical designers: cost and timing of investment, operations and decommissioning (if applicable).

TECHNICAL ANALYSIS, DESIGN AND SUPERVISION DURING INVESTMENT PHASE

The detailed engineering of site, civil works, machines, installations, infrastructure are completed after the commitment to the project has been taken. Other major tasks during the investment phase include the procurement of materials and equipment for plant and installations (adherence to technical specifications demands the competency of technical personnel).

Detailed engineering designs: Site development plan, installation of civil works (buildings, utilities, roads and other infrastructure), installation plans for machinery and equipment

Procurement of materials and equipment for construction and plant: Materials and machinery must be procured to build the plant and for the production process.

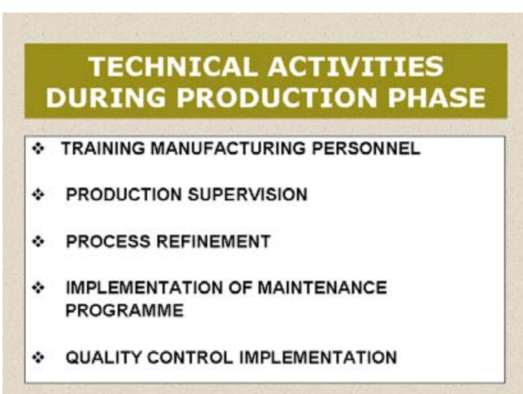
Construction and installation supervision: Technical personnel are required to manage and supervise construction of the plant and facilities and to direct the installation of machinery and equipment for the production process.

Maintenance and quality control plans: Plans for maintenance and control of product quality should be developed, including the procedures and monitoring methods. Project personnel are trained in their implementation.

Recruiting and training management and operating personnel: Technical staff are required to recruit and train management and operating personnel.

Supervise plant commissioning: Commissioning and start-up operations are supervised by technical personnel to verify capacity, resource consumption, quality requirements, and compliance of the process with product specifications.

TECHNICAL ACTIVITIES DURING PRODUCTION PHASE



After the plant has been commissioned and normal operations commence, the technical staff has continuing responsibilities in regard to the production process.

Training manufacturing personnel: Training of production personnel is usually required after commencement of operations. Production levels tend to increase over time, requiring the recruitment and training of additional personnel.

Production supervision: Supervision of production is an ongoing responsibility of technical personnel. A 'learning curve' is normally experienced that adversely affects production in the early stages. As difficulties arise, engineers and technicians should guide the correction of the problem but at the same time deeply involve the staff so that the problem is internally comprehended.

Process refinement: As engineers and technicians become more familiar with the characteristics of the plant it is often possible, particularly in the early stages but continuing indefinitely, to identify modifications that would significantly improve operating performance. The process will invariably be subject to refinements, which are identified and facilitated through the cooperation of technical staff and workers.

Implementation of maintenance program: Periodic plant maintenance procedures should be implemented, including training and supervision of maintenance personnel, initially under the supervision and control of engineers.

Quality control implementation: A quality control programme is important for minimizing production wastes and for maintaining good relations with clients. This involves obtaining samples and performing and analyzing results of performance tests on the samples. The quality control system is implemented with hands-on training and supervision by engineering personnel.

TECHNICAL ACTIVITIES DURING DECOMMISSIONING PHASE

Projects that have a finite and pre-determined life should include a decommissioning phase that includes dismantling and disposal of facilities and residual materials and site restoration, if necessary.

Supervision of project dismantling: The decommissioning plan is carried out under the supervision of technical personnel, and perhaps representatives of the regulatory agencies. Facilities are dismantled the site restored to the required condition, which may be the original condition or as specified by the regulatory authorities.

Arranging for disposal of materials: Residual materials are disposed in a safe and orderly manner.

Site cleanup: Any additional residues from dismantling and materials disposal are collected and properly discarded.

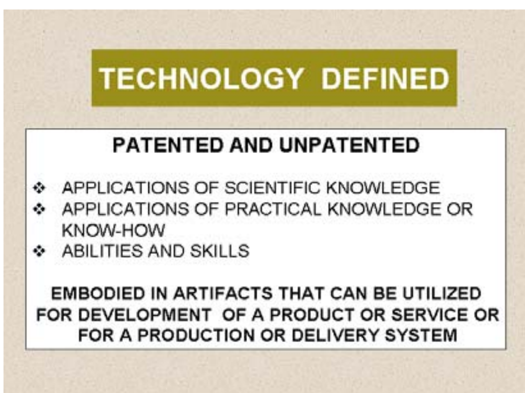
The costs of decommissioning may be significant, even on a discounted basis. Engineering design and supervision of the decommissioning is essential as it generally involves sophisticated analysis, planning and execution.

TECHNOLOGY CONCEPTS

What is technology? It has been cited as the hallmark of human identity, the core ability that separates humans from the rest of the living world. It has been defined as the ability to make tools, which can then be employed for undertaking tasks that could otherwise be achieved only by much less efficient means, if at all.

In the context of industrial project development, technology is embedded in the product and in the means of its production and distribution. The problem for the project designer is to select the technology that is most appropriate in each area, the former to attract potential clients and the latter to provide for production and delivery to standards acceptable to the market in terms of quality, reliability and price.

TECHNOLGY DEFINED

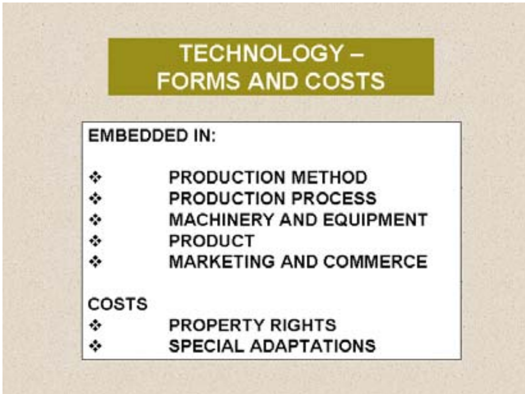


Technology is the embodiment of knowledge concerning the method of designing, producing or delivering a good or service. Technology can be "owned" in the form of intellectual property rights to knowledge. Often the knowledge is protected in the form of a patent, copyright or trade mark (brand name). In other cases the knowledge is embodied in products, equipment or other items that are provided to the project by the owner of the technology.

Patents provide protection by governing authorities for a period of time to exclusive rights of the inventor to the use or licensing of the concept. Other technology is un-patented, either protected by the inventor by maintaining proprietary controls, made available to selected clients or distributed freely.

The embodiment of technology derives from: applications of scientific knowledge; applications of practical knowledge or know-how; abilities and skills that can be utilized for development of a product or service or for a production or delivery system.

TECHNOLOGY - FORMS AND COSTS

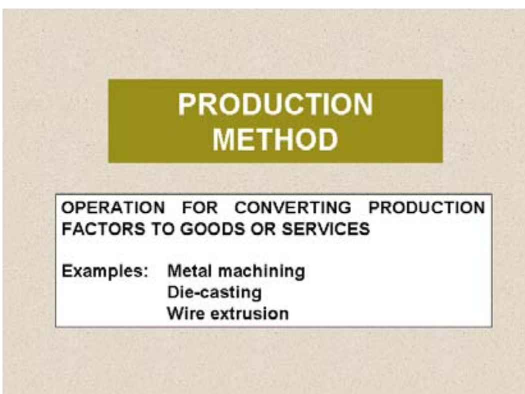


Technology can be found in several forms, embedded in the production method or process, in the machinery and equipment, in the product and also at times in the marketing and delivery system. In some cases the product and the technology are linked in a package that is inseparable. In other cases it may be possible to 'un-bundle' the technology so that various components can be obtained from sources that may be more favourable for investors.

A technology package can be embedded in one or more of indicated components (product, production method or process, machinery and equipment, marketing and commerce). A license to use technology may involve only the use of intellectual property, with implementation left to the licensee.

Owners or controllers of technology usually require payments in exchange for access to, or use of, the intellectual property. There may also be costs for special adaptations to accommodate to the internal and external conditions of the project.

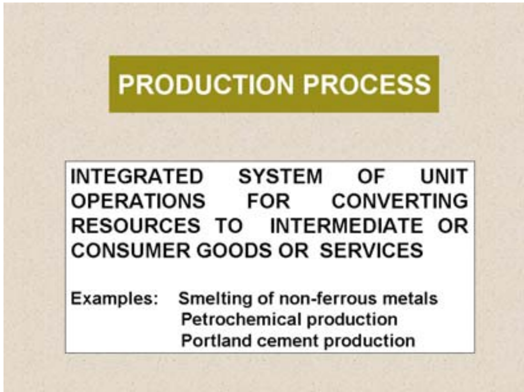
PRODUCTION METHOD



A production method may consist of one or more operations that convert production factors (materials, labour) into intermediate or final products. The technology is the series of operations and their sequence.

Examples are metal machining (application of machine tools), die-casting (forming moulded parts from molten metals or other materials under pressure), extrusion of wire. Assembly processes, often automated, specify the sequence of operations and the manner of using tools and machinery.

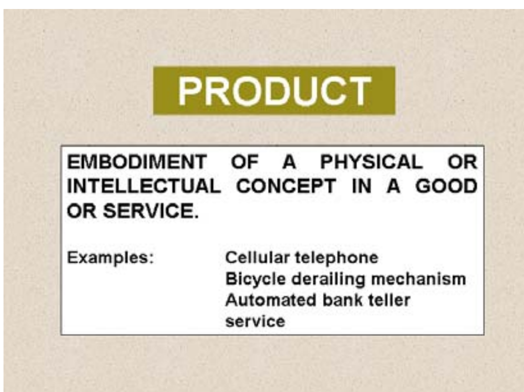
PRODUCTION PROCESS



A technology package may consist of a production process, an integrated system of unit operations that convert one or more materials into a final product, normally through chemical and thermal processes. The series of unit operations may be in series or parallel, each contributing to the modification of the inputs toward the final product characteristics and quality. Normally the complex of unit operations is an inseparable package; however, in some cases it may be possible to acquire a stand-alone unit operation that meets the specific requirements of the project.

Some examples of production processes are: Production of petrochemicals, including fuel and lubricant refining; smelting non-ferrous metals; production of Portland cement.

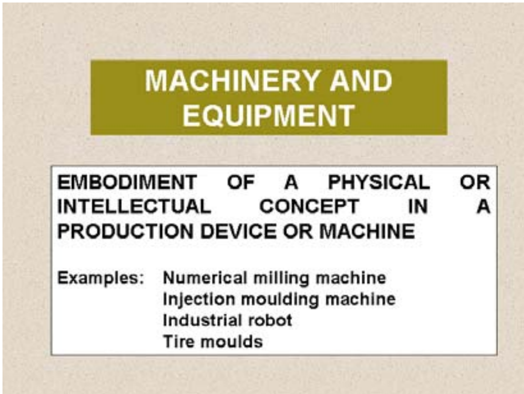
PRODUCT



The technology may be embodied in the product itself, the good or service delivered to the ultimate consumer. The better mousetrap is an example of product-embedded technology (in fact there have been a proliferation of product ideas to defend against these ubiquitous interlopers). Some examples of technology embedded in products are: The cellular telephone, bicycle derailing mechanism, automated teller service.

The rights to produce the product would ordinarily be transferred to the licensee. Often the product and the method of production are intimately linked so that the package consists of both the product and the methods of manufacture.

MACHINERY AND EQUIPMENT

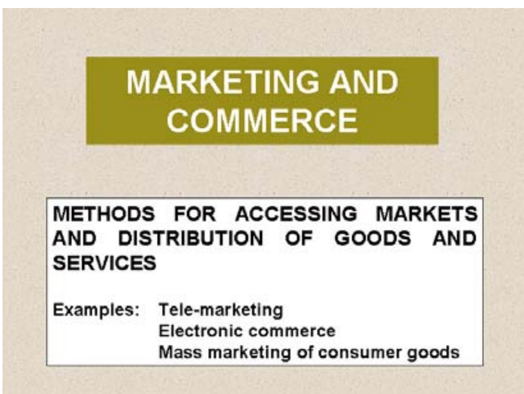


The embodiment of the technology can be in the design, applications and methods of manufacturing the production machinery and equipment. The rights to the design and manufacture of protected machinery and equipment do not ordinarily pass to the purchaser of the machine. The buyer has the right to use the equipment, but not to replicate it.

Ordinarily there are no special agreements or payments required for use of this type of technology other than the costs of purchase, spare parts and perhaps maintenance. In some instances the owner of the technology may seek ways to protect intellectual property rights where the normal mechanisms are considered inadequate. Special tooling, keys, codes and passwords have been used in such instances.

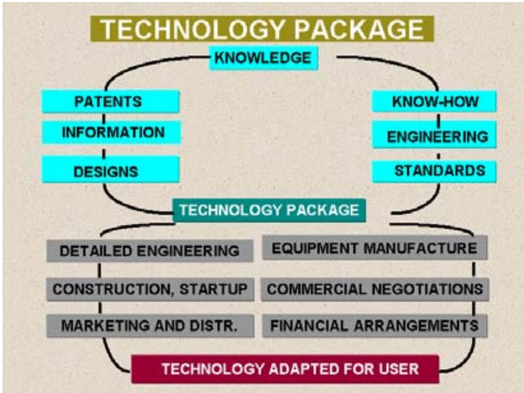
Some examples of this type of technology are numerical milling machines, injection moulding machines and industrial robots. Special forms of tools and dies would also fall into this category, for example tire moulds.

MARKETING AND COMMERCE



Trademarks and copyrights are are commercially protected properties. In some cases marketing and distribution are part of the technology package, particularly in regard to franchising of non-durable consumer products such as foods and toys, and consumer services such as messaging and package delivery services. Increasingly with the advent of electronic commerce proprietary rights to systems of marketing and distribution are becoming more common.

TECHNOLOGY PACKAGE



The technology package may consist of any combination of intellectual property (patents, information, know-how) or the physical devices and systems in which they are embedded (engineering, designs, standards).

Adaptation of the technology to the needs of the project, in the form of special design and engineering, may be required for production and implementation. The adaptation may include detailed engineering, construction and implementation of facilities, manufacture of machinery and equipment, commercial negotiations, marketing and distribution systems, and even financial arrangements.

All aspects of the technology package should conform to the specific needs of the project, which may differ from the configuration of the package as originally developed. The need for adaptation can arise from internal or external factors. For example, cultural patterns can require adaptations for workers and consumers.

TECHNOLOGY CHOICE AND SELECTION

When an investment project idea arises, it usually includes a conception of the way that the good or service will be produced. The conceptual construct of the project is "hardwired" into the minds of the sponsors so that it gains a great deal of psychological momentum. It is a struggle, but one well worth the effort, to open the mind to other possibilities. There are many paths to Wickersham and "many ways to skin a cat".

The choice of technology is one of the major decisions for project planners. Under ordinary circumstances there are available alternative methods for carrying out a production programme. The choice should reflect careful consideration of options and optimal satisfaction of the selection criteria.

The issue is: what means of production will meet all of the desired product specifications and produce the necessary quantities reliably and safely at minimum cost and with the least perturbation of the surrounding environment? A systematic analysis of how each alternative satisfies criteria would provide the best opportunity to make the right choice.

The choice of technology is one of the key decisions that will affect the prospects for success in the project. Under ordinary circumstances there are a number of methods available for carrying out a production program.

MAJOR INTERNAL FACTORS INFLUENCING TECHNOLOGY CHOICE

The project designer is faced with the challenge of finding the best way to produce what is required by the project plan while minimizing costs and risk. The internal characteristics influence the choice.

Product design and quality: Product specifications are a determinant of the required accuracy and precision of production processes.

Production scale, plant capacity: The project's planned production programme must lie within the feasible range of scales (minimum and maximum) for the selected technology.

Raw materials properties and price: The quality of available materials and other required resources must be consistent with the demands of the technology. Locally available materials may need additional processing to reach the required specifications. The total cost of resources, including any additional pre-processing, is a deciding factor.

Consumption of scarce resources: Scarce resources are those for which demand exceeds supply. If such resources are needed as inputs for the technology, there may be interventions by regulatory authorities to ration or otherwise allocate them. Such constraints may preclude some technologies from consideration.

Labour vs. Capital costs: The cost of labour as compared with the cost of capital consumed, per unit output, is a determinant of technology choice. Labor-intensive technologies have the advantage of production flexibility. Capital-intensive technologies usually offer better control of quality.

Reliability considerations: Reliability (continuity of operations within specifications) of the technology under the plant's ambient operating conditions will affect the degree to which the planned production programme is at risk. A reliable technology will tend to minimise costs by minimising down time for repairs and the cost of lost production and sales.

Part-load performance: The vagaries of forecasting tend to place some importance on the effects of lower-than-expected demand on the project's performance. A technology that can operate efficiently at reduced levels provides some protection against inordinate unit costs if the sales levels are less than anticipated.

Cost of technology: The acquisition of technology, whether developed internally or procured from an external source, has a cost. In addition to acquisition costs are the capital and operating cost for the technology. The total cost and reliability for each alternative should be weighed against the acceptability to consumers of goods and services produced by each technology alternative.

Capacity to absorb technology: The capacity of project staff to absorb the technology has to be considered. If the technology can not be readily internalised so that the project operates self-sufficiently then perhaps some other option should be selected. Extended reliance on expatriate staff to manage, maintain or operate the technology is risky and costly.

MAJOR EXTERNAL FACTORS
INFLUENCING TECHNOLOGY CHOICE

Interactions of the technology with the external environment affect technology choice.

Environmental impact and mitigation requirements: The choice may hinge on the impact of the technology on the environment. What measures are necessary to mitigate the effects levels acceptable according to existing regulations and statutes, the likelihood of future regulatory actions and maintenance of harmonious relations with the surrounding community should all be considered.

Sustainability under local climatic and environmental conditions: The ability of technologies to continue functioning normally may be subject to differing impacts of climatic and other environmental conditions. Some organic materials, for example, are subject to severe weathering in hot and humid conditions. Ordinary steel rusts and aluminium corrodes. Sustained attention of technicians under extreme heat and cold is difficult. Many metals become brittle at low temperatures.

Infrastructure (services, skills, facilities, etc.): Advanced technologies generally require more complex services and skills. Capital intensive technologies, unless backup utilities are provided internally, are more affected by interruptions of services.

Long-term trends in relevant industrial sub-sectors: Trends in industrial sub-sectors that will affect the performance efficiency of the technology should be considered. For example, if there is a programme for improving energy efficiency in the country there will likely be incentives for lower consumption of power and increases in energy costs.

The choice may hinge on the impact of the technology on the environment and what are the measures necessary to mitigate the effects to a level acceptable to the authorities, and also considering the likelihood of future regulatory actions. The analysis of environmental impacts could be included as part of the assessment of the economic costs and benefits if this is warranted by the planning authorities.

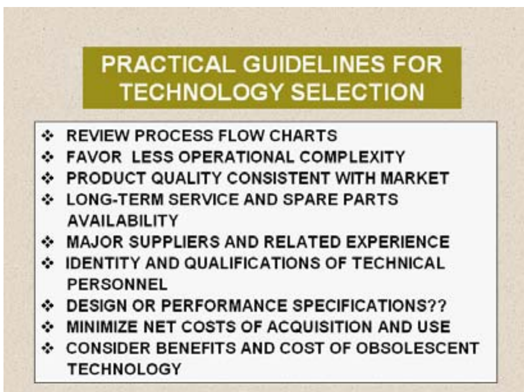
The necessary infrastructure services will differ according to the technology. Trends in industrial sub sectors that will affect the performance efficiency of the technology should be considered. For example, if there is a program of improving energy efficiency in the country there will likely be incentives for lower consumption of power and the likelihood of increases in energy costs.

Priorities of authorities: Another consideration is that "you can’t fight city hall". The priorities of the local licensing authorities should be taken into account if this will have any impact on the technology choice. Officials of the host country may be interested in uplifting the technological status of the country, and will therefore favor advanced technologies that can be absorbed. Incentives may be offered for projects that tend to upgrade the technological level of the country. On the other hand, there may be opposition to low-level technology as not in keeping with aspirations for self-sufficiency and international competitiveness. However, the sustainability and absorption issues should be a part of the negotiations with licensing authorities if there is opposition to a low-level technology favoured by project sponsors.

Economic benefits vs. costs: The net value-added created for the country by technology alternatives could be an influential factor in gaining the approbation of authorities. Labor-intensive projects inherently tend to increase domestic value-added. Advanced technologies for developing countries often require expenditures in foreign exchange, which tend to diminish positive impact on the local economy.

The analysis of environmental impacts could be included as part of the assessment of the economic costs and benefits if required by the planning authorities.

PRACTICAL GUIDELINES FOR TECHNOLOGY SELECTION



Review the process flow chart: A description of unit operations and their material inflows and outflows helps to clarify the nature of the technology. The operating system should also be considered - this will point to the skills necessary for operation and maintenance and any problems associated with the absorption and sustainability issues. Flow charts also help to identify environmental impacts of process wastes and effluents.

Favor less maintenance and operational complexity: In most emerging economies it is prudent to select for less complexity in operation and maintenance, so long as quality requirements are not compromised.

Select for product quality consistent with market requirements: Product quality is very much a function of technology. A bushing (small pressure plate) for a pump shaft can be inexpensively stamped in a punch press or produced in a sintering mould and heat treated to precise specifications. A hydraulic pump can be used to aerate a fish tank or to activate flaps on a jet aircraft. The quality requirements for the pump in each instance are markedly different.

Consider long-term service and spare parts availability: A major issue is the long-term availability of spares. If the technology is late in its life cycle suppliers may well cease production of spares once it is no longer in their product lines.

A description of unit operations and material flows helps to clarify the nature of the technology. The operating system should also be considered - this will point to the skills necessary for operation and maintenance and any problems associated with the absorption and sustainability issues. In most emerging economies it is prudent to select for less complexity in operation and maintenance, so long as quality requirements are not compromised.

Information concerning major suppliers and related experience should be obtained: The reputation of the technology supplier can shed some light on how well the project will be supported when problems arise. It is virtually impossible to specify every last detail in a contract, so that the good intentions of the supplier are important. This can best be gauged by the attitudes of former clients.

Identity and qualifications of technical personnel: The supplier's personnel that will support the technology transfer and absorption (delivery, installation, commissioning of plant and training) should be identified, including their qualifications and prior experience in this field. Inexperienced engineers and technicians often commit errors that are costly and time-consuming.

Design or performance specifications?: Should the technology be specified in terms of design or performance specifications? If the former is selected, then the supplier's responsibility for performance may be limited. Acceptance test criteria should be specified (not merely inspection at point of delivery). Regardless of the design specifications, a demonstration of performance under actual operating conditions should be a condition of final acceptance of the technology.

Consider benefits and costs of obsolescent technology: Obsolescent technology can usually be acquired at relatively low cost and with operational benefits (low production cost, lower skills requirements, cheaper products). However there are caveats - lack of spare parts, high maintenance costs, higher per unit manufacturing costs.

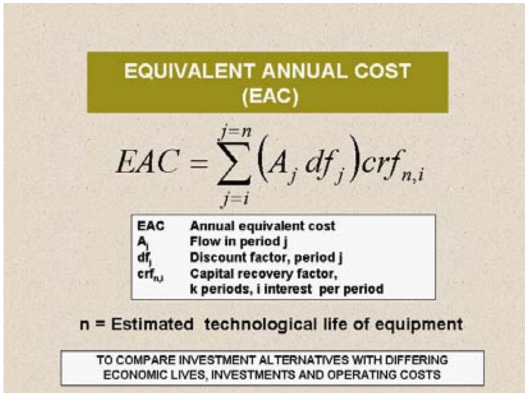
ANNUALIZED COST AS BASIS FOR TECHNOLOGY SELECTION

The cost of the alternative technologies can best be compared on the basis of Equivalent Annualized Cost. The technological lives of the alternatives usually differ; there are differences in the pattern of acquisition, investment, operating and decommissioning costs, and the value of salvage. These cost patterns are best compared by using an approach in which the pattern of costs during each period of the project's planning horizon are compared on a normalized basis using time value principles.

The Equivalent Annualised Cost (EAC) can be the basis for comparison of the cost of technology alternatives. This method reduces the cost of investment and operations over the technological life of each of the alternatives to an "average" value per year, essentially a common denominator of cost. The "average" value is determined by considering the pattern of cash outflows over the technological life, then reducing these flows to present value, and finally determining an annual cost equivalent.

The reason for using this process is that the technological lives of the alternatives usually differ; there are differences in the pattern of acquisition, investment, operating and decommissioning costs, and the value of salvage. These cost patterns are best compared by using an approach in which the pattern of costs during each period of the project's planning horizon are compared on a normalized basis using time value principles.

EQUIVALENT ANNUAL COST (EAC)

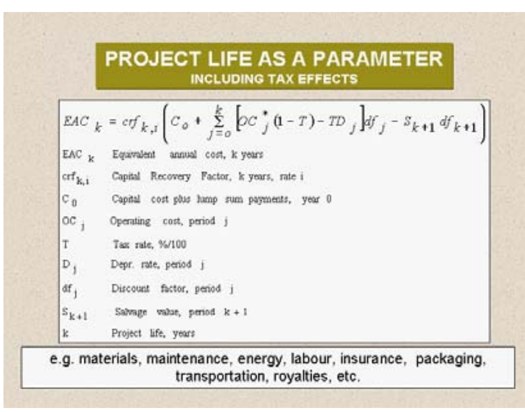


The Equivalent Annual Cost takes into account the technological life of the equipment and the variations in financial flows for each alternative. The technological life is defined as the period during which the equipment and systems can continue to function effectively so that repairs and maintenance do not materially affect profitability. The approach is to find the net present value of the costs for each alternative by discounting the cost Aj for each period j and summing, where each Aj is the net of cash outflows (positive) and inflows, e.g salvage value (negative). The outflow for each period is the sum of capital (acquisition, investment and decommissioning) and operating costs. As the calculation is performed on a cash basis the flows do not include depreciation. However, if taxation is to be taken into account depreciation would have an effect on cash flow, and consequently the EAC. The formulation shown in the subsequent slide does account for the after-tax effects.

The Capital Recovery Factor (CRF) for the technological life n and the discount rate i is determined and multiplied by the net present value of costs. The CRF is a value (<1) that spreads the present value in equal instalments over the technological life span (the point at which the technology is physically spent, essentially to the level of scrap. A detailed explanation of the CRF is provided in a section of the Financial Module.

It is best to do the comparison for the technological life of each alternative, which may differ, rather than to include major replacement.

PROJECT LIFE AS A PARAMETER - INCLUDING TAX EFFECTS



The formula shown is intended to determine Equivalent Annual Cost (EAC) for technology alternatives using the project life as a parameter. In this formulation the EAC can be determined for a project life starting from a small number of years, say 2 or 3, and increasing to a selected maximum. When the EAC is plotted on a graph as a function of project life it will ordinarily decrease as the project life increases. When the EAC's for each alternative are plotted on the same graph there will generally be cross over points, where the capital-intensive technologies have high costs for low project lives and relatively low costs for longer project lives. Labour-intensive projects will have relatively low EAC's for short projects but will decrease more slowly as project life increases.

The scrap or salvage value is shown as an inflow in year k+1, the year after the technology ceases operation. If the actual liquidation of the assets is assumed in the year k, the formula should be changed accordingly.

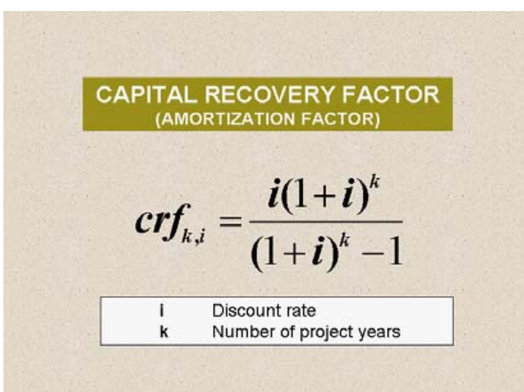
This formulation has another feature absent in the former. The operating costs (OC) and depreciation (D) are adjusted for taxation (T). Operating costs are multiplied by (1-T) to account for their after-tax effect (assuming marginal rates are constant) - the actual after-tax cost will be lower than the outlay. Depreciation is multiplied by T - this is not a real cash outflow, but does have an effect on cash flow in the form of reduced taxes.

Another application of this formulation is to compare project alternatives with differing technological lives (previously defined). In this case the EAC would be determined for each alternative based upon their respective technological lives. The investment is assumed to occur in year 0 (C0). If investments are required for spare parts or other minor replacements in other years their values should be included in OCj and properly discounted.

A detailed explanation of the Capital Recovery Factor can be found in the Financial Analysis Module.

The cost of alternative technologies can be compared using the technological life (or project life) as a parameter. A capital intensive technology will generally show high costs for short life spans but will decrease more rapidly than technologies that are more labor intensive. There is usually a cross over point that can be helpful in determining which technology is the more financially advantageous. For a particular investor such a comparison can be applied to determine which best meets the criterion of lowest annualized cost over the specific time horizon.

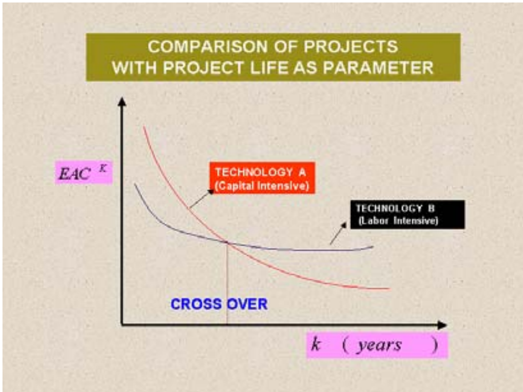
CAPITAL RECOVERY FACTOR



The Capital Recovery Factor (CRF), or Amortization Factor, is a constant that defines the amount to be received in each period to cover the capital invested and its rental cost. The amount in each period consists of a portion of the capital and the current rental cost based upon the outstanding balance of un-recovered capital. In the Equivalent Annual Cost application, the CRF acts more like an amortization of the total capital and operating costs for each technology alternative.

The CRF essentially spreads the present value of capital and operating costs, as determined in the previous EAC formulas for each alternative technology, in equal amounts per period over the project life. In this way the Equivalent Annual Cost for each alternative can be compared, even though the technology alternatives have differing useful lives.

COMPARISON OF PROJECTS WITH PROJECT LIFE AS PARAMETER



Alternative technologies selected for projects will ordinarily have differing patterns of EAC as a function of project life. When comparing two alternatives there is usually a cross over point that can be helpful in determining which technology is the more financially advantageous, depending upon the planning horizon for the investor. For a particular investor such a comparison can be applied to determine which best meets the criterion of lowest annualised cost over the specific time horizon selected for the project. This may be a function of the anticipated life cycle for the product rather than technological obsolescence of the plant.

In the example shown, Technology A (capital intensive) has a relatively high EAC for short projects, but the EAC is lower than that of Technology B (labour intensive) when the project life is relatively long.

The relationship of Equivalent Annualized Cost using life as a parameter is shown. The capital intensive technology shows high annualized cost for a short lifetime but decreases relatively sharply. For the less capital intensive technology the cost for short lifetime is lower but decreases much more slowly with increasing project life. There is some life at which a cross over occurs. The planning horizon of the particular investor can be used to select which technology is more favorable based upon the cost criterion alone. Other criteria should also be included in the final determination of the most appropriate technology.

PRODUCT ANALYSIS

Why product analysis? Performance specifications, materials and components selection, methods of manufacture and testing criteria - all have to be defined. Decisions on the product's characteristics affect the supplies program and design of the production system.

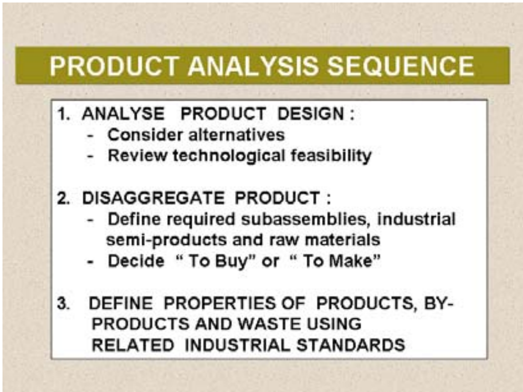
Determine standards for materials and processes: Materials standards are essential for assuring product quality and performance under the conditions specified in the marketing programme. There is usually a choice of materials for achieving desired product characteristics. Even within a class of materials there are often alternatives, each of which may be adequate but for which there is a best choice when price and material properties are considered jointly.

Provide technical inputs for make-or-buy decisions: Each of the processed materials, components and subsystems that are integrated to comprise the product can, at least theoretically, be produced by the project or procured externally. Product analysis, in conjunction with consideration of the internal capabilities of the project vs. those of potential suppliers, will assist in determining whether to produce or purchase. The project may retain responsibility for assembling the product but subcontract for components and subsystems.

Determine most effective way to produce: For those production functions within the project, product analysis will provide information concerning the most effective and efficient way to perform the various stages of production and unit operations. For example, the plant layout will be affected by the product assembly sequence.

Provide information for supplies programme: Materials and component specifications, together with planned production quantities and the make-or-buy decisions emerging from analysis of the product, provide the necessary information for specifying the supplies programme and related costs.

PRODUCT ANALYSIS SEQUENCE



Product analysis is performed in a sequence of steps:

Analyse product design: The product design is analysed in regard to material properties, assembly sequences, process implications, etc. Alternative designs are compared in regard to material and production characteristics. The technical feasibility of alternative designs is assessed.

Disaggregate product: The most promising product designs are disaggregated into subassemblies, components, semi-products and raw materials. This analysis leads to information concerning the costs for materials and production processes and their feasibility. When a design is selected, whether to make or buy the various component parts can be decided.

Define properties of products, by-products and waste using related industrial standards: If possible, it is prudent to use local or international product and material and industrial standards when defining the properties of product components, by-products, wastes and effluents. These standards are used in production, in procurement and in plans for disposal of effluents and other waste materials.

ROLE AND IMPORTANCE OF INDUSTRIAL STANDARDS

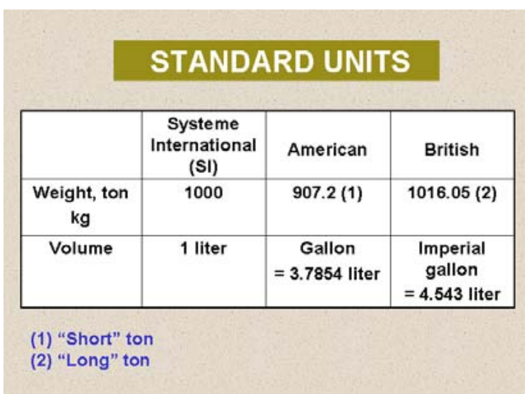
Standards: "*The rules of technology and engineering*": In negotiating contracts or other agreements for the supply of materials, components or subsystems, it is extremely important for the project designers to adhere as closely as possible to materials and industrial standards. This approach reduces the risk of product or process deficiencies and weaknesses.

Standards apply to materials and to the design of parts and systems. For the design and construction of civil works, such as roads and bridges, most countries or development authorities publish standards with which engineers must comply. Standards are established and maintained by government bureaus, international bodies and technical societies, or may be promulgated by an enterprise or one of its branches. The national and international bodies may be affiliated with testing laboratories. Often the standards of these societies are adopted by reference by the government standards bureaus.

Advantages of standardization: Insisting upon compliance with national and international standards for materials and processes assures and defines quality and compatibility with market requirements. It provides ready-made solutions to technical problems - why reinvent the wheel when a good solution has already been discovered? Particularly for export products, adherence to international standards is virtually mandatory, as products otherwise would often not be accepted in the target market. In some cases the standards are so well defined that little flexibility exists in the product design.

Disadvantages: One disadvantage to adherence to standards is the possible obstruction of advancements of recent technical solutions that have not yet been recognized by the established institutions. Standards often do not keep up with the technology. Some developing countries have discovered methods of utilizing waste materials in unique ways, for example in the construction industry where agricultural wastes become the binding fibers for building blocks. When modular designs were first developed they were unacceptable in many applications because the standards had not kept pace with developments. For many years the use of PVC piping for water and wastewater distribution was not accepted in some localities because the building standards had not been adjusted to the new technology.

STANDARD UNITS



STANDARD UNITS

	Systeme International (SI)	American	British
Weight, ton kg	1000	907.2 (1)	1016.05 (2)
Volume	1 liter	Gallon = 3.7854 liter	Imperial gallon = 4.543 liter

(1) "Short" ton
(2) "Long" ton

As an example of the need to adhere to standards, the differences in standard units for weight and volume are shown. The weight unit, ton, for example, can mean different things depending on the system employed. In the Sisteme International (SI) the unit is the metric ton (one thousand kg). The American ton is 907.2 kg (short ton) while the British ton is 1016.05 kg (long ton).

The volume in the SI is the litre. In the American system a gallon contains 3.7854 litres. The British imperial gallon contains 4.543 litres.

In the United States of America design standards for pressure vessels usually refer to the ASME standards (American Society of Mechanical Engineers). Materials standards usually cite the ASTM standards (American Society of Testing Materials). Product standards often refer to the UL (Underwriter's Laboratory).

Similar organizations develop standards in other parts of the world.

PRODUCT DESIGN AND PERFORMANCE SPECIFICATIONS

Specifications for the design of the product and its performance should be defined.

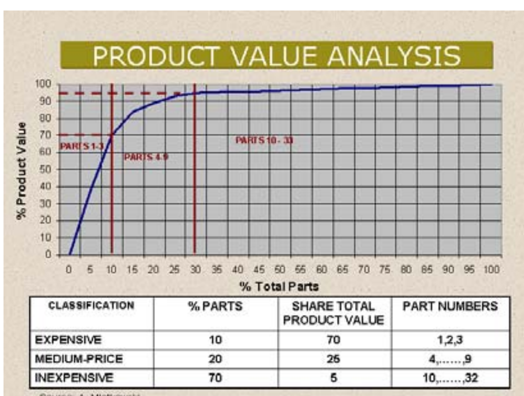
Design: Specifications should include the type of materials (product configuration (shape, size, volume), operating environment (e.g temperature, pressure, humidity), assembly procedures (if applicable), service requirements (procedures and material requirements) and inputs (electrical, fuel, water, other materials).

An example of a design specification for a refrigerator could be: ½ horsepower compressor, 300 liters capacity, no frost process.

Performance: How the product is used and what it does should be specified. The performance should be specified quantitatively, if possible. Machines and other mechanical and electronic devices are more amenable to quantitative performance specification, but the output of other products can also be specified in this way, e.g. a gallon of paint will cover 100 square meters of surface.

An example of performance specification for an automobile would be: acceleration 0 to 100 km per hr in 10 seconds; fuel efficiency 80 km per liter.

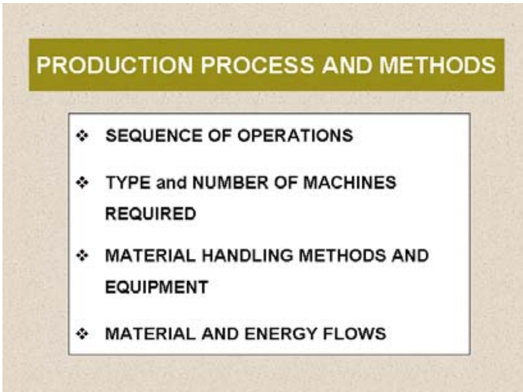
PRODUCT VALUE ANALYSIS



A relatively small proportion of the parts of which a product is comprised can account for much of the value. This analysis can be used in the process of reducing production costs to a minimum by concentrating on those parts or components.

In the example, 10% of the parts account for 70% of value. In the medium price category 20% of the parts represent 25% of value. The low price parts comprise 70% of the total number but only 5% of value. Efforts to minimize product cost should logically concentrate on the few parts that account for a major part of value.

PRODUCTION PROCESS AND METHODS



What is the scope of production process analysis? In a turnkey project the process engineering is the responsibility of the technology provider. Otherwise process design and engineering would be undertaken by the sponsor's engineers. This information is necessary for the plant design and for determining investment and operating costs:

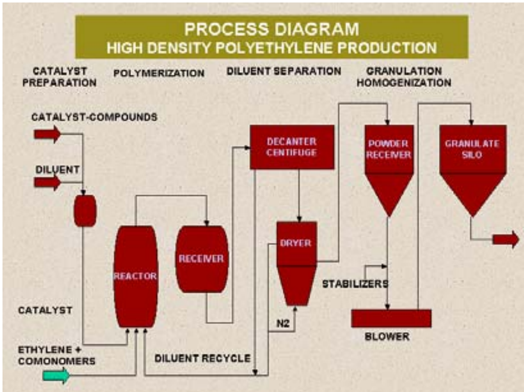
Sequence of process operations: The production process has to be defined. This consists of the sequence of manufacturing operations. The unit operations and their sequence and the type of processing (batch, continuous, semi-continuous, etc.) must be determined. Process diagrams are very useful for this purpose.

Type and number of machines required: After designing the process, the type and number of machines and equipment necessary to carry out each unit operation can be selected.

Material handling methods and equipment: The process design indicates the quantities and types of materials that must be moved between operations. A process flow chart is very useful for this purpose as it indicates the types and quantities of materials that flow between operations. The material specifications also indicate any special requirements, such as conveyors or special vessels for handling heated or hazardous materials.

Material and energy flows: The process analysis is the source of information on material and energy flows. Combined with the process diagram, other diagrams showing the quantities and types of material and energy flowing within and without the plant can be generated (see the section on Material and Energy balance). This information is necessary for developing the supplies programme and also for dealing with issues of waste and effluent disposal.

PROCESS DIAGRAM -
HIGH DENSITY POLYETHYLENE PRODUCTION

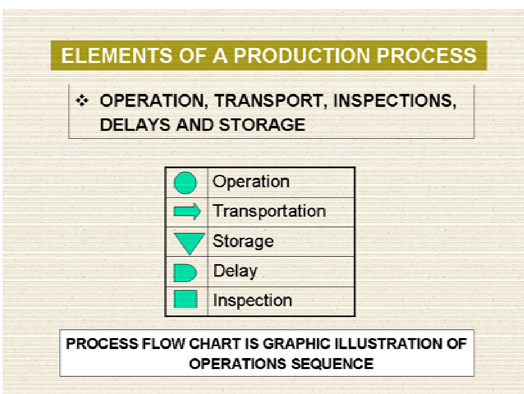


A process diagram indicates the sequence of operations for a continuous or semi continuous process. It helps to visualize the relationships between unit operations.

An example is shown for the manufacture of polyethylene granules. Catalyst compounds and diluent are combined in a mixer with ethylene and co-monomers. These are passed through a reactor. From a receiver the polymer is sent to a decanting centrifuge, where the diluent is separated and recycled. The decanted polymer is then dried in a nitrogen environment and sent to a powder receiver, where granulation and homogenisation take place. Stabilizers are injected into the stream before depositing the granules in a silo.

This information forms the basis for analysis and would be developed further into more detailed operations process charts and material and energy flow diagrams. These, in turn, would be used for more detailed analysis of unit operations: machinery and equipment needs, material inputs, wastes and effluent flows.

ELEMENTS OF A PRODUCTION PROCESS



A production process generally consists of the elements shown.

Operations: Transformation of materials to another form or composition. The aggregation of all operations comprises the sequence necessary to convert all material inputs to the final product. This relates to machine and tool loading and manpower requirements

Transport: Movements of materials and personnel from one location to another. This information provides materials handling data - the equipment and facilities necessary to transport materials and personnel through the plant as necessary.

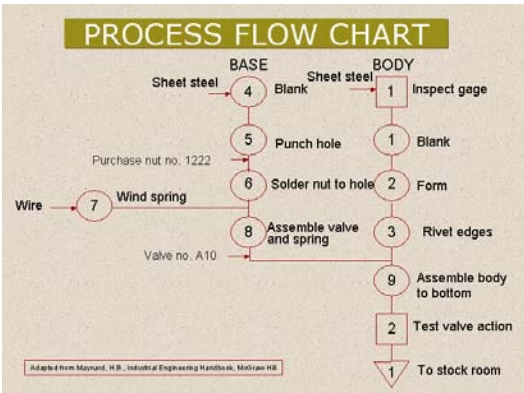
Storage: Placement of materials, integrated components or finished products into a holding area or facility. Warehousing and temporary storage areas and characteristics are indicated.

Delay: A temporary interruption of processing, either as part of the process (e.g. curing) or to accommodate imbalances in the capacities of sequential production stages. If the delay is a function of imbalances in unit operations processes, this information can be employed to the improvement of the process.

Inspection: Sampling and quality control procedures. This information relates to measurement techniques and devices and to inspection personnel.

These symbols are used to construct a process flow chart showing the relationships between various plant operations.

PROCESS FLOW CHART



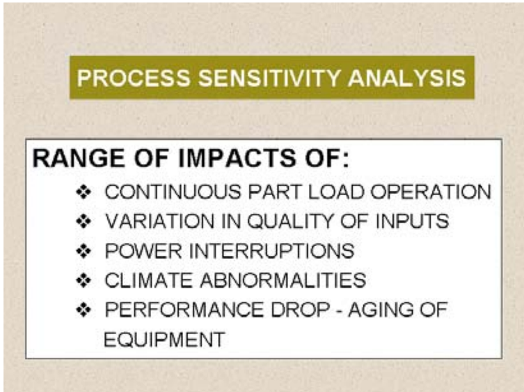
Charts and graphs are helpful for the analyst in understanding the nature of all processes and functions that comprise the physical plant.

A production process flow chart indicates the sequence of manufacturing and assembly operations and how they are interrelated. Inputs to the process, such as pre-fabricated and purchased parts, are also indicated. In the flow chart shown, symbols for operations, inspections and storage are shown, in accordance with the standard charting symbols described elsewhere in this section. Two parts (base and body) are fabricated and assembled into a valve subassembly. This part would be integrated with other components in a subsequent process to complete the final product.

Charts of this type should be prepared for all major functions, including administrative operations, within the enterprise. This will be very useful in establishing the space requirements and flow of material and other relationships that are a necessary step in the design of the plant. Process diagrams and operations process charts form the basis for more detailed information on material and energy flows that indicate all material substances that enter or leave the process, including gaseous, liquid and solid wastes and by-products (see the section Materials and Energy Balance). This information is important for estimating material costs and can also be used in the environmental impact assessment.

The time for each operation (although not shown in the illustration) is also included in the diagram. For example, a time of 0.020 would require 72 seconds (0.020 hrs * 3600 sec/hr) or 1.2 minutes to complete the operation. This information is used to balance capacities at each production stage.

PROCESS SENSITIVITY ANALYSIS



Process engineering takes into account the production process per se and those project elements with which it is intimately related: the product, the technology and the selection of machinery and equipment. To better comprehend the possible range of operating conditions and their implications for investment and operating costs the sensitivity of the process should be examined with regard to:

Continuous part load operation: Part load operation can affect technological coefficients such as specific fuel consumption and emissions characteristics.

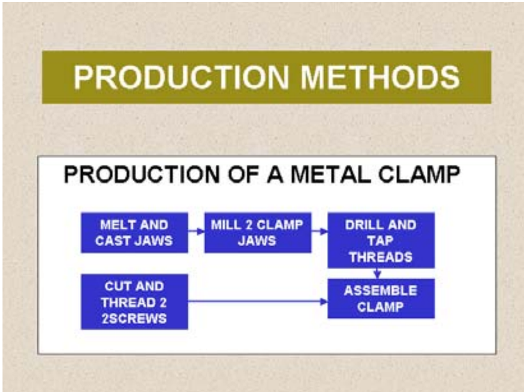
Variation in quality of inputs: The possibility of uneven quality of inputs, the range of qualities to be expected and their implications on yield and waste factors should be examined.

Power interruptions: Interruptions can have serious implications for batch processes, for example. Analysis of the reliability of the public power source should be undertaken to understand probable percentage of down time and it cost implications. It may be advantageous for the project to be self-sufficient in power generation or to provides some degree of stand-by capacity.

Climate abnormalities: Sensitivity of the process to climate changes should be considered in conjunction with a statistical study of climate variations at the site. The statistical variation should be commensurate with the life expectancy of the project. For example, if the project is expected to continue for 25 years, climatic phenomena that are likely to occur in that time span should be included in the sensitivity analysis.

Performance drop - aging of equipment: Aging of equipment usually has an impact on performance and is a factor in the cost of repair and maintenance. The efficiency of heat exchangers such as condensers and evaporators decrease as transfer surfaces deteriorate with use.

PRODUCTION METHODS



A product can be produced by a series of operations on parts or subassemblies and then integrated into the final product.

An example is shown for the manufacture of a metal clamp used to hold two pieces of material together. The sequence is as follows:

Steel for two jaws is melted and then formed into rough jaws in a sand mould. The jaws are further processed by finishing in a milling machine (to bring the shape to final specifications). The jaws are then drilled and tapped as needed to accommodate the screws.

Round steel stock is machined in a lathe to produce two threaded screws.

The clamp is then assembled (two screws are threaded into the jaws) into the final product.

PLANT DESIGN

During the planning stages (before the investment is committed) it is necessary to have some ideas about the plant design in order to firm up the cost estimates for the project. Estimates of the amount of land, the type and size of buildings and other installations are necessary to complete the estimates of project cost and to plan for implementation.

Design of the plant is dependent upon the space and facilities required to carry out all necessary production and administrative functions. This requires an understanding of all internal processes and functions - their organization, sequence, interrelations and interfaces with the external environment.

PRELIMINARY FACILITIES LAYOUT

A preliminary facilities layout consists of drawings or sketches of the site showing the footprint and location of buildings and other installations, roads, loading and storage areas, etc. Every significant facility that is to be located on the site should be indicated. Further layouts should be prepared for individual buildings, to assure that there is sufficient floor space and that the facilities are properly situated with respect to one another. Only in this way can it be ascertained that the site is adequate for the project and that the building configurations will house all the necessary facilities (production, administration, marketing, sales and distribution, etc.).

Allocation for main equipment and buildings, loading docks: Production buildings, shipping and receiving

Plan for roads, rail lines, conveyors, utility lines.

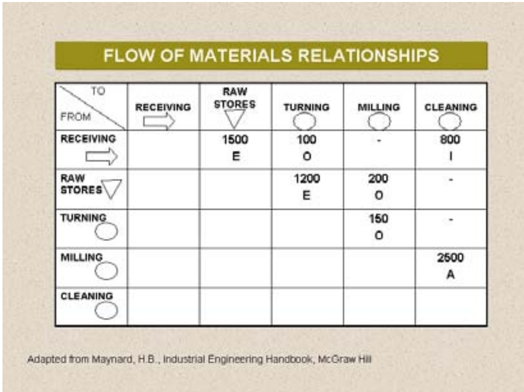
Storage areas for raw material, semi products and products: Buildings, storage pits and cribs, silos, tanks

Office and service building areas: Administrative, marketing and distribution, personnel facilities

Areas provided for future expansion

Security facilities: Fences, gates, outdoor lighting

FLOW OF MATERIALS RELATIONSHIPS



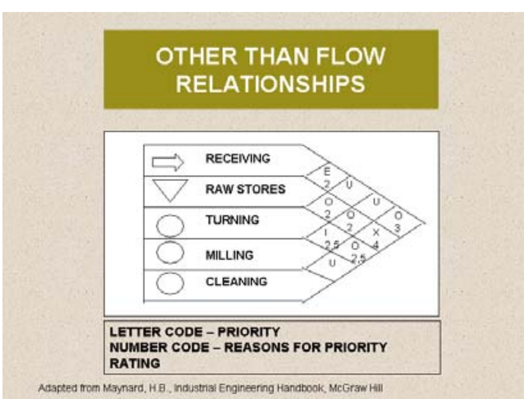
The flow of personnel and materials in the plant will affect the design. Operations that are strongly related by virtue of large inter-department material and personnel flows should be located in proximity to one another.

A	Absolutely
E	Especially
I	Important
O	Ordinary
U	Unimportant
X	Undesirable

The relationships between various plant operations are better understood using a chart of the type shown. Relationships are rated according to a system as shown in the table below. Symbols are used to indicate the type of activity (operation, storage, etc.)

This type of analysis during the planning stage helps to clarify the building and facilities sizes and characteristics, and consequently helps to determine the capital investment.

OTHER THAN FLOW RELATIONSHIPS



In addition to the flow relationships that are determinants for the plant layout, there are other factors that enter into the design decisions. The ratings for the relationships between departments can be examined systematically using the type of chart shown. The box (diamond shape) at the intersection of any two departments has two codes, one for the priority of the relationship (see previous table) and the reason code (see below).

- Movement of personnel
- Degree of communications or paperwork contact
- Use of same equipment or facilities
- Use of common records
- Sharing of same personnel
- Specific management desires or personal convenience
- Supervision or control
- Noise, dust, dirt, fumes, hazards
- Distractions or interruptions

Multiple reasons for a priority rating should be indicated, as shown in two of the cells (2,5).

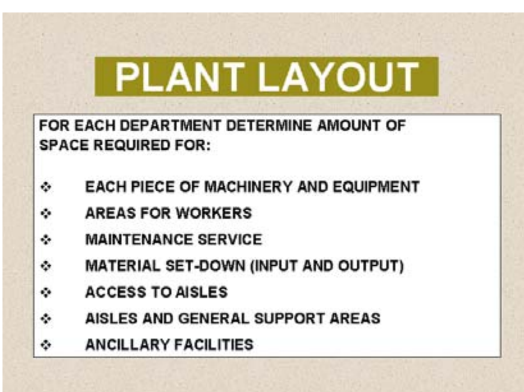
The space relationships in the site and within the facilities located on the site are based on the flow of materials and other relationships between functions or departments. The flow relationships and other-than-flow relationships can be combined to provide an overall rating using a system of weighting at the discretion of the designer. Each factor could be given equal weight or any other combination of percentages. For example, flow could be assigned 50% and each of 10 other reasons 5% (total 100%).

When the strength of these relationships has been determined, the space requirements and physical layout of the site and plant can be defined. An example of such a system is shown in the following table:

		OTHER RELATIONSHIPS					
		A	E	I	O	U	X
FLOW RELATIONSHIPS	**A**	A	A	A-	E	E-	I
	E	A	A-	E	E-	I	I-
	I	A-	E	E-	I	I-	O
	O	E	E-	I	I-	O	U
	U	E-	I	I-	O	U	X

Maynard, H.B., Industrial Engineering Handbook, McGraw Hill

PLANT LAYOUT



All activities areas and features should be systematically described. Then space allocations should be attempted for each department or type of area:

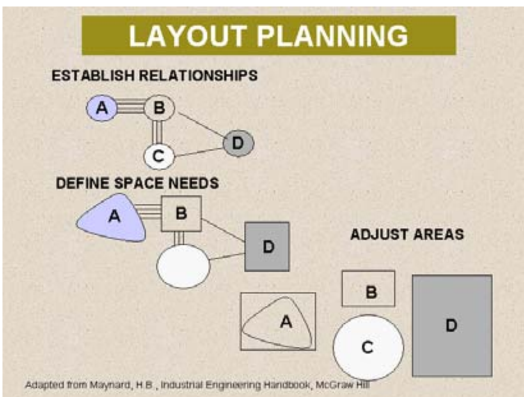
- Each piece of machinery and equipment
- Areas for workers
- Maintenance service
- Material set-down (input and output)
- Access to aisles
- Aisles and general support areas

- Ancillary facilities: materials handling; storage areas for materials and supplies; offices for supervisors; personnel facilities; utilities areas; maintenance facilities.

The plant layout can be visualized with drawings and diagrams, templates and layout boards or three dimensional models for complex facilities. For the overall plant complex, a three-dimensional scale model of the site and all facilities is an excellent way of visualizing the physical interfaces between functions.

In the early stages the cost of plant construction can be estimated on basis of construction indices. However, in the latter stages estimates should be obtained from reputable contractors or consultants based upon fairly accurate sketches and descriptions of plant facilities.

LAYOUT PLANNING



Layout planning should be applied to all facilities and to the site in which they will be located. Basically the analysis involves three steps.

Establish relationships: The relationships between various activities should be established. This is a function of flow of materials and other relationships previously described. In preparing a preliminary layout the strength of the relationship can be indicated by the number of lines between the symbols for each pair of activities.

Define space needs: Space necessary to accommodate all of the necessary components within each function are determined.

Adjust areas: Space needs and relationships are adjusted for the specific site or building characteristics.

BUILDINGS

Once space requirements for all production and administrative functions have been determined, they can be incorporated into the design requirements for buildings.

Space requirements: For each of the enterprise functions (administration, production, stores, packing, shipping and receiving, research, any staff facilities (housing, recreation) the space requirements can be translated into building specifications (size, layout, interiors, air-conditioning).

Construction specifications: The various options for building construction (e.g. masonry, wood frame, pre-fabricated, foundations) should be examined in regard to investment and maintenance costs.

Construction scheduling: Scheduling of construction will be significantly affected the the construction specifications. For example, construction time for a masonry building will be greater that for a pre-fabricated metal building. This subject is covered more extensively in "Implementation".

Cost of construction: Construction contracts can vary from ‘turnkey’ to individual subcontracting. The choice depends upon the interests and capabilities of project sponsors. The type of construction contracts awarded, in addition to building specifications, will have an impact on construction costs. Construction usually represents a significant part of the overall investment costs. Overruns are often the result of a poorly executed construction programme.

BASIS FOR COST ESTIMATION

The plant layout is the basis for estimating the cost of the site development and plant facilities. Once the plant layout is determined, costs can be estimated for:

Land and site preparation

Civil engineering works

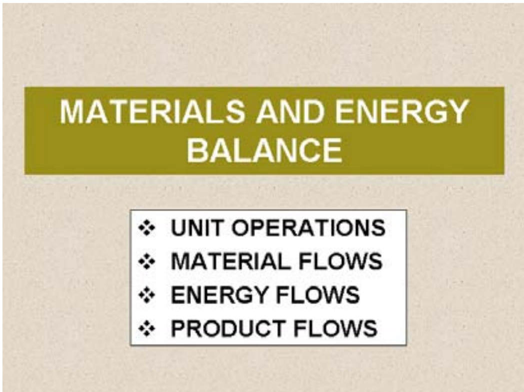
- Buildings
- Utility installations
- Roads
- Railroad sidings
- Loading and unloading facilities

Operating costs for in-plant transport (materials handling) and communications.

In the early stages estimates can be based upon standard cost factors, e.g.: cost per cubic meter of earth movement for site preparation; average price per square meter for the type of building construction; standard road construction cost per meter (based upon quality of road construction). For the feasibility study actual tender offers will provide more accurate estimates.

The information pertaining to site requirements and building areas can be used to develop cost estimates of the site, civil works, plant and ancillary facilities that will be located on the site. This analysis can also provide information concerning the materials handling and intra-plant communications costs.

MATERIALS AND ENERGY BALANCE



"Balance" is an important word for project analysts and designers. It should be applied in virtually every area of project design. All aspects of the project should be properly proportioned so that wasted resources are kept to a minimum.

In regard to the technology, there are several areas in which the concept of balance is particularly important:

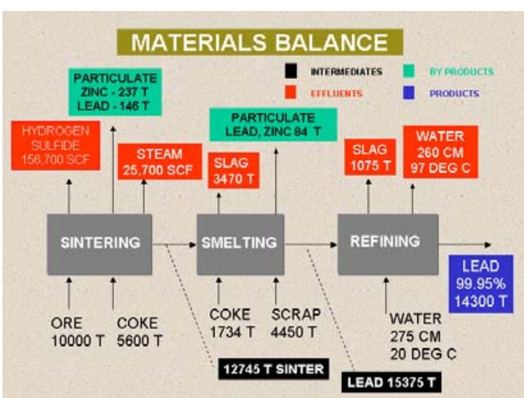
Unit operations - providing for capacity balance for all operations to minimize investment and operating costs.

Material flows - analysis of material inputs and how they flow into the product, into byproducts, waste materials and effluents.

Energy flows - how energy is provided to the project, where it is utilized, how energy is discharged and its impact on the external environment.

Product flows - the relationship between production and sales, and how an optimal storage and inventory policy can have positive effects on project performance when demand is cyclical.

MATERIAL BALANCE



Materials flowing into the project are either consumed in production of primary products and by-products or become wastes that must be disposed.

It is useful to develop a complete material flow diagram to understand the quantities of materials required and the anticipated quantities of wastes and effluents. Means to dispose of the latter two must be determined. As wastes and effluents are of increasing environmental concern and inevitably involve costs to the project, the design should include provisions for their disposition.

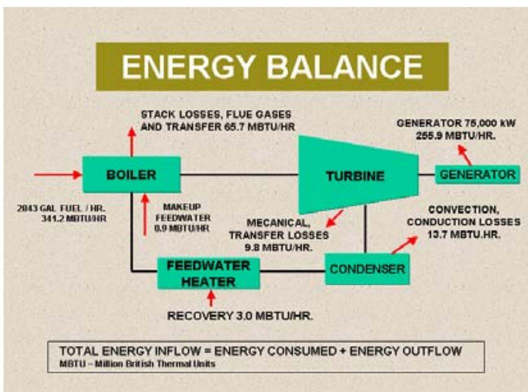
The illustration is for a non-ferrous smelting plant (values are for illustrative purposes only). The quantities of inflows and outflows of materials correspond to the operating period, in this case the operating year.

Ore and coke enter the sinter. The effluents are hydrogen sulfide, particulates (lead, zinc and other trace metals) and steam. The sinter enters the smelting process, where coke and scrap lead is added. The smelted lead (unrefined) is produced along with slag consisting of residual materials. There are also particulates generated that are expelled into the atmosphere (lead, zinc and trace metals).

Water enters the refining stage and is heated from 20 to 97 deg C in the process. A residual slag remains from refining lead to 99.95% purity required.

The material flow diagram clarifies the quantities of material inflows and production. It also identifies issues left to the designer to deal with wastes and effluents - treatments of the hydrogen sulfide gases, the discharged particulates, the disposition of slags and discharge the heated water.

ENERGY BALANCE



The energy flows in an investment project have an effect on investment and profitability in a number of ways. Energy has a cost - the proportion of energy applied in actual production as compared with the total energy consumed is a measure of energy efficiency.

A principle of nature is that energy and matter can neither be created nor destroyed, but can be converted to other forms. In most industrial applications there is very little conversion of matter to energy - virtually all conventional applications involve primarily the conversion of energy from one form to another. Fuel-fired plants and hydro-electric generators are the major sources of non-nuclear energy.

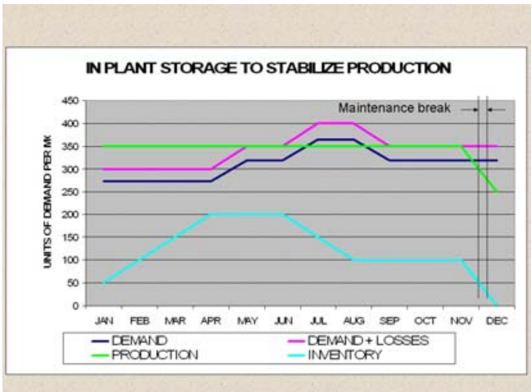
Within the plant energy enters, usually in the form of fuels to fire boilers or through the electrical power grid. Sometimes, at least for back-up purposes, plants are powered with generators driven by internal combustion engines or turbines fired with natural gas or fuel oil. The energy flows into production, ancillary uses such as internal heating, or is wasted.

With fuel prices under pressure from limited supply, it is incumbent upon project designers to assure efficient use of energy. This will tend to minimize investment and production costs and also contribute to reducing the pressure on international fuel supplies.

A very simplified energy flow diagram is shown for a steam turbine installation (all heat values only for illustrative purposes). The boiler is fired with fuel oil with a Higher Heating Value (energy content) of about 18,500 BTU/lb. The energy of the fuel is used to generate steam, which then is used to drive a 75,000 kW turbine. Some of the fuel energy is lost in the flue gases and heat transfer in the stack. There are mechanical and heat transfer losses in the turbine itself (e.g. friction losses) and in the condenser. Some energy is recovered in a feedwater heater.

The disposition of the heat losses is usually of environmental concern. For example, the condenser heating loss can be transferred to the air (air-cooled) or to a water body (water-cooled).

IN-PLANT STORAGE TO STABILIZE PRODUCTION



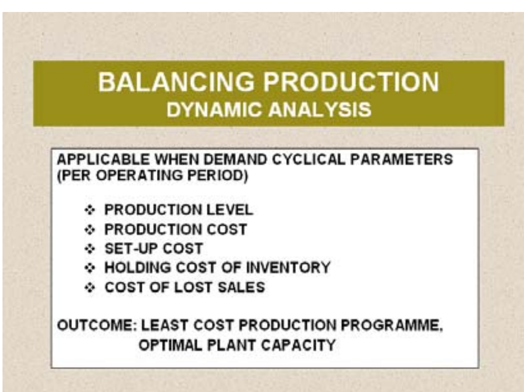
When the demand or the projected sales program is cyclical the production program can be stabilized by utilizing a policy of building up finished product inventory when demand is slack and drawing it down when demand is heavy. The real impact of this policy is to minimize the size of the plant and consequently the investment costs. A capacity of 350 per month is required rather that the peak demand of 364.

In the illustration shown there is relatively low demand in the first four months of the year. It then builds to a peak in July and August and slacks off a bit in the final four months.

The data is shown in the following table:

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DEMAND	273				318		364		318			
LOSSES (10%)	-				-		-		-			
TO STORAGE	50				-	-	-	-	50	100	150	200
FROM STORAGE	350	250										
INVENTORY	273	318	364	318			27	32				36
PRODUCTION	-											-

BALANCING PRODUCTION - DYNAMIC ANALYSIS



When demand is cyclical it is possible to determine a production programme that satisfies demand requirements and that also satisfies other criteria, such as minimum operating cost. The parameters of this analysis can be the following (other parameters can be included at the discretion of the analyst:

- Production cost as function of time
- Number of units produced in each period

- Holding cost (inventory storage and losses)
- Set-up cost (for batch processing - incurred for production in set-up period)
- Stock-out cost (if available stocks plus production is less than demand); in this case the loss equals the contribution lost.

This type of analysis can be performed manually for small projects with a limited number of parameters.

For large projects a computer may be necessary. A model is described for determining the optimal production program in the file *Dynamic Inventory Analysis*.

PROJECT INPUTS

Material inputs are one of the major cost elements of production. In many developing countries with relatively low wage rates, materials costs by far outstrip labour as a cost of production. Efficient material utilization can therefore have a very large impact on the feasibility of the project. In fact, in some cases it can represent the difference between success and failure.

Material inputs can be in any natural form - solids, liquids and gases and any combination thereof. They can consist of raw materials, semi-processed materials, components and subsystems.

Reliability of sources of materials and supplies is a concern to project designers, as is the difficult task of estimating future costs and trends.

MATERIALS AND SUPPLIES – CLASSIFICATIONS

The project designer is faced with the task of identifying all material inputs, their sources and risks, and their present and future costs. One way of pursuing a comprehensive compilation of needed materials and inputs is to consider all possible classifications:

Raw materials: Unprocessed materials such as ores and natural agricultural produce.

Processed industrial intermediates: Processed materials that are produced for end-use, such as aluminium billets, hot and cold-rolled steel forms.

Manufactured materials and parts: Generally used in assembly processes (automobile tyres, engine blocks, standard hardware such as nuts and bolts). Some manufactured materials may be in the form of components and subsystems. Make or buy decisions may lead to a fairly high level of integration in the components. A satellite manufacturer may purchase the entire power system from a subcontractor. Computer manufacturers buy storage devices and fully integrated processor boards that are assembled into their products.

Auxiliary materials: Materials that are incidental to the product, e.g. solvents in some paper manufacture or catalysts in some chemical processes.

Factory supplies: Materials and devices used in maintenance, repair and other plant functions such as water purification and sanitation.

Utilities: Utilities have material content (e.g fuels and potable water) purchased in bulk or are purchased from suppliers' grids (electric power) and pipe systems (natural gas).

Spare parts: Parts of machinery and equipment have a rate of failure, i.e. failures can be expected. The project analyst should estimate the quantity of spares needed for each operating unit and for each period of operations. A plan for securing these spare parts should be included in the study. Particularly if spares have to be imported the analyst should take delivery times into account as well the need for foreign exchange.

Moulds, dies and other special tools: For some processes there is a recurring need for special tooling. The supplies programme should provide for their procurement and costs. This can lead to local vendor development, provided that the needed skills, capacity and materials are available.

ANALYSIS OF MATERIALS AND SUPPLIES

Quality: What is the required quality? The quality specifications should match the needs of the market and other criteria of the sponsor. It may be prudent to specify a superior quality material in a critical application (one that traditionally fails) that has a significant impact on product performance as a means of attaining loyalty of clients.

The quality of a material can be defined either in terms of its composition and the purity of its constituents or by performance specifications under standard conditions.

Failure rate of parts, components or an entire subsystem is another way to specify quality. This will have an impact on product reliability.

Reference to *industry, national or international standards* is a good way to avoid risk and to provide accurate cost estimates, particularly for raw and semi-processed materials. Standards can also be used to check the availability of materials locally (see section on Product Analysis for more discussion on industrial standards).

When there are doubts, the materials can be laboratory-tested or proven in test runs at a similar plant (preferably one with whom the sponsor has good relations).

Alternative or substitute materials that can be obtained from local sources (with adequate quality standards) can result in lower cost. Steel reinforcing mesh wire, for example, can be replaced in some applications with low cost reinforcing rod that can be produced with relatively simple processes.

Quantity :Quantities are established from production coefficients and production levels. Losses of materials in storage, handling and in the process should be taken into account. The procedure is to use process diagrams and flow charts to determine process and factory supplies requirements. Provisions should be made for yield factors and for losses in handling and storage.

The yield factor is the ratio of the number of units of input per unit of output. For example, in processing fruit juices, yield depends upon the extractable liquid vs. solid content. One ton of mangos, for example, may yield 0.3 tons of mango juice.

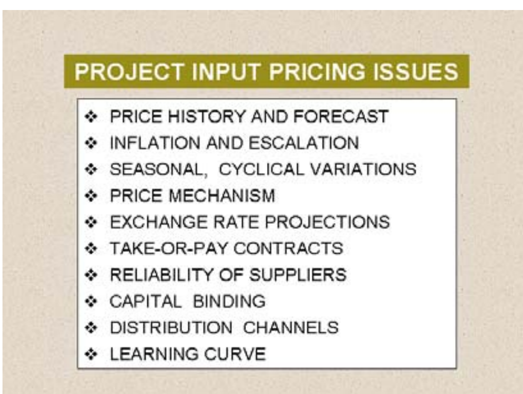
The same concept applies to ores. A ton of iron ore will yield less than a ton of pig iron, the exact amount depending on the quality of the ore.

In addition to yield, product losses will occur in handling and storage and also from unauthorized uses. Shelf life of materials is an important part of the product specifications. Some organic compounds, for example, have rates of deterioration that are a function of storage conditions. Inventory policy, yield and loss factors will assist in determining the storage facilities and space requirements.

A supplies programme defines quantities to be procured in each operating period and their sources.

Costs: Materials and supplies costs must be estimated for each of the construction and operating periods. This will derive from a combination of quantity and price. For imports there may be considerations of tariffs and duties, transportation costs. The CIF price will not include transport and handling to the factory site. The reliability of price estimates and possible escalations should be taken into account (escalations are price increases relative to the general price trend).

PROJECT INPUT PRICING ISSUES



Price history and forecast: The price history of inputs may give some indication of an appropriate price for estimating purposes. Some materials, e.g. commodities, have widely fluctuating price histories with no apparent pattern. These price histories can be analysed statistically to discern the price trends, parameters and probability ranges. Then the nominal price can be adjusted within the expected range to develop best and worst case scenarios. Prudence suggest that conservative price estimates should be employed.

Inflation and escalation: Should price inflation be assumed in the supplies programme? This depends on the characteristics of the financial analysis. If constant pricing is assumed in the analysis then any input price that is expected to follow the general trend should be assumed constant. However, even when there is no prospect of inflation certain materials or commodities may be subject to escalation from the demand-supply situation. In some cases clean water has become a scarce commodity and industrial users are increasingly asked to pay the full price of purification and distribution. In such cases the current price should be included in the supplies programme, but taking into account only the relative price increase expected. When the financial analysis is to be performed at current prices general inflation should be included plus any expected relative escalations.

Seasonal, cyclical variations: If prices of inputs are seasonal or cyclical, such variations should be estimated for each period in the supplies programme. Agricultural prices are generally seasonal. Some commodities, e.g. building materials, vary in price with the economic cycle. If the financial analysis covers periods of a full year or an economic cycle an average price would have to be applied.

Price mechanism: The pricing mechanism for a project input (commodity or material) may be anywhere from the free market to near monopolistic. Petroleum, for example, is largely under the control of the oil cartel. Power costs are often regulated. The price mechanism should be factored into cost estimates.

Exchange rate projections: The price of imported inputs will be affected by the exchange rate. The project analyst should be aware of any pressures or constraints on currency exchange rates, particularly when there are exchange controls. If the local currency is overvalued there is a likelihood of devaluation at some point, which would have to be taken into account in the input price. The general state of reserves and the trade and current balances should be examined.

Take-or-pay contracts: When a needed input is in short supply, it may be necessary to negotiate long term contracts with take-or-pay features to secure a reliable supply. This type of contract assures supply but requires paying for a specific quantity of the input during each period regardless of need.

Reliability of supplies: Proposed suppliers should be examined in terms of their dependability. Enterprises have varying degrees of respect for the needs of their clients, particularly when it is a suppliers' market. The requirement of the project as a percentage of total capacity of suppliers is significant. In tight markets slight shifts in demand or transportation costs, for example, can alter client preferences of suppliers.

The reliability of agricultural supplies is dependent upon climatic variations from one year to another. An analysis of variances in crop yields, in such a case, should be attempted. In any case the reliability in terms of availability and cost for all materials should be thoroughly investigated during the planning stage, in terms of suppliers and conditions affecting supplies.

Capital binding: The amount of capital tied up in supplies of inputs is a function of payment terms, inventory policy and lead times. In the case of imports, a letter of credit usually must be opened at the point of order, and the full amount of the order must be deposited in the local banking institution. Whether these funds are borrowed or not there is always either a direct or opportunity cost.

Distribution channels: The price build-up through the various stages of the distribution channel should be understood.

Learning curve: In the early stages quantities of materials required are affected by inefficiencies as production procedures are refined (machines and workers).

SUPPLY PROGRAMME COMPONENTS

The supplies programme spells out the sources, quantities, and product specifications and delivery schedule for all material items. Lead times and order cycles should also be specified (time between orders and order points).

Quantities: How much and when materials and supplies will be required.

Sources: Sources should be identified for each material and supply. The important information for each supplier is the name and location of the company, its history, capacity to supply, and payment terms. The history is important as a means of understanding the stability of the supplier. The percentage of its total output required by the project should be ascertained to understand the purchasing leverage of the project. Payment terms will help to understand the true cost of the material based upon the inventory policy adopted.

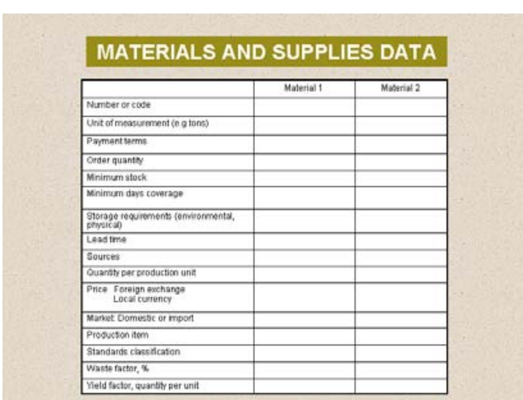
This information should be collected for domestic suppliers and for exporters and their trading links.

Specifications: The specifications of materials and supplies should be determined and used for all procurements and cost estimates. These specifications should refer to industrial standards when possible, or to content and/or performance standards.

Price: The price of the material or input has to be specified. The ex-factory price may be adjusted for transportation and handling charges to the project site. For imported goods the CIF price may be adjusted by any import duties and inland charges.

Transportation and handling: Facilities and costs for transportation and handling from supplier to plant should be planned carefully. For multi-plant operations it may be appropriate to use an optimization model to plan supply routes for each plant.

MATERIALS AND SUPPLIES DATA



MATERIALS AND SUPPLIES DATA

	Material 1	Material 2
Number or code		
Unit of measurement (e g tons)		
Payment terms		
Order quantity		
Minimum stock		
Minimum days coverage		
Storage requirements (environmental, physical)		
Lead time		
Sources		
Quantity per production unit		
Price Foreign exchange Local currency		
Market Domestic or import		
Production item		
Standards classification		
Waste factor, %		
Yield factor, quantity per unit		

Information should be systematically collected and organized concerning the materials and supplies required for the production program and for ancillary uses.

<u>Number or code</u>: Designation for identifying item

<u>Unit of measurement</u>: Standard unit, e.g. tons, liters, packets

<u>Payment terms</u>: Terms of payment for identified sources will assist in estimating

the price to be used in financial analyses and the amount of working capital requirements.

Order quantity: This will assist in determining the required level of stocks and is also an element that determines working capital requirements (see the file Order Quantity).

Minimum stock: The minimum, or buffer stock, is dependent upon the lead time and reliability of suppliers and factors such as shelf life.

Minimum days coverage: MDC is the number of day that the buffer stocks will support production in the absence of additional supplies.

Storage requirements (environmental, physical): Materials may require special facilities for storage and transport, e.g. refrigeration or air purity. This information will feed into the plant design and capital investment required.

Lead time: The time from placement of order to delivery is a determinant of buffer stock requirements and is also an element of working capital requirements, particularly for imported items that require deposits at the time the Letter of Credit is opened.

Sources: The identification and other information about sources has been discussed previously.

Quantity per production unit: The technological coefficient, consumption per unit of output, should be determined considering the standard quantities and yield, waste factors and losses.

Price: The price per unit, including transportation, should be ascertained. For imported goods the cost of inland handling and transport and any duties should be added to the CIF price.

Market: Procurement from identified domestic suppliers or exporting country.

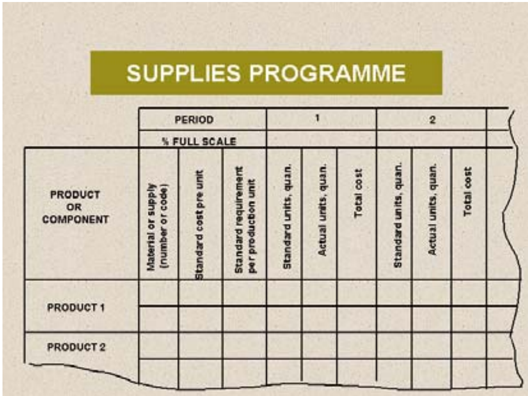
Production item: The item of output within the project's product line or the ancillary use of the material or supply should be should be identified.

Standards classification: The institutional, national or international standards that apply; also any applicable content or performance standards.

Waste factor, %: Of the material purchased, the percentage that actually finds its way into finished product should be determined. Quantities to be included in the supplies programme must be adjusted for the waste factor that compensates for storage losses in-plant and in handling and transportation. An example of the use of material waste factors is provided in Material Waste Factors.

Yield factor, quantity per unit: Some materials contain impurities and other substances that do not become part of the finished product. Ores, for example, have impurities that must be separated and discarded. Agricultural produce contains water and other components that are also separated and discarded. The quantity of sugar in cane, for example, varies widely based upon soil, climatic conditions and the amount of time from harvest to processing. The quantities to be purchased as inputs to the production process must take into account the yield of such materials.

SUPPLIES PROGRAMME



The supply programme specifies the timing of purchases, i.e. how much will be needed in each production period. Some materials may also be required during the late stages of the construction phase for trial runs and plant commissioning.

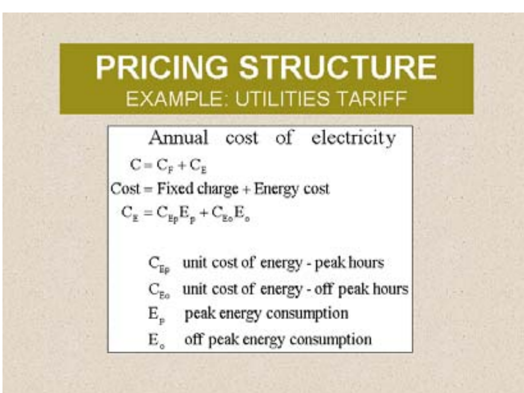
One way to visualize the requirements is the type of table shown. For each product in the line the type of materials are listed. This should also be done for factory supplies. The standard consumption per unit of output is indicated and the standard unit cost of the material or supply item. An *identifying number or code* for each material and supply item can assist in maintaining correspondence between the data files.

For each period of production (and construction, if applicable) the standard number of units is listed based upon the percentage of full scale production planned. The actual quantities are adjusted from the standard for yield and waste factors, as applicable. Then the price is applied to the actual consumption to determine the cost for each material and supply for each period.

The inventory policy may affect the amounts to be procured in each period. During those period when inventory changes are contemplated (increases or decreases) the impact on the procurement of supplies should be taken into account in the quantities listed in the supplies programme.

For the purposes of cash flow planning the lead times should be taken into account. This is particularly true for items with very long lead times, say six months or longer. Analysis of working capital requirements (capital binding), takes into account lead times, order quantities, and inventory issues (see Material and Energy Balance and Order Quantities).

PRICING STRUCTURE



When determining the cost of project inputs it is sometimes necessary to take into account the structure of pricing in the supplier industry.

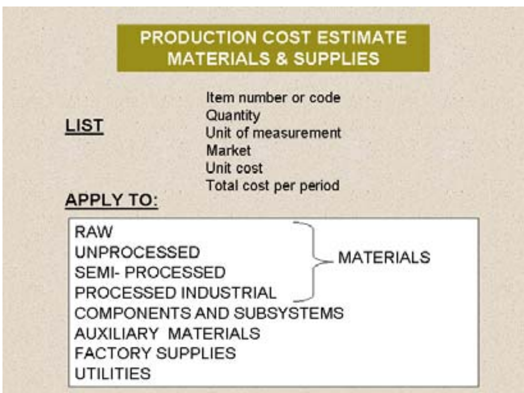
Utilities, for example, have a pricing structure that may include connection charges, fixed charges per period, consumption rates for peak hours (when consumption by all users is at a high level, e.g. during evening hours when lighting is generally required) and for off peak hours.

Electric utilities may also charge a fee for fuel consumption, based upon the varying costs of their inputs. The rates may also be a function of the level of consumption, sometimes higher for low rates (with stimulation of consumption intended) or higher for high rates of consumption (when discouragement of consumption is intended).

The point is that the structure of pricing for utilities and other suppliers should be examined before attempting to estimate project costs.

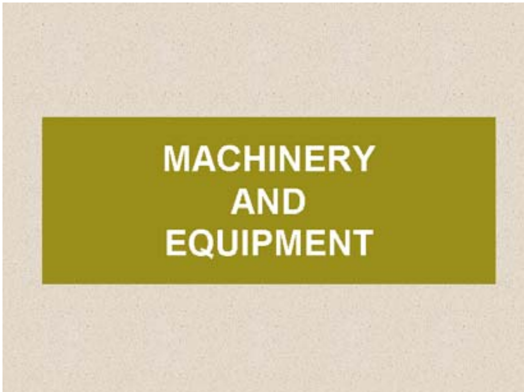
An example is illustrated for an electric utility with pricing based upon a fixed charge and consumption cost based upon peak and off peak hours. The total tariff is the sum of the fixed charge plus consumption during each of the separate time periods.

PRODUCTION COST ESTIMATES - MATERIALS AND SUPPLIES



Production cost estimates are derived by listing each item with the item identification number or code, quantity, unit of measurement (e.g. tons), market (local or foreign), unit cost in local or foreign currency, and total cost using a specified exchange rate. This is applied to all classifications of materials (raw, unprocessed, semi- processed and processed industrial materials, components and subsystems, auxiliary materials, factory supplies and utilities. The total cost is determined in conjunction with the quantities specified in the supplies programme. This information is utilized in determining the financial viability of the project.

MACHINERY AND EQUIPMENT

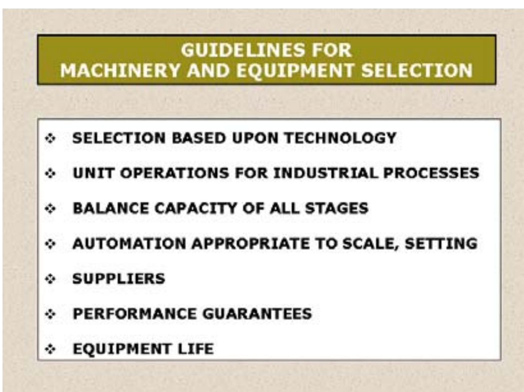


Selection of machinery and equipment to meet the production requirements is one of the major engineering responsibilities. Machinery and ancillary equipment should be selected according to the required capacities and considering the operating environment as it affects performance.

The impact of the machine or equipment on its environment should also be considered, both in-plant and in the surrounds. In-plant impacts on working conditions can affect availability and costs of labour. Impacts upon the surrounding areas can have regulatory implications and may require mitigation measures with attendant capital and operating costs.

Selection of machinery and equipment to meet the production requirements is one of the major engineering responsibilities. Equipment should be selected according to the required capacity and considering the operating environment.

GUIDELINES FOR MACHINERY AND EQUIPMENT SELECTION



Selection based upon technology: If the technology is acquired through a turnkey agreement machinery and equipment will be selected by the technology provider. Otherwise, project designers must select machinery and equipment in accordance with the technology, which may be embedded in the machinery. When the technology involves the product or process, machinery and equipment should be selected that produces the desired effects in terms of quality and performance standards for the product. Project designers should understand the features of the machines and equipment that have an impact upon product or process characteristics.

Unit operations for industrial processes: The production sequences should be studied to assure that machinery and equipment is included to complete each operation, that precision and accuracy standards can be maintained and that the capacities for processing the required quantity and quality of materials are adequate. For continuous processes the required flow rates establishes the capacity. When the technology calls for high-precision machining, for example, only machine tools that meet the high performance standards will be acceptable.

For batch processes the load capacity and time per batch determine the capacity per unit time. Set-up time should be considered. Both continuous and batch processes should be adjusted for normal maintenance and local operating conditions. Waste and yield factors should be taken into account.

Balance capacity of all stages: To minimize investment costs the capacities of all stages of operations should be balanced. This is true for both processes and machining and assembly operations. For machining and assembly projects the number of machine hours at each stage will provide information for balancing the capacities.

Automation appropriate to scale, setting: To what extent should machinery and equipment be automated? The answer depends upon cost and internal capabilities. Automatic processes can provide greater precision and accuracy but are more difficult to maintain. A trade-off between cost of automation and its operation, and perhaps enhanced quality of the product has to be weighed against the cost and quality of alternative manual processes. If the manual process produces quality fully adequate for the market then this factor should be removed from the decision process. Then it is only a question of whether or not automation provides sufficient operational savings to justify its cost.

Suppliers: Equipment may be obtained from agents not directly connected with manufacturer. Selection of such dealer should be predicated on their past history in similar transactions.

The terms of sale should be clearly specified - timing of payments in relation delivery schedules and performance demonstration, after-sales service and costs, point and conditions of delivery.

Performance guarantees: The issue of machinery and equipment performance guarantee should be resolved as part of the purchase and sale agreement. The terms of any warranties (who bears the cost of repairs and replacements) for a specified period of time in which the machinery is to operate to specifications and the time between notification of failure and commencement of repair services should also be included.

Equipment life: The analyst should have information from equipment suppliers on historical economic life of machinery and equipment. This information is necessary to deal with replacement schedules and associate investment costs, which will have an impact on the financial viability of the project.

BALANCING MACHINES AND EQUIPMENT

BALANCING MACHINES AND EQUIPMENT

MACHINING TIME, MINUTES

PROCESS	MILLING	DRILLING	TURNING
BASE	3	5	4
VALVE	5	3	-
CASE	-	2	-
TOTAL TIME	8	10	4
RATIO	2	2.5	1
INTEGER RATIO	4	5	2

The capacities of machinery and equipment in each process or production stage should be balanced to minimize investment and maintenance costs.

An example is shown of a plant in which a product requires milling, drilling and turning in three different operations, production of a base, a valve and a case or housing. The machine time for each of the three operations and for each of the three processes is shown. The base production requires all three types of operations, the valve milling and drilling and the case drilling only. The amount of time required for each type of machine to complete all the processes on a single unit of output are 8, 10 and 4 minutes respectively.

The number of machines required should be predicated on the ratios of machine time for each process (the times include maintenance down time adjustments). If the operation with the smallest amount of time is taken as 1 (turning), then the time for other operations are in proportions 2 (milling) and 2.5 (drilling) respectively. In terms of integral numbers of machine units that would ideally be required, they would be in the proportions 4 (milling), 5 (drilling) and 2 (turning).

CATEGORIES OF MACHINERY AND EQUIPMENT

Production or manufacturing equipment

- Plant (process equipment)
- Mechanical equipment
- Electrical equipment
- Instrumentation and controls
- Process conveying and transport
- Other plant and machinery

Auxiliary equipment

- Transport: cars, buses, trucks, tank trucks, forklifts, railway equipment, ropeways, etc.
- Utility supply: electric power equipment, water supply, gas
- Generating plants for: electricity, steam, hot and cold water, compressed air
- Emergency power: stand-by diesels, batteries
- Workshop equipment: mechanical, electrical, measuring equipment, etc.
- Laboratory

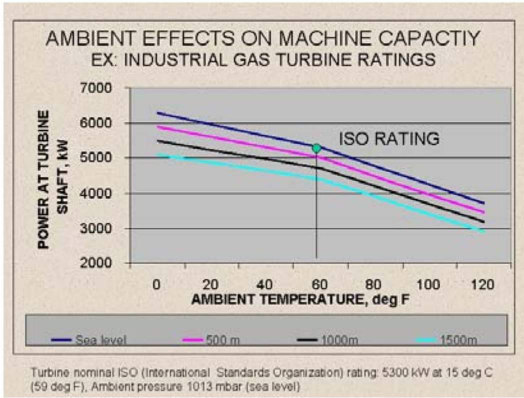
Storage and warehouse equipment

- Communications: central units for telephone, wireless, etc.
- Heating, ventilating, air conditioning
- Packaging equipment, mechanical saws, nailing machines, drums, containers
- Sewage disposal and treatment: pumps, conveyors, treatment plant
- Waste disposal, treatment and other auxiliary equipment

Service equipment

- Office equipment: machines, reproduction, furniture, lockers etc.
- Canteen
- Medical service
- Plant security: fire protection, supervision
- Plant yard cleaning and service: mechanical sweepers, sprinkler cars, etc.
- Staff welfare and residential buildings
- Other

AMBIENT EFFECTS ON MACHINE CAPACITY - EXAMPLE: GAS TURBINE RATINGS

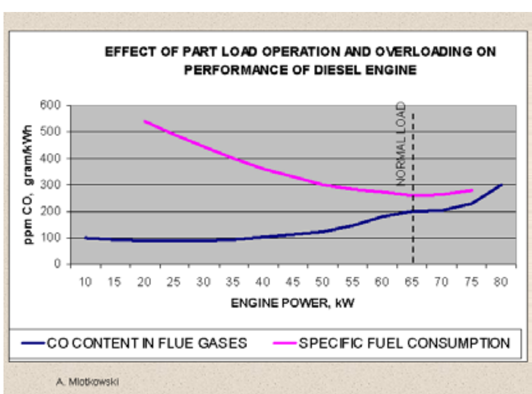


Ambient conditions of temperature, humidity, atmospheric pressure, air purity and wind velocity can affect the performance of machinery and equipment. The selection should be based upon the ambient conditions at the site, as well as other factors related to internal capabilities. When negotiating purchases or manufacturing contracts, the capacity under specified ambient conditions drawn from the site conditions should be included. Any performance requirements or tests should also specify the ambient conditions in which the equipment will be operated.

An example is shown of a commercially available gas turbine. Four graphs are presented for various levels of atmospheric pressure from sea level (14.7 lbs/sq.in. in the British system of units or 1013 mbar in the international system) to 1500 meters (atmospheric pressure declines at higher altitudes). Typically altitude can affect performance by 20% or so of the ISO capacity rating. Temperature has the greater impact on performance in this case: above 60 C the developed power falls off sharply.

All environmental factors should be taken into account. In addition to temperature and altitude, precipitation, humidity and air purity may be significant. High humidity promotes many types of corrosion processes. Air purity can affect combustion, condensation and filtration processes. Precipitation in the form of rainfall, snow or sleet can impede outdoor functions such as conveyor devices. The quality of water can be a factor in heat processes - high mineral content can contribute to fouling of thermal transfer surfaces, thus reducing their efficiency.

EFFECT OF PART LOAD PERFORMANCE AND OVERLOADING

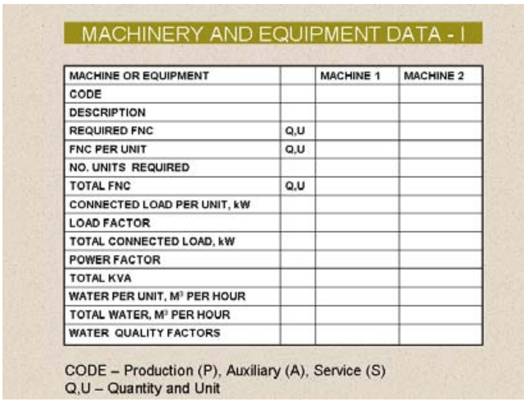


Machinery and equipment should be applied within appropriate ranges of workload. Deleterious effects on performance can result when the application is outside the range of acceptable loads.

The example shown is for a diesel engine. Below its rated load of 65 kW the engine runs smoothly with the CO (carbon monoxide) content of flue gases at a maximum of 200 ppm (parts per million). CO content is an indication of incomplete combustion of the engine fuel. At part load the CO reduces approximately to 100 ppm. When the engine is overloaded the CO content rises sharply to about 300 ppm at 80 kW.

Fuel consumption also varies widely with load. At partial loads in the vicinity of 20 kW the specific fuel consumption is about 540 grams/kWh. At the normal load this reduces to about 260 grams/kWh, approximately twice as fuel-efficient. When the engine is overloaded the specific fuel consumption increases to about 280 grams/kWh at 80 kW.

MACHINERY AND EQUIPMENT DATA - I



MACHINERY AND EQUIPMENT DATA - I

MACHINE OR EQUIPMENT		MACHINE 1	MACHINE 2
CODE			
DESCRIPTION			
REQUIRED FNC	Q,U		
FNC PER UNIT	Q,U		
NO. UNITS REQUIRED			
TOTAL FNC	Q,U		
CONNECTED LOAD PER UNIT, kW			
LOAD FACTOR			
TOTAL CONNECTED LOAD, kW			
POWER FACTOR			
TOTAL KVA			
WATER PER UNIT, M^3 PER HOUR			
TOTAL WATER, M^3 PER HOUR			
WATER QUALITY FACTORS			

CODE – Production (P), Auxiliary (A), Service (S)
Q,U – Quantity and Unit

A data base concerning machinery and equipment should be compiled systematically and used for estimating investment cost, utilities requirements and implementation schedules. In the list below some utility requirements are included. If a machine or equipment requires other utility services they should be included also in the data base (e.g. natural gas).

Code: Designates each specific type of machinery or equipment and whether needed for Production, Auxiliary or Service application.

Description: The purpose, manufacture and model number

Required FNC: The feasible normal capacity (FNC) required to meet the production plan

FNC per unit: FNC may differ from manufacturer's specified capacity

No. units required: Integer value of required (FNC/FNC per unit)

Total FNC: FNC per unit * No. of units required

CONNECTED LOAD PER UNIT, kW: Power demand in kW at full capacity

Load factor: Average percentage of full load to be utilized by equipment

TOTAL CONNECTED LOAD, kw: Connected load per unit * number of units

Power factor: Ratio of true power [EI cos(phase angle); E - voltage, I - current] to apparent power [EI]; installation requires apparent power, which is higher than true power.

Total kva: The magnitude of the apparent power to be installed for the project, kVA (thousand Volt-Amperes)

MACHINERY AND EQUIPMENT DATA - II

MACHINERY AND EQUIPMENT DATA - II

MACHINE OR EQUIPMENT		MACHINE 1	MACHINE 2
WATER PER UNIT, M^3 PER HOUR			
TOTAL WATER, M^3 PER HOUR			
WATER QUALITY FACTORS			
OTHER UTILITIES	D,Q,U		
SOURCE			
COST PER UNIT	F, L		
TOTAL COST	F, L		
DUTIES and LOCAL TAXES			
TRANSPORT, INSURANCE, ETC.	F, L		
TOTAL DELIVERED COST	F, L		
INSTALLATION REQUIREMENTS	D		
MAINTENANCE REQUIREMENTS			
INSTALLATION COSTS	F, L		
DELIVERY SCHEDULE			
EXPECTED LIFE			

D, Q, U – Description, Quantity, Unity
F, L – Foreign, Local

Water per unit, m3 per hour: Process water; auxiliary and service water should also be noted

Total water, m3 per hour: Process water per unit * number of units

Water quality factors: Specifications for water purity required, mineral content restrictions.

Other utilities: Any other utilities required for the equipment, e.g. natural gas, compressed air, and their specifications

Source: The equipment supplier - name, location, contact information

Cost per unit: Ex factory or import price (CIF) as applicable in foreign or local currency

Duties and local taxes: Duties and other taxes levied by government for procurement of machinery or equipment

Total cost: Number of units * cost per unit in foreign and / or local currency, including taxes and duties

Transport, insurance, etc.: Inland charges for imports, transportation costs borne by project for domestically procured items

Total delivered cost: Total cost in local and foreign exchange for delivery of equipment to site

Installation requirements: Description of foundations, piping, electricity and other utilities

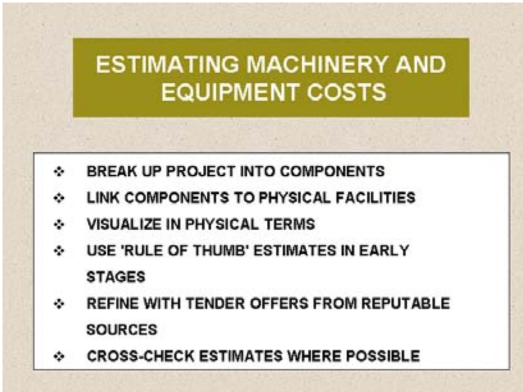
Installation costs: Costs in local and foreign exchange for all installations necessary to place equipment in service.

Maintenance requirements: Special maintenance requirements and estimate of maintenance costs

Delivery schedule: Lead time, payment terms

Expected life: Anticipated technological life of equipment

ESTIMATING MACHINERY AND EQUIPMENT COSTS



Sound information on machinery and equipment cost is needed for the estimate of investment.

Break up project into components: Estimation of machinery and equipment costs can be facilitated by listing the individual machine and equipment types on the basis of the production process design and auxiliary functions such as administration and marketing.

Trace each component to physical facilities needed: Each type of equipment has its specific needs for ancillary facilities such as utilities and service. When these services are listed they should be reviewed to see if costs appear to be reasonable in relation to the basic equipment cost.

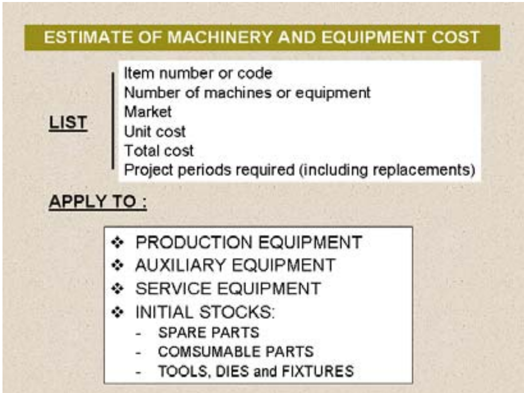
Visualize as much as possible in physical terms: Process diagrams, flow charts, layouts, organizational charts, diagrams of distribution channels, storage arrangements, etc. are the best way to understand the need for machinery and equipment. Equipment lists should be developed with reference to these types of documents.

Use factors and percentages or 'rule of thumb' estimates in early stages: Secondary sources such as project profiles and studies of similar projects provide factors or ratios that can be used for estimating in the early stages of project development.

Refine with tender offers from reputable contractors, suppliers and consultants: When the project progresses to the investment stage it is essential to acquire firm and reliable tender offers.

Cross-check estimates where possible: Multiple tenders can provide a means of cross-checking estimates. In the latter stages these offers should be further checked against other similar projects and advice from knowledgeable consultants. Bids may be excessively high or low depending upon conditions in the market and the current business status of bidders.

ESTIMATE OF MACHINERY AND EQUIPMENT COSTS



The estimate is structured to develop the total cost for the machinery and equipment in each period of the construction phase and also for replacements. Financial analysis requires both the amounts and timing of capital investments.

Item number or code: An identifying designation for the machinery or equipment.

Number of machines or equipment: Quantity of item required in each project period.

Market: Procured in domestic or foreign market.

Unit cost: Total delivered cost for machine or equipment, in foreign and local currency. Installation costs should also be indicated.

Total cost: Cost of the number of units to be purchased for the initial investment in foreign and local currency.

Project period required: Period of construction phase when required, and period when items are expected to be replaced.

Cost for machinery and equipment items in each of the category - production, auxiliary and service requirements are summed to determine the total. The initial stocks of spare parts, consumables and tools, dies and fixtures are included in the estimate. These will become part of the total investment cost for the financial analysis.

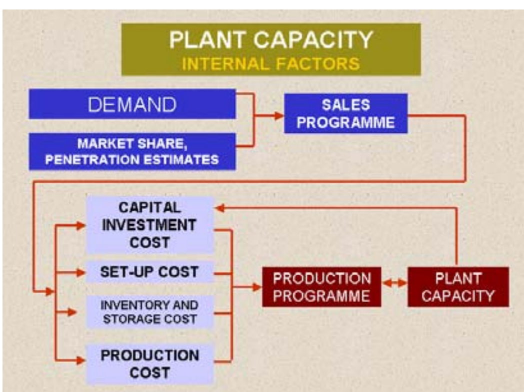
PLANT CAPACITY

Production facilities are designed for a level of output to satisfy the project's production plan. Technical capacity (production rate) is a function of the quantity and types of resources to be employed (e.g. machinery, inputs, personnel) and can be expressed in terms of a production rate - units of production per time unit (day, week, etc.).

Plant capacity is a function of the production rate and operating schedule. Some processes, e.g. oil refining, are inherently continuous, operating 24 hours per day and 7 days per week, shutting down only for periodic maintenance. Other types of production, e.g. vehicle assembly, can operate continuously or on a one or two shift per day basis.

To select the most appropriate types and quantities of production resources and for cost and revenue estimates, the project analyst should consider production rate and operating schedule alternatives.

PLANT CAPACTIY – INTERNAL FACTORS



The logical progression of steps necessary to determine the production programme and plant capacity are shown.

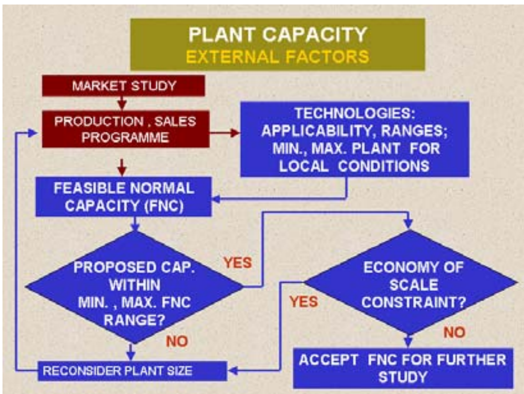
The starting point is the market analysis, which provides estimates of demand and the market share estimated to be captured by the project. The rate of market penetration is another factor that determines the sales programme or sales estimates, i.e., what quantities of product are expected to be sold in each project period to the planning horizon..

The production programme must be predicated on the projected sales programme, but is affected also by other considerations involving operational optimisation: the plant capacity requirements (capital costs for production facilities), the cost of setting up production runs, inventory and storage costs for inputs and finished products, and any variations in production costs over time.

Inventory and storage costs include depreciation of capital facilities, storage and handling losses (product degradation and obsolescence) and the cost of financing working capital necessary to cover inventories.

The plant capacity must, in turn, be sufficient to satisfy the requirements of the production programme. The selected technology is an important consideration in determining the most appropriate plant capacity, such as the minimum and maximum plant size for the process. The determination of the optimal plant capacity is based upon the interplay between the production programme and the production factors indicated.

PLANT CAPACITY - EXTERNAL FACTORS



The schematic representation of the process of determining plant capacity shows the interplay of information and external constraints.

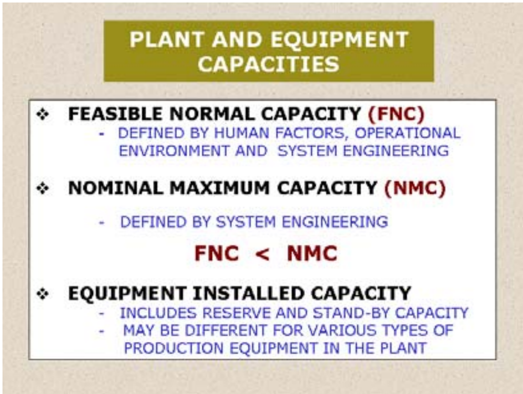
Market information provides a basic guideline. A proposed production capacity can be estimated on the basis of the sales programme and some consideration of the inventory policy.

After selecting an appropriate technology there are basically two external constraints that must be considered: the range of Feasible Normal Capacities (FNC's) available for the selected technology and the minimum economic scale. The minimum and maximum available FNC's are a function of the range of capacities that are technically feasible and offered by technology suppliers. Some processes become technically infeasible if capacity exceeds a certain limit. There may be structural or thermal constraints, for example. There is a minimum economic scale below which practical operations are precluded by high cost.

The minimum and maximum range of operating scales for a given technology can be adjusted for the local conditions to arrive at the FNC limits. If the tentatively proposed capacity is within the FNC limits for the technology, this can be considered a possible solution. Economies of scale should be investigated to refine the selection of capacity. There may be economic constraints beyond the technological. For example, as production costs usually decrease with increasing scale, the production cost of the competition may place a limit on the minimum economic size - for a smaller sized plant the operating costs would be too high. Another factor to be considered in some cases is the cost of lost sales if the maximum capacity is smaller than the sales projections (multiple plants might be considered).

If the proposed capacity is outside the range of FNC's for the technology it would have to be discarded as a possibility and the project size reconsidered.

PLANT AND EQUIPMENT CAPACITIES



When dealing with technology and equipment suppliers, consultants and other parties involved in the project, it is important that a common terminology by employed, particularly in regard to such critical issues as capacity of the plant.

The Feasible Normal Capacity (FNC) is the plant capacity operating under representative local conditions. It can be determined by analysis of the specific conditions in which the technology, machinery or equipment will function, taking into account factors such as operating environment management and worker skills and material qualities.

The Nominal Maximum Capacity (NMC) is generally what is specified by process or equipment manufacturers or providers, as presented in promotional information, when operated under specified conditions. It is defined by the engineers and systems analysts, who have developed the technology package, the machinery or the equipment, as the case may be. Ordinarily this capacity can not be used as the basis for the project design, as it is based upon conditions that usually do not prevail at the project site. Invariably the FNC will be less than the NMC. The FNC should be used as the basis for determining the size and quantities of machines and tools necessary to meet the production requirements.

Additional plant capacity should be considered to account for maintenance down time and for reserve and stand-by capacity to handle emergency production. In determining the utility of such reserve capacity the cost should be compared with the cost of lost sales that could be anticipated in the event of failure of the infrastructure system or interruption of production for any reason.

FACTORS AFFECTING FEASIBLE NORMAL CAPACITY (FNC)

The difference between the Nominal Maximum Capacity (NMC) and the Feasible Normal Capacity (FNC) are essentially attributable to technical factors. Some involve the actual technology and others the environment in which the technology is to function.

Environmental conditions: Factors such as temperature, atmospheric pressure and humidity can affect the performance of machinery and equipment. At high elevation, for example, the reduction in average pressure of the atmosphere can affect output of turbines and other combustion processes. Ambient temperature affects the performance of heat-related processes such as condensers and evaporators.

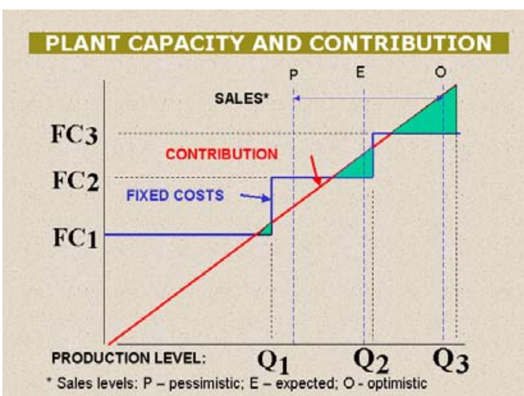
Management and worker skills, cultural factors: FNC can be affected by the quality of operations management - plant layout, worker relations, material flows. Skills such as manual dexterity and logical reasoning can be affected by culture, the habitual activities of worker populations. Cultural patterns such as individual vs. social identity can affect how workers perform in a group setting. Education and other features of the nurturing system, such as athletic activities, can affect the skills that people bring to the workplace.

Planned and unplanned maintenance: The amount of maintenance required for trouble-free operation is a factor in the FNC. Combined with climatic effects, the inherent frequency of required maintenance will determine how much actual useful production can be realized. Some equipment designs inherently require frequent periodic maintenance, such as filtration systems.

Reserve capacity: The FNC of the plant should take into account any reserve capacity for equipment that is crucial to operations, e.g. power generators where transmission lines are not installed.

Constraints on inputs and resources: A practical constraint on FNC is the availability of inputs and other resources. For example, agricultural projects generally are constrained by seasonal harvests and land available for cultivation. Necessary utilities (water, natural gas) may have capacity limitations that restrict equipment operations. Some limitations may be seasonal. The determination of FNC is not straightforward. It requires interplay of factors that are internal and external to the technology.

PLANT CAPACITY AND CONTRIBUTION



Profit can be measured as the difference between the total contribution or margin, revenue minus variable cost, and fixed costs. It can be either positive or negative.

The capacity of the plant, in relation to investment costs, can have a large influence on profits. Higher capacity plants tend to have higher fixed costs, if for no other reason than the increased capital costs.

In the diagram it is assumed that contribution (difference between sales price and variable cost) is constant regardless of scale - this assumption can be adjusted when the characteristics of particular technology are considered. What should be the plant capacity in this case? The nominal projection of sales (E or expected value) is in the range of the intermediate scale. O (optimistic) and P (pessimistic) represent the ranges of possible sales levels.

For the smallest plant the profitability, with production level at Q1 and fixed cost at F1 the profitability is low but secure, even below the pessimistic sales estimate. The mid-level plant, with production level at Q2 and fixed cost at F2 is more profitable, but there is the possibility of loss if sales fall below the contribution, within the range of expected values. For the largest plant, production l evel at Q3 and fixed cost at F3 , although profitability is potentially highest, the probability of loss is about 70%, attributable to the high fixed costs (if sales are actually at the pessimistic level the losses will be severe).

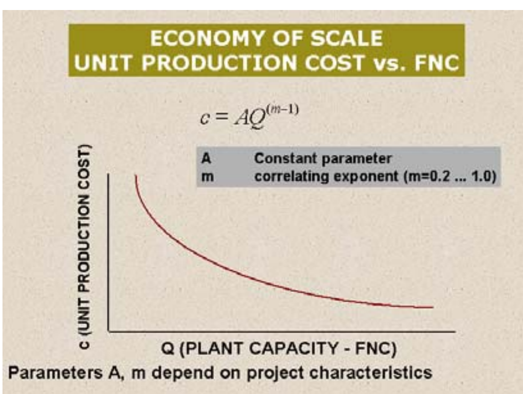
It may be prudent to construct a smaller plant with a more secure profitability, building larger capacity only when the market conditions are better defined. This may involve larger capital costs, but accompanied by a lower level of risk. The decision depends largely on the risk tolerance of the investors.

An approach to analysing the optimal expansion policy is show in Expansion Optimisation.

Fixed costs increase with plant scale. In the diagram it is assumed that contribution (difference between sales price and variable cost is consistent regardless of scale - this assumption can be adjusted when the characteristics of particular technology are considered). What should be the plant capacity in this case? The nominal projection of sales (E or expected value) is in the range of the intermediate scale. O (optimistic) and P (pessimistic) represent the ranges of possible sales level to be realized.

The smallest plant shows a virtually certain but small profit. The intermediate plant shows larger profit, but with the possibility of loss (considering the full range of possible levels of sales). The largest plant offers the possibility of largest profit, but is rather risky (if the sales are actually at the pessimistic level the losses will be severe). The decision depends largely on the risk tolerance of the investors.

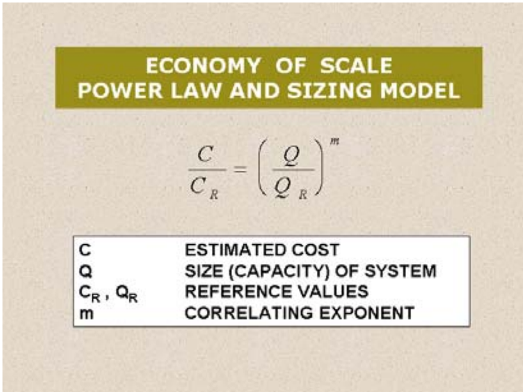
ECONOMY OF SCALE - UNIT PRODUCTION COST VS FNC



As the size of the installation increases the unit cost of production normally decreases. Most of the efficiencies are found in the capital costs. Some efficiencies can be realized in material and labor costs.

The coefficient **A** and the exponent **m** can be determined fairly from a minimum of three representative (but reasonably spread) situations. Theoretically only two cases are needed, but the third would give more confidence in the result.

ECONOMY OF SCALE - POWER LAW AND SIZING MODEL

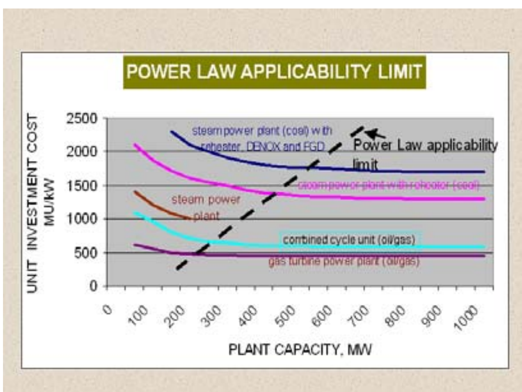


In the early stages, before entering into relationships with potential suppliers of the technology, it is useful to have some 'rules of thumb' concerning the economies of scale.

Power Law and Sizing Model: This is the mathematical description of economy of scale.

The relationship of investment cost C to capacity Q is shown. The exponent m has a value less than one. The fact that the relationship is less than linear indicates the economy of scale. Typical values for m are in the range of about 0.2 to approaching 1.0. For the petrochemical industry in general m is about 0.6. The value of m should be investigated for the industrial sector or subsector of interest.

POWER LAW APPLICABILITY LIMITS

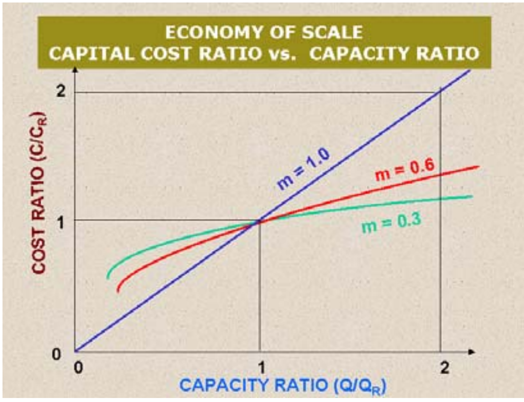


The power law for determining specific investment cost per unit of output does not extend through the entire range of plant capacities.

In the example shown the limits on economy of scale for power plants of various classifications are indicated. It can be seen that when the specific cost of investment per kW is plotted against the plant capacity, at some level of capacity for each type of plant there is an obvious limit. Above this limit the specific cost levels off and does not decrease further in accordance with the power law.

This limitation applies to virtually any type of industrial plant. As a rough approximation, it is rare that specific investment cost, regardless of size, would fall much below 50% of the cost at the smallest practical level of production.

ECONOMY OF SCALE –
CAPITAL COST RATIO VS. CAPACITY RATIO



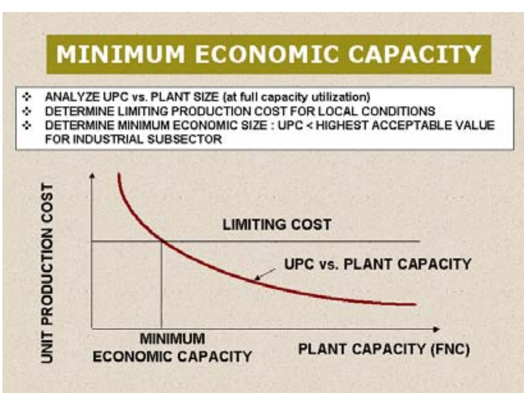
In the early stages, before entering into relationships with potential suppliers of the technology, it is useful to have some 'rules of thumb' concerning economies of scale.

Unit Production Cost vs. FNC: As capacity increases the unit production cost decreases, reflecting economies of scale. Most of the efficiencies are found in the capital costs. Some efficiency can be realized in material and labour costs. The coefficient A and the exponent m can be determined fairly from a minimum of three representative (but reasonably spread) situations. Theoretically only two cases are needed, but the third would give more confidence in the result.

Cost Ratio vs. Capacity Ratio: A lower exponent m increases the rate at which unit production cost declines with increasing capacity. The cost ratio (unit production cost for a particular plant size compared with unit production cost for a base size) declines as the plant capacity ratio (plant capacity compared with a base plant capacity) increases. This relationship, the consequence of economy of scale, is illustrated with three values of m. As m is reduced the economy of scale becomes more pronounced. Industries which are labour intensive generally approach a value of m = 1 as the technology is usually simple and the capital investment per worker is fairly linear. For capital intensive process industries such as petrochemicals m would tend to be lower. Completely automated systems would show the lowest values of m. Typical values for m are in the range of about 0.2 to approaching 1.0. For the petrochemical industry in general m is about 0.6. The value of m should be investigated for the industrial sector or sub-sector of interest.

As m increased from 1.0 to 0.6 to 0.3 the rate of decline of the cost ratio is increasingly more pronounced, showing the advantage of scale.

MINIMUM ECONOMIC CAPACITY

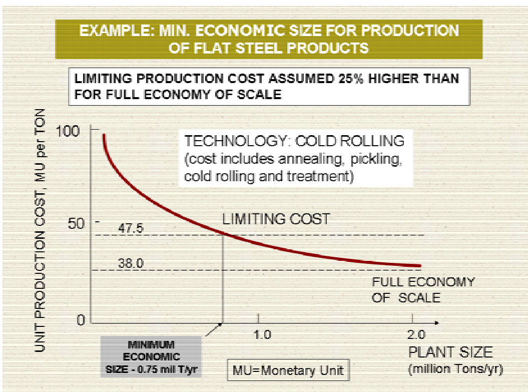


Once the relationship between unit production cost (UPC) and plant scale is established, a limiting UPC defines the minimum scale. The limit can be established in a number of ways, perhaps on the basis of competitor's production cost, the cost that would provide a reasonable margin based on the prevailing or expected sales price or the import price. For any capacity lower than this the results would be unsatisfactory. If the minimum scale is higher than the production planned by the project there is a strong likelihood that the project is not feasible.

The procedure for determining minimum economic capacity for a plant in the industry of interest is as follows:

1. Analyze Unit Production Cost (UPC) vs. plant size (at full capacity utilization)
2. Determine the limiting production cost for local conditions. This can be based upon the production cost for the most efficient competitor, or the cost that provides an acceptable profit margin.
3. Determine minimum economic size: The UPC must be equal to or less than the highest acceptable value for industrial branch.

EXAMPLE: MINIMUM ECONOMIC SIZE FOR PRODUCTION OF FLAT STEEL PRODUCTS

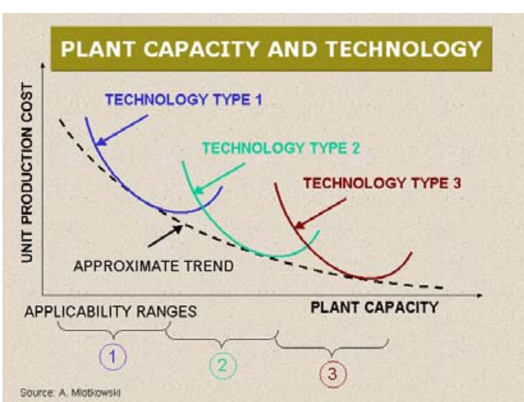


The minimum economic size of a plant for production of flat steel plates is illustrated.

For the cold rolling process, the limiting Unit Production Cost is taken as 25% over the cost for the largest scale of MU 38 per ton, or MU 47.5 per ton. This limit could be related to the favourable differential in transportation or other non-production costs for the smaller producer. In this case, with the above assumption, the minimum scale is about 0.75 million tons or 750,000 tons. In addition to competitor's production cost, another basis could be the import price (plus inland charges).

In the example shown for a cold rolling process, the limiting UPC is taken as 25% over the cost for the largest scale. This limit could be related to the favorable differential in transportation or other non-production costs for the smaller producer. In this case, with the above assumption, the minimum scale is about 0.75 million tons or 750,000 tons. In addition to competitor's production cost, another basis could be the import price (plus inland charges).

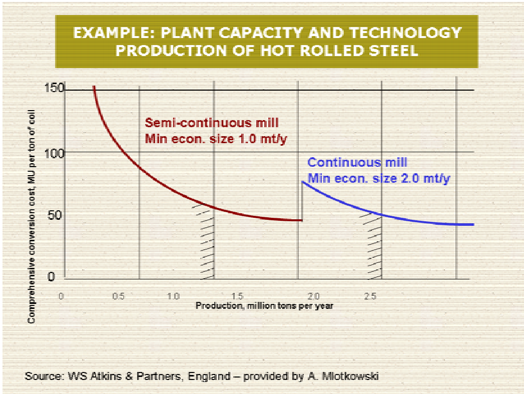
PLANT CAPACITY AND TECHNOLOGY



Technology alternatives may have varying ranges of applicable production capacity. In the illustration three alternatives are considered with capacity ranges that are only slightly overlapping.

The envelope of the unit production cost curve can be employed in a manner similar to that used for establishing minimum economic size, considering the composite of unit production costs for the three technologies.

PLANT CAPACITY AND TECHNOLOGY – Example

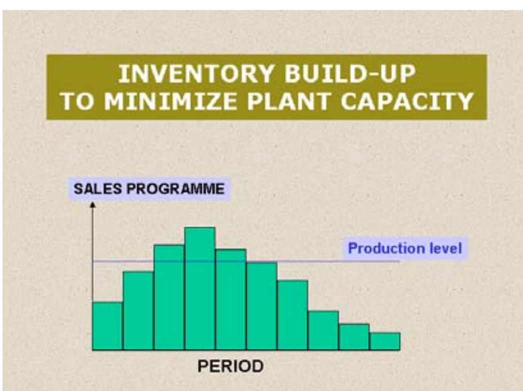


Economy of scale is applicable to each of the alternative technologies that may be considered for a project. A particular technology is generally restricted to certain practical ranges for economic and engineering reasons.

In the illustration there are three technologies that could be considered. Each has its applicable range of scale, which overlap to some extent. There may be a general trend of unit production cost (UPC) as a function of plant capacity. On the basis of UPC alone there is usually a technology that is clearly the best choice. However, other factors come into play in the selection of the technology such as strategic and reliability considerations.

In the example shown the semi-continuous and continuous milling processes for hot rolled steel are applicable in ranges dependent upon the UPC (comprehensive conversion cost) for each of the processes. There is a limiting minimum cost at about USD 60 per ton. At capacities below about 1.0 million tons per year for the semi-continuous process and 2.0 million tons per year for the continuous mill the UPC is too high to be competitive.

INVENTORY BUILD-UP TO MINIMIZE PLANT CAPACITY



Minimizing the necessary capital investment is in the best interest of a project. When demand fluctuates seasonally or cyclically the sales programme can be accommodated by smoothing out the production program so that the plant capacity, and consequently the investment cost, can be minimized. During periods when demand is lower than the plant capacity, inventories would be built up to a level to meet the expected higher demands in the future.

As previously discussed, other factors such as costs associated with maintaining inventories to satisfy seasonal or cyclical demand variations should be taken into account. When demand fluctuates seasonally or cyclically the possibility exists to meet it by smoothing out the production program so that the plant capacity, and consequently the investment cost, can be minimized. This would require a policy of building up inventories to meet peak demands, and should take into account the costs associated with inventories previously discussed.

MAXIMUM PLANT SIZE

The maximum plant size for the project industry depends to some extent on local conditions. As plant size increases in a given environment the point of diminishing returns will inevitably be reached. This is one factor in determining the maximum capacity.

The determinants of maximum plant size are:

Type of technology: Normally unit production cost (UPC) declines with increasing capacity. There is a limit, however, beyond which the UPC increases. The reasons for the increase depends upon the particular technology and may be attributable to structural considerations, power consumption, thermal design limitations, efficiency of chemical reactions. An example is the jet aircraft. Beyond a certain size the structural and weight requirements of airfoils result in increasing fuel consumption per unit of payload.

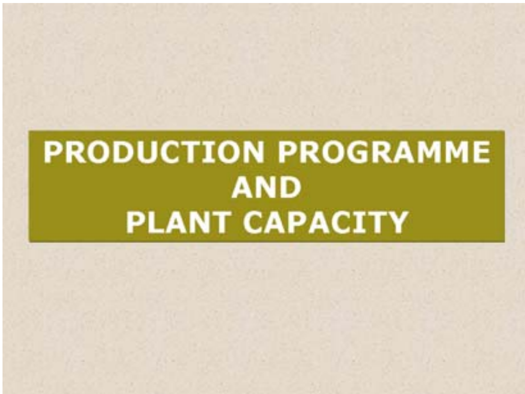
Plant location and transport costs: Infrastructure limitations can impose a constraint on plant size. The capacity of existing transportation facilities may limit quantities of inputs and delivery of outputs. Additional investment by the project in increasing infrastructure capacity may put the project out of the range of acceptable financial returns. If project markets are geographically widespread transportation costs may indicate the advisability of multiple locations.

Availability of materials and supplies: The capacity of existing sources of supply may limit capacity. In marine, forestry and agriculture-based projects, for example, supplies may be limited to sustainable yields. The price impact of project demand on constrained supplies is another factor.

Environmental constraints: Plant emissions may be acceptably absorbed by the environment up to a certain point, beyond which the environmental hazards may be unacceptable.

Reliability and strategic factors: Risk is reduced by not "putting one's eggs in one basket". Markets can be served more reliably when plant capacities are limited so that interruption of operations do not completely shut down production. Promotional strategy may dictate identification as a local enterprise serving only local markets.

PRODUCTION PROGRAMME AND PLANT CAPACITY



Plant capacity defines the quantity of production possible under existing operating conditions for the plant design. The basis is the capacity defined by engineering specifications, adjusted for operating conditions at the site - the feasible normal capacity.

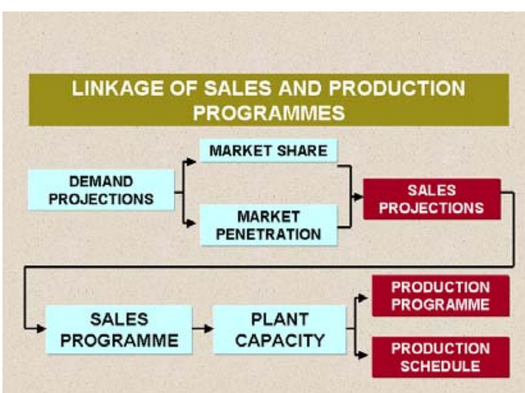
The starting point is market analysis, which provides estimates of demand and the market share estimated to be captured by the project. The rate of market penetration is another factor that determines the sales programme or sales estimates, i.e., what expected quantities of product are to be sold in each project period to the planning horizon.

The production program must be predicated on the projected sales programme, but is affected also by other considerations involving operational optimization: the plant capacity requirements (capital costs for production facilities), the cost of setting up production runs, inventory and storage costs for inputs and finished products, and any variations in production costs over time.

Inventory and storage costs include depreciation of capital facilities, storage and handling losses (product degradation and obsolescence) and the cost of financing working capital necessary to cover inventories.

The plant capacity must, in turn, be sufficient to satisfy the requirements of the production programme. The selected technology is an important consideration in determining the most appropriate plant capacity, such as the minimum and maximum plant size for the process. The determination of the optimal plant capacity is based upon the interplay between the production programme and the production factors indicated.

LINKAGE OF SALES AND PRODUCTION PROGRAMMES

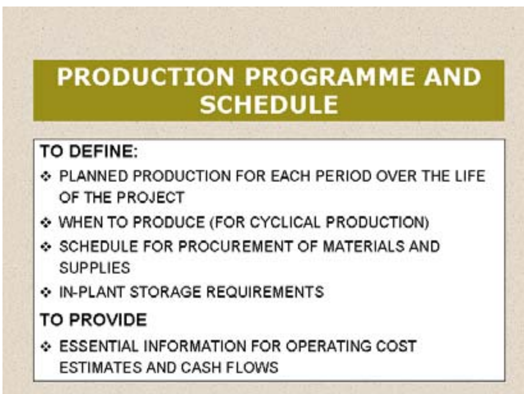


The production programme and schedule derive from the market analysis, the projections of demand. The sales projections for the project arise from the projections of demand, which has to be "filtered" through considerations of market share and the rate of penetration to arrive at an estimate of sales potential.

The estimates of sales potential may not be the final answer in regard to the actual sales programme. The project may not wish to avail itself of the full potential for strategic, financial or other reasons. The plant capacity selected by the project designer enters into the decision on planned sales programme. The decision on plant capacity is, in a sense, a filter for the decision on production programme and schedule.

As in any aspect of investment project design, the process is not linear. Feedback of information at one stage of the process of determining production programme and schedule may alter views of factors on which they are dependent. Only at the last stage would all the pieces be consistent.

PURPOSE OF PRODUCTION PROGRAMME AND SCHEDULE



After products and by-products have been identified from the market study and analysis of the technology selected the production programme is determined on the basis of projected sales in each project period over the planning horizon and what levels of finished product inventories are planned. One way is to estimate the inventories on the basis of turnover, as discussed in the Financial module, Capital Investment section (working capital). The planned inventory levels, in turn, establish the extent of storage facilities required.

The production programme defines:

Planned production for each period over the life of the project: The quantities of each product in the line to be produced in each project period are defined. Care should be taken in distinguishing between the sales programme and the production programme. The sales programme is basically information derived from analysis of the market and estimates of market share and penetration. The production programme must supply the products for sale that are not necessarily to be produced in synchronisation with the sales programme. The build-up and withdrawal from finished product inventories is a factor that is discussed in some depth in the sections on Plant Capacity (both in Market and Technical modules).

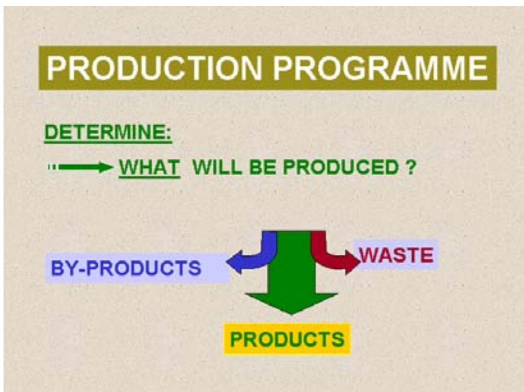
When to produce (for cyclical production): Within each planning period, it may be prudent to plan production to accommodate a cyclical sales pattern. This can impact upon the capacity of the plant and, consequently, investment costs. This matter is also discussed in the Plant Capacity sections of the Market and Technical modules.

Schedule for procurement of materials and supplies: The production programme and schedule (if applicable) determine the types and quantities of materials and supplies to be procured during each project period. There may be differences in materials requirements and the procurement programme, depending upon the inventory policy adopted.

In-plant storage requirements: Materials and supplies are generally procured in order sizes that may or may not be equivalent to the total period production. The inventory policy will determine how much space and other facilities are needed to accommodate materials and supplies awaiting processing. The subject is discussed in some depth in Supplies Programme and also in the file Order Size.

The production programme provides information for operating cost estimates and cash flows, essential as input to the financial analysis. It is the basis for a large proportion of the operating costs. The supplies programme and labour requirements may be derived directly if technological coefficients are employed in the estimating process.

PRODUCTION PROGRAMME



The production programme defines the items and quantities to be produced. It is linked to the planned sales programme as previously discussed. Primary products, by-products and production wastes must be taken into account. Estimates of losses of finished product in the process and in storage and transport are derived from analysis of the technology. Finished products inventory policy may be an aspect of the marketing strategy, which depends on storage costs and the cost of lost sales. Storage costs include product losses (deterioration, pilferage, damage in handling and other losses during handling and transport) and the cost of providing storage facilities.

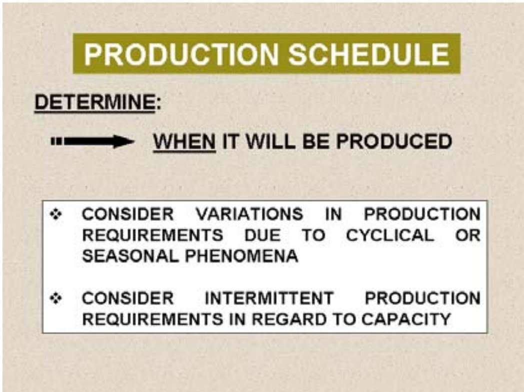
Production facilities do not convert all the materials that enter into useful products. Some of the output has to be rejected because quality standards are not met. With a good quality control program this will be kept to a minimum, but some percentage of the production will inevitably become scrap. Another destination for some products may be warranty services, if such a policy is contemplated.

The project designer should attempt to determine the expected percentages of waste during normal production operations. This may be a function of the site environment, so standard waste factors may have to be adjusted.

There are also production wastes, materials that are segregated from the raw materials or which have been chemically or mechanically altered during the production process. These somehow have to be discarded or another use found for them so that disposal costs are minimized. Solvents are used in certain processes (e.g. paper manufacture) that do not become part of the main product. In many cases significant savings can be realized by recycling such materials.

By-products are off-takes from the production process that do not enter the main product stream. In crystal sugar production, for example, molasses is in a sense a by-product as it contains sugars that do not crystallize. Molasses is, however, a valuable by product with many uses. When there are wastes generated for which a use can not be identified, then costs must be included for disposal.

PRODUCTION SCHEDULE



Detailed production scheduling during the planning stage may be required if there are seasonal or cyclical variations in demand. The analysis should be dynamic, i.e. considering the inter-relations of the production levels and inventory build-up for each period during the cycle.

Consider variations in production requirements due to cyclical or seasonal phenomena: Short-term production requirements should be considered in determining the adequacy of the plant capacity. If the capacity has been determined on the basis of annual requirements, use of multiple shifts or overtime may be able to accommodate peak demand.

Consider intermittent production requirements in regard to capacity: It is possible to accommodate intermittent or cyclical production requirements with a capacity less than the maximum if finished product inventory is built up in the periods prior to peak demand. This implies a build-up of materials and supplies inventories as well. This is discussed further in the Plant Capacity section of the Market module. See also Dynamic Inventory Analysis and Order Quantity. An example of the use of the production buffer is shown in the section Materials and Energy Balance - Use of In Plant Storage to Stabilize the Production Schedule.

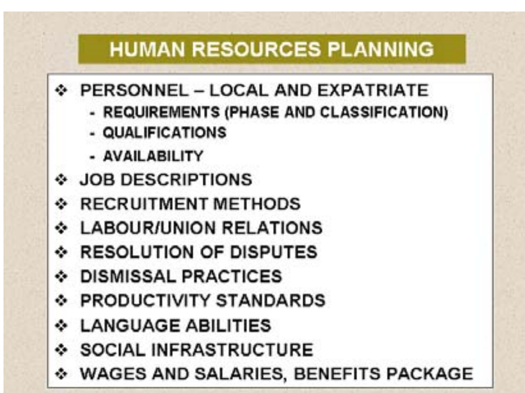
HUMAN RESOURCES

The project plan should include analysis of personnel required to operate the enterprise. Recruiting qualified personnel in sufficient numbers, arranging for training when skills of available personnel are insufficient, determining what services are required to support the staff, and all associated costs are needed to complete the plan and to estimate the financial implications.

Personnel can be categorised in terms of role (management, supervision, workers), skills (professional, highly skilled, semi-skilled, unskilled) or application (direct, indirect labour). The job of the project planner is to identify personnel requirements and to develop a plan for assuring that the skills and numbers required can be secured for the project.

Planning for the project's personnel involves deciding the required qualifications of employees, the numbers of each classification and availability. This is facilitated by design of an organization that will be suitable for the industry and region. Some personnel will be directly involved in production. Others will be considered 'indirect' and will be included as a part of overheads, which are costs of operations not directly related to production. In addition to the indirect personnel costs there will be invariably other indirect costs to be included as overheads. For cost accounting purposes overheads are usually tacked on as a 'burden rate' for each unit of production to establish sales margins.

HUMAN RESOURCES PLANNING



Deciding how to provide the project with the necessary personnel and skills to carry out the business plan is part of the overall planning process. Planning for human resources involves specifying the classifications and qualifications of personnel (including language abilities), estimating the numbers of each classification required, and then analysing availability. If personnel in sufficient numbers for a given classification are not available, then training has to be considered along with its costs.

If construction and decommissioning phases (if necessary) will be conducted under the sponsor's leadership personnel needs and other related costs have to be included in the estimates. This would not be necessary for a turnkey contract.

The need for expatriate personnel during all project phases should be assessed. There may be expatriate managerial and technical expertise required during the planning and construction phases and during the operations phase. This may be required for a smooth absorption of the technology if it is imported, with the expatriate experts having responsibility for training local staff. The costs will usually involve foreign exchange.

Personnel - local and expatriate: The organization structure defines the types and number of personnel required at various levels.

- Classifications (contractors /consultants, managerial, staff (administrative, factory, sales and distribution, etc.), labour (skilled, semi-skilled, unskilled).
- Number required for each project phase (planning, implementation, operations, decommissioning).

The qualifications, or background, training and skills needed for each key position should be identified. Then the local and expatriate labour pools should be investigated to determine availability of these personnel.

Job descriptions: Job descriptions should be developed, at least for key personnel. They can be used to clarify responsibilities and qualifications and lead to more accurate cost estimates.

Recruitment methods: When local skills are not adequate there are two possibilities: to train to the required levels of competence or to recruit expatriates with the necessary skills. Recruitment of local personnel, even if they need training, has its advantages. The need for cultural adaptation is eliminated; there are also political considerations. Recruitment methods should be analyzed and the most appropriate means recommended.

Labour/union relations: Another factor to consider in planning personnel requirements is the local labour situation. If there is likely to be the need for negotiations with labour organizations, the assumptions on costs of negotiations and consequent labour costs should be taken into account.

Resolution of disputes: In some countries management-labour disputes are resolved in the judicial system. The analyst should take into account the skills necessary for such litigation and associated costs.

Dismissal practices: Will layoffs in periods of slack production will be possible? In some cases where necessity or regulations mandate, factory labour has to be considered virtually a fixed cost.

Productivity standards: Cultural and climatic conditions may impact upon the productivity standards for personnel at the project site. When there are man-machine interactions the standard machine production rates can also be affected. The labour-machine numerical relationships may have to be adjusted to reflect local conditions. Assumptions concerning labour productivity should be realistic based upon local norms and practices and upon the local working environment. The ‘learning curve’ should be taken into account in determining the number of workers required. If the project wishes to attempt to transcend some of the local practices that run counter to high labour productivity some mechanism will have have to be included to address this. Bottom up management is one approach that might work in some cases. In others the provision of good social infrastructure facilities for workers might enhance the level of commitment to project goals. For new technologies productivity may be lower than normal during the learning phase.

Language abilities: If machinery and equipment are imported the operations manuals and other support documents may be written in the language of the producing county. Another possibility is direction by expatriate personnel who may not be fluent in the local language. Local personnel with responsibility for maintenance and operation of imported equipment and who need to be able to extract information from these documents, or who must take direction from expatriate supervisors may require language training.

Social infrastructure: To maintain the cooperation and loyalty of project staff their social needs should be accommodated. Housing and access to human services (food supplies, health, education, recreation) must somehow be provided. If the social infrastructure is not provided by the local community the project may have to bear some or all of these costs.

For expatriate personnel the social infrastructure and associated costs may have to reflect some of the accustomed amenities in terms of housing characteristics, access to international-level education facilities for children, transportation and services for spouses.

Wages and salaries, benefits package: Wages and salaries, and the benefits package provided for workers, should inspire the loyalty and commitment of employees. The "carrot" is a more fruitful policy than the "stick", which does not now and never has served as an effective motivating device. Wages and salaries should be fair, offering workers the opportunity to maintain reasonable standards of living without having to seek supplementary income. In many countries there is no public social safety net, so workers are particularly sensitive to benefits such as health care, education allowances for children, retirement benefits and unemployment insurance.

If expatriate personnel are required the estimates of salaries and benefits package should be realistic in terms of the international scales and practices.

CHARACTERISTICS OF THE PROJECT LEADER

Among the most important issues to be considered by investors is the qualifications and commitment of the driving force behind the project. Any project needs a leader. The investor/entrepreneur could assume this role, or could either recruit or select someone from the organisation. The most important qualities are energy and commitment. Energy is the activation force that can overcome the many obstacles that a project normally faces. Commitment is the will to apply that energy in this particular situation, that usually derives from psychological identification with the project's goals. Some of the characteristics that should be sought in a leader are:

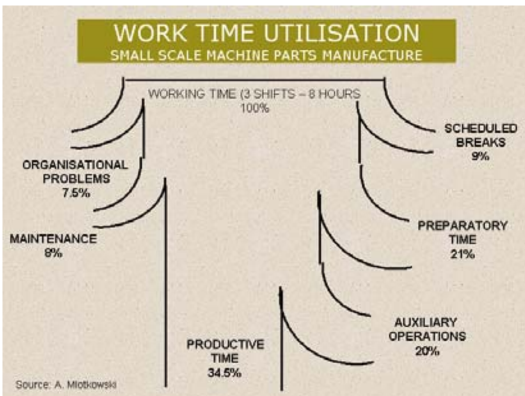
Individual profile: Initiative, risk tolerance, decisiveness, bravery, motivation, financial prudence, ability to handle stress, creativity, intuition, self-confidence, dedication and commitment, integrity, responsibility

Leadership qualities: Motivational and organizational skills.

Knowledge and ability: Understanding concepts relevant to the venture, a good track record (more successes than failures).

Where can the project find such a super-human? Good luck!

WORK TIME UTILISATION



In addition to unproductive workdays, the project designer may have to consider how time is utilized in the workplace. An example is shown of small scale machine parts manufacture. Of the normal work time available per worker (e.g. 8 hours per day), in this case 65.5 % of time is not put to productive use (scheduled breaks, preparatory time, auxiliary operations, organizational problems and maintenance). Only 34.5% of the work day is actually spent in production.

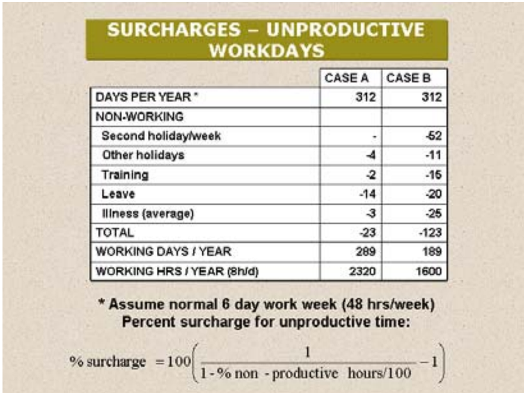
How these factors are taken into account depends on the nature of the production process and worker-machine relations, and to this extent is at the discretion of the project designer.

Suppose that the process is semi-automated and that the lost time involves both worker and machine. If the estimate of manpower assumes an operator for the machine, then there would not be a need to adjust the number of workers for the unproductive time. The production capacity of the plant, however, would have to be adjusted.

If the process consists of a number of discrete stations that can be operated by a pool of workers, then some of the non-productive time involves workers and others the machine. Maintenance, preparatory time and perhaps auxiliary operations affect the machine utilisation. Organizational problems, scheduled breaks, and preparatory time (assuming the worker is involved in preparation) affect the amount of unproductive time for the worker. In this case both the plant capacity and the number of workers required would have to be adjusted if standard coefficients were used for the basic analysis.

The worker adjustments based upon the unproductive time would be added to the adjustments for unproductive work days previously discussed.

SURCHARGES - UNPRODUCTIVE WORKDAYS



	CASE A	CASE B
DAYS PER YEAR *	312	312
NON-WORKING		
Second holiday/week	-	-52
Other holidays	-4	-11
Training	-2	-15
Leave	-14	-20
Illness (average)	-3	-25
TOTAL	-23	-123
WORKING DAYS / YEAR	289	189
WORKING HRS / YEAR (8h/d)	2320	1600

$$\% \text{ surcharge } = 100\left(\frac{1}{1 - \% \text{ non - productive hours}/100} - 1\right)$$

Holidays and lost workdays for training, illness and leave require that the project hire more workers than would be indicated based upon the standard work week.

In the example two cases are shown, Case A with a total of 23 unproductive days per worker and Case B with 123. In Case A assume that the total number of unskilled workdays required is 15,600. With an assumed 6 day per week work schedule, or 312 days per year, nominally 50 unskilled workers would be required. However, taking into account the 23 unproductive days for leave and other purposes with only 289 work days (average) per unskilled worker, the number of workers required would be 54. This means that 4 additional workers would have to be employed to satisfy the requirement.

The wage surcharge can be calculated using the formula shown. Suppose the annual wage per unskilled worker is R 5000. For case A the result would be:

% non-productive hours = 23/312*100 = 7.37%

% surcharge = 100*(1/(1-(%nonproductive hours/100)) - 1)

% surcharge = 100*(1/(1-7.37/100)-1)=7.96 or 8%

The total wage bill for unskilled workers would be R 5000*50*1.08=R 270,000. This factor (8%) would also be added to the benefits package. If there are any fixed charges a better approach is to use the actual number of workers (in this case 54) and then calculate the wage bill.

ESTIMATE OF HUMAN RESOURCES COSTS

To prepare an accurate estimate of human resources costs the following data should be first compiled:

Classifications: The job classification and number of employees in each classification based upon the organizational structure. The classification should include every employee in the organization, from top management down to the lowest paid worker.

Salaries and wages: The standard compensation for each classification should be indicated. Some workers, such as management personnel, may have annual salaries while other workers will receive hourly wages. The currency of payments, foreign or local, should also be indicated.

Benefits and surcharges: To the salary and wage scale for each classification the cost of the benefit package should be added (e.g. social security, leave, sick pay, health benefits, housing allowance) and can be expressed in terms of a percentage of the standard wage or salary. Surcharges for payroll taxes, unproductive time, etc., should also be added to the base wage or salary.

Training: Training costs should be added for each classification depending upon the level and number of employees requiring training. In a given classification not all prospective employees may need the same level of training.

Recruitment: For scarce technical personnel it is often necessary to provide housing, shipment of personal belongings and transportation for the immediate family, and possibly education costs for children of such employees.

Personnel costs should be identified separately for each project phase (planning, construction, operation, decommissioning). Costs during the operations phase should be included for each functional area (administration, production, marketing, sales and distribution, research and development, etc.). The organization chart for each stage can be used to identify the numbers and classifications.

PLANT ORGANIZATION AND OVERHEAD COSTS

The project requires an organization to carry out the business plan. The organization should be designed to fit the needs of the enterprise - to carry out the business plan during each phase of the project. Once the various functional departments are identified, an organizational structure can be formulated to cover all the necessary functions.

The organization should be defined from top management down to the lowest level factory worker. This will help to clarify the job classifications and numbers and lead to reasonably accurate estimates of costs. The organization will usually differ during each project phase (planning, implementation, operations, decommissioning if necessary).

The organization decisions involve:

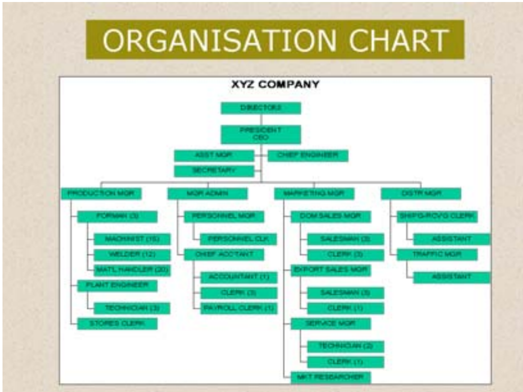
Classifications: The types of jobs required from top management down to the lowest paid worker.

Job descriptions: Descriptions of responsibilities for each classification should be sketched out, in increasing detail as the project nears the commitment stage. These descriptions should be sufficiently detailed to estimate availability and appropriate wages and salaries, and to understand functional interfaces.

Direct and indirect: In the plant human resources planning should include direct (production workers) and indirect staff (not directly involved in production, i.e. maintenance personnel).

Numbers of employees: The number of employees in each classification should be estimated, taking into account unproductive workdays and unproductive hours as previously discussed.

ORGANISATION CHART



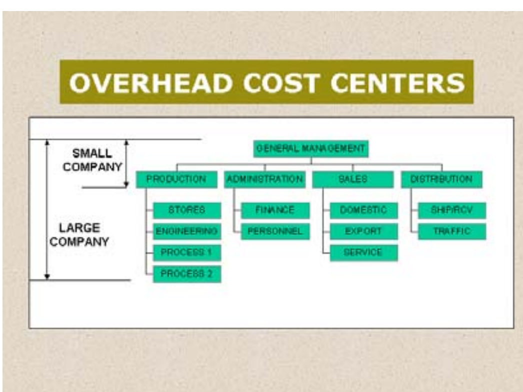
The organization chart is a layout showing the relationship between all positions planned for the enterprise. It provides a way of visualizing the structure of the organization and provides a basis for analyzing the interfaces between functions.

The chart of the XYZ company illustrates four functional areas: production, administration, marketing and distribution. Within each structure all subordinate positions are shown with the numbers of employees planned for each category.

The plant organization chart (organigram) may vary according to project phase. It may be advisable to create a separate organisation chart for each project phase. Although factory workers are not normally involved, for trial runs it may be necessary to employ and train a full complement of workers during the construction phase.

Another use of the organigram is to identify cost centers that will require direct worker costs and also the indirect costs. In addition to indirect labour costs, there will also be indirect (overhead) costs of other types, for materials, transportation, communications, etc. One way to keep track of this is to structure the organigram down to the lowest level of organization and to identify all costs, direct and indirect, for each function. This will be helpful for determining the labour part of production costs and the overheads associated with all the other functions.

OVERHEAD COST CENTERS



For cost estimating it is useful to identify the cost centers that will involve overheads. This systematic way of dealing with overheads is a way to avoid omissions and overlaps.

The structure of cost centers may or may not coincide with the organization structure. In some cases overheads will cover multiple functions, and in others overheads for a single organization function may better be estimated by dividing it into sub-functions. In the example shown there are two Process Cost Centres under Production. These are shown separately in the cost centre structure but may not appear as such in the organization chart. This would be helpful if the processes were sufficiently dissimilar to warrant separate analysis of overheads for each.

FACTORY AND ADMINISTRATIVE OVERHEADS - NON LABOUR

An estimate of non-labour overhead costs, all costs that can not be attributed directly to production such as direct production materials, is needed to complete the financial analysis of operating costs and profitability.

The estimate of non-labour overhead costs is derived from first identifying all the cost centres in which overheads (indirect costs) will be incurred. Then the specific cost items are identified and estimated. These can include such costs as repair and maintenance, supplies, rents, communications, etc. Within the plant, as previously discussed, costs of indirect personnel can be included as part of a production overhead burden.

Identify cost centres: This identification can assist in organizing costs so that there are no omissions or overlaps. Cost center identification is a function of the type of project. Cost centres can be identified for Administration, Production, Marketing, Sales and distribution, Research and Development and other functions.

Identify overhead cost categories: Cost items can be identified within each cost centre, for example Rent, Office expense, Fees and allowances, Advertising and selling, Supplies.

Estimate quantities and price: For each cost item and in each cost centre the quantities and prices should be estimated.

Determine overhead costs: Overheads for each cost centre can then be determined as the aggregate of costs.

Include overhead costs in production and operating costs: Non-labour overheads for each functional area should be included in the operating costs for the project. Production overheads may or may not include the indirect production labour costs, depending upon the approach preferred by the financial analyst.

LOCATION AND SITE SELECTION

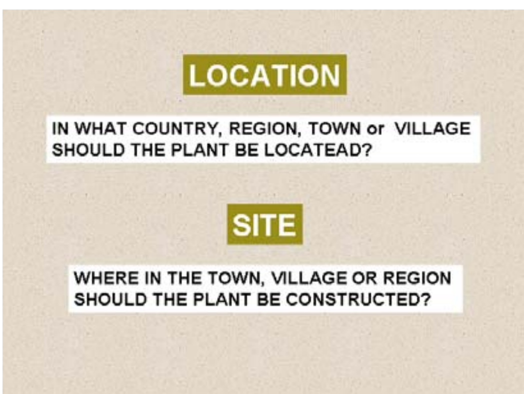
What are the three most important business decisions? **Location, location and location**. This adage may be a slight overstatement for industrial projects (perhaps more applicable for retail trade); nevertheless location has its significance as a determinant of the project's external environment. Normally the criteria of an industrial project's sponsor are a bit more diverse.

With international borders becoming less formidable barriers the range of possibilities often extends offshore. Geographical diversification may reduce risk from economic and political upheavals.

A location is selected based upon the criteria of the project sponsors. A site selection, the particular plot of land upon which the plant will be constructed, is more a function of the characteristics of land, its preparation costs and infrastructure considerations.

A site has to be selected to accommodate the plant and ancillary facilities. In vertically integrated projects (e.g. agro-industrial) sites have to be found that are optimal for each of the activities and that also mesh well together.

LOCATION AND SITE



The location is identified as the country, region, city or town in which the project's facilities are to be located. The project designer logically seeks a location that optimizes the multiple criteria of the project sponsor.

Alternative sites in the selected location are compared to find the one which best meets the operational requirements. In each case the analysis should be done systematically so that biases are minimized. The method should be to first determine the factors to be considered, then the criteria for judging these factors and finally an evaluation of the factors for each alternative in terms of its conformance with the criteria. Once this is done, then more subjective factors may enter into the picture to arrive at a decision.

The site should be selected to accommodate the plant and ancillary facilities. In vertically integrated projects (e.g. agro-processing) sites have to be found for cultivation and processing that are optimal for each of the activities and that also mesh well.

MULTI-CRITERIA LOCATION ANALYSIS

A location should be selected considering simultaneously all appropriate criteria. One way to accomplish the analysis systematically is to rate each alternative location according to a list of weighted criteria using a point system. This adds objectivity to the analysis; however, the system should be set up realistically, applying appropriate weights to each factor in accordance with the sponsor's preferences.

Production factors: How will the environment at each prospective location affect operating efficiencies and costs? The characteristics of alternative locations may vary in regard to availability of resources needed by the project. Urban locations usually provide greater quantities of potential workers with a higher level of skills. Rural locations provide opportunities for expansion and few design constraints.

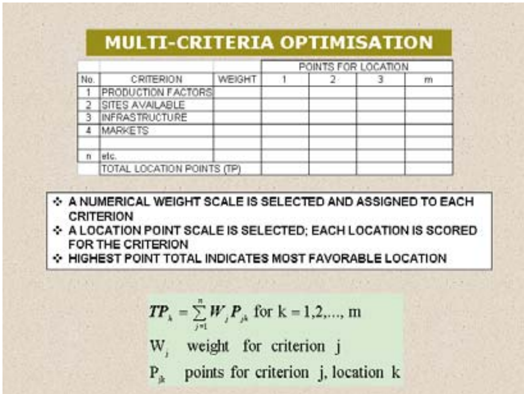
Site requirements: A location may be ideal strategically but may lack appropriate sites to build the plant.

Infrastructure: To what extent do the alternative locations provide transportation (roads, rails, airports), communications and utility services? If access by road is required, for example, and if the only available sites are on steep slopes, the design and cost of roads may render the location unsuitable. If the project requires large volumes of raw materials then the existence of a rail spur may weigh heavily on the decision.

Markets and suppliers: Location close to markets may be more important for perishable items and for those that require close contacts, such as industries that are fashion-dependent. If the volume or weight of inputs were very much greater than that of the finished product then a location near the supplier would have cost advantages. When there are significant imports or exports, proximity to port facilities may be advantageous.

Strategic factors: How does each location alternative fit into the project's strategic concept? For example, if the project is to compete in a country where xenophobic sentiments prevail, it may be prudent to locate the plant in that country, seeking to increase identification with the local culture. Cost factors: Investment and operating costs for each location and the risks associated with setting up and operating the plant underlies all other factors.

MULTI-CRITERIA OPTIMISATION



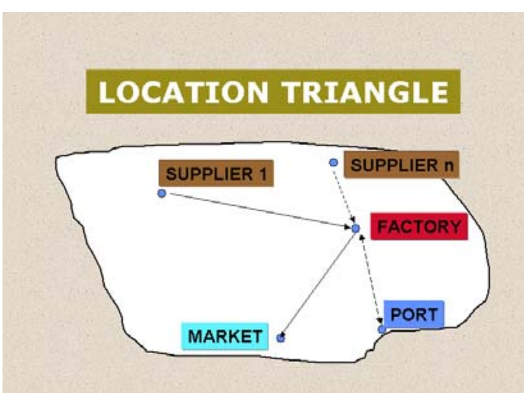
The problem is to select the location or site that optimises satisfaction of multiple criteria. Analysis of location and site, and in fact other project decisions, are best made on a systematic basis. This can be accomplished by first identifying the factors (criteria) and their functional characteristics.

The same ground rules should be applied to each alternative. Considering the same factors for each alternative, weights can be assigned to each factor and then each alternative rated on a scale. The scale should be sufficient to discriminate, but not so precise as to cloud the issue. Something like a scale of 1 to 5 might be appropriate for the ratings of each factor. The factors themselves might be weighted on a 1-10 scale. The alternative with the highest overall point score would ordinarily be the most favoured alternative. The ratings should be done by several individuals independently, if possible, at or near the top of the project. Then any gross discrepancies in their ratings can be discussed for further clarification.

In the illustration the factors and the assigned weights are shown in columns at the left. The locations, from 1 to m, are listed across the top row. In the column for each location alternative the points for each factor (or criterion) are entered. Then the total points for each location can be determined as the sum of the products of each weight and the points assigned to each factor. The location with the greatest sum of points (assuming that the system is set up objectively) should be the most favourable.

The criteria used in analysis differ according to the local situation. In some case availability of labour might be one criterion. Even though costs for other factors might be high the location, the uniqueness of labour availability might warrant a weight structure that causes the site to appear most favourable.

LOCATION TRIANGLE



A "location triangle", or in the case of exports and imports a quadrangle, can be the basis for determining the least cost alternative. The volumes of materials and products to be transported between market, plant, suppliers and ports can be combined with unit transportation costs to determine the overall transport cost for a particular location or site.

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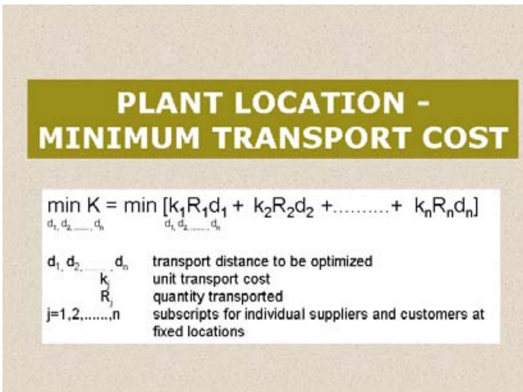
PLANT LOCATION - MINIMUM TRANSPORT COST



This is the same idea as the previous presentation expressed as a minimization problem. The method of solution is to evaluate the discrete options that are available for location and site. Another approach would be to use a search routine for the minimization and then to select the available location or site closest to the optimal point.

In either case the total cost of transport is determined for each possible location (or site), calculated as the sum of the products of (1) quantity (or volume, depending upon rate structure for the item or commodity) shipped, (2) transport rate in cost per km or mile and (3) the distance in km or miles.

In the formulation the variables are as follows:

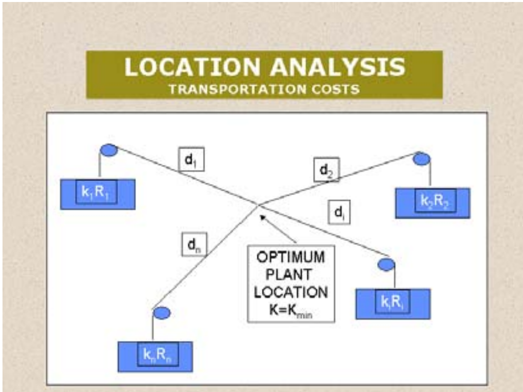
K - the total cost of transportation for a particular plant location

k - unit transport cost for a path between the plant location any other site: market, supplier and port

R - quantity transported between the plant location and any other site: market, supplier and port

j=1,2,......,n: j is the subscript for the path between the project plant and individual suppliers, domestic customers and the port (for imports and/or exports) at fixed locations.

LOCATION ANALYSIS - TRANSPORTATION COSTS



Mathematically the problem of least cost analysis for a site or location looks like a force table in a physics laboratory. The combination of weight or volume, transportation cost per km. and distance represents the weight for that supplier or market. Some position (site or location) minimizes the cost. Once the location of markets, suppliers and port facilities (in case of international trade) are identified, the location closest to the ideal would be selected on the basis of minimized overall transportation costs. This would be relevant if all transportation costs are to be borne by the project.

The ideal location is actually the "centre of gravity" of the transportation system. If each weight is represented by the product of the weight (or volume if that is the basis for transport costs) and the cost per km the point at which the attached flexible cables would come to rest represents the "centre of gravity". A change in any one of the factors, volume or unit transportation cost, for any of the sites of suppliers, markets or ports would change the position of the "centre of gravity".

PROJECT LOCATION PREFERENCES

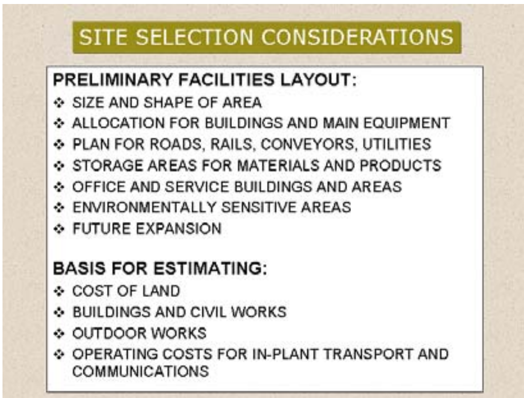
The nature of some industries and production processes affects the choice of location. Proximity to markets or supplies of raw materials may influence the selection for some types of projects while others are independent of such considerations.

Raw materials-oriented: Projects such as hydro-power, mining or petroleum extraction are tied to the source of materials. Others that use raw materials with large weight or volume loss in processing are better located near sources of supply to minimize transportation costs of inputs. Much agro-industrial processing involves significant weight or volume loss, e.g. fruit juices or sugar production.

Market-oriented: Projects that need to maintain close links with clients are better located near the market. Examples are service industries such as specialized computer programming or maintenance and repair. Others industries that have large weight or volume gain of ubiquitous materials are better located near markets to minimize transport cost of finished product, e.g. water-based beverages or ready-mixed concrete.

Flexible location: When markets and suppliers are widespread there is more flexibility in choice of location. Some examples are machine tools and electronics. When products have large value per unit volume or weight, choice of location in terms of minimizing transport costs is not particularly significant, e.g. pharmaceuticals.

SITE SELECTION CONSIDERATIONS



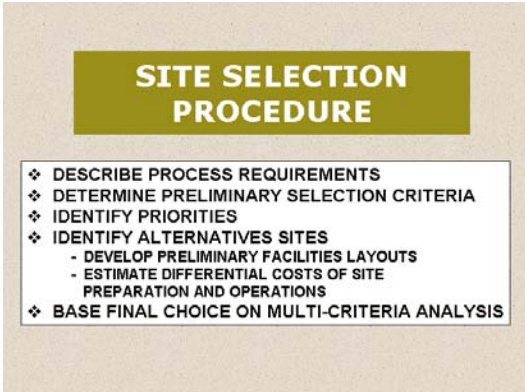
When there are several sites available for consideration they should be compared systematically. The analysis should start with a preliminary facilities layout indicating:

- Size and shape of area: The configuration of a particular site may involve unfavourable compromises with regard to positioning project functions.
- Allocation for buildings and main equipment
- Plan for roads, rails, conveyors, utilities
- Storage areas for materials and products
- Office and service buildings and areas
- Environmentally sensitive areas: Sites can have sensitive environmental areas such as wetlands or natural habitats for endangered species that may involve additional costs for mitigation. In other cases development on such areas may be prohibited.
- Future expansion: A growing business should plan on additional space for building plant extensions or other add-on facilities.

The layout is the basis for estimating and comparing costs for each site alternative:

- **Cost of land**: The price per acre or hectare should be considered in conjunction with site preparation costs. The total land cost is really the acquisition cost plus the cost of preparing it for the plant construction.
- **Buildings and civil engineering works**: The differential costs among potential sites should be taken into account in the selection, as mentioned above in conjunction with acquisition cost. Some examples of engineering calculations are shown in Site Engineering Examples.
- **Outdoor works**: Utilities may be available at the site from public sources and consequently would not require investment by the project, e.g power, natural gas, water mains. Some sites would require either installation by the project or extension of existing public utilities with the cost of extension borne by the project, e.g. power transmission lines from existing substations.
- **Operating costs for in-plant transport and communications**: The site configuration, particularly land contours and shape of the lot, can affect transport and handling costs. Communications may be affected by other wireless communications facilities in the area.

SITE SELECTION PROCEDURE



Describe specific process requirements: How does the production process affect site requirements? Are there significant geographic or climatic factors that differentiate potential sites? Are the contours of the land important, e.g. in terms of using natural gravity as opposed to pumping fluids?

Determine preliminary selection criteria: All desirable features of the site should be listed on a preliminary basis, e.g. infrastructure capacities, size, accessibility. Some of the criteria may have to be changed if such sites are not available or if subsequent steps in the analysis eliminate or add to criteria.

Identify priorities: Priority indicators should be assigned to each criterion. These can be indicated by a numerical scale, say 1 (most important) to 10 (least important).

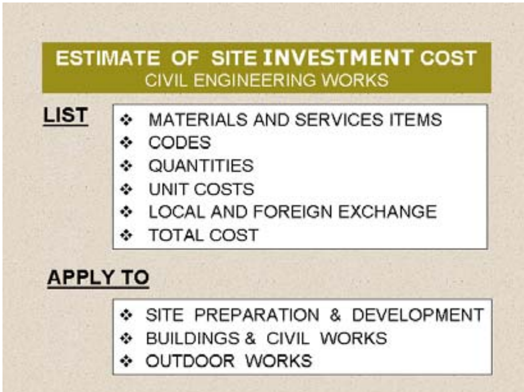
Identify alternative sites: For each a preliminary facilities layout should be prepared to show how project functions will be located and their relationships. This type of analysis is similar to that described for the plant design. Sites will normally differ in regard to how each can accommodate the ideal functional relationships.

Estimate differential costs of site preparation and operations: With one site used as a base, the relative, or differential, costs of site preparation and operations should be estimated. Another approach is simply to compare the total costs. Operations costs may be site-dependent in terms of utilities and services or functional relationships.

Base final choice on multi-criteria analysis: The weighted point system approach described for location choice can similarly be applied in the selection of site. Whether the analysis is performed formally or informally all criteria and priorities should be considered simultaneously so that all factors are given appropriate weight in the final decision.

For further discussion see More on Site Selection.

ESTIMATE OF SITE INVESTMENT COST - CIVIL ENGINEERING WORKS



Item of materials and services: A listing of all items and services needed to completed prepare the site for construction of plant, buildings and other facilities should be prepared showing the Code number, Quantity, Unit, Price and Currency (local or foreign exchange).

Some of the cost elements to be considered for inclusion in the final cost estimates for site development and civil works are as follows:

Site preparation and development:

- Relocation of existing structures, pipes, cables, power lines, roads, etc.
- Demolition and removal of structures and foundations.
- Wrecking, grubbing.
- Site grading, cutting and filling.
- Drainage, removal of standing surface water, reclamation of wetlands, etc.
- Diversion of streams, dams, etc.
- Utility connections: electric power (high, low voltage), water (process, drinking water), communications (telephone, radio, satellite, etc), roads, railway sidings.
- Other site preparations and development work.
- Temporary work for plant construction (site overheads).

Buildings and civil works:

- Excavation, concrete works, bricklaying, waterproofing, masonry, roofing, steel sheet works, etc.
- Finishing: masonry, carpentry, steel works, plaster, joinery, glazing, tiling, flooring, asphalting, parquetry, paving, wall papering, painting, etc.
- Technical installations: Heating, ventilation, air conditioning, plumbing, gas, power current, and low-tension current.
- Special civil engineering, e.g.: pile foundations, soil consolidation, drainage ramps, chimneys and stacks, foundations for heavy equipment
- Facilities for: steam, hot and cold water, air purification, high and low voltage currents, emergency power, storage tanks for fuel, filling stations, communications, fire fighting, compressed air, pneumatic systems, elevators, cranes, kitchens, laundries, laboratories, etc.

Outdoor Works:

- Utility supplies and distributions: water, electricity, communications, steam, gas.
- Emissions handling and treatment: electrostatic precipitators, cyclones, sewage systems, oil and grease separators, pumping stations, screw conveyors, treatment plants, waste storage pits, refuse treatment plants, others.

- Traffic installations: yards, roads, paths, parking areas, railway tracks sheds for bicycles, traffic lights, outdoor lights, etc.
- Landscaping: trees, plants, grass, water basins, others Fencing: fences, walls, doors, gates, barriers, security installations, others.

ENVIRONMENTAL ANALYSIS

The environment of an investment project consists of the land, air and water bodies in the vicinity of the project, the flora and fauna that inhabit the surroundings, and the social, economic and political systems in which people function. How the project interacts with these surroundings usually has an important bearing on its success.

Investors are well advised to take a pro-active stance in regard to the environment of an investment project. The point has been presented earlier that an enterprise is like an organism striving for survival and growth in an environment. The ideas are drawn from biology and ecology, but are apt for the investment community. When promoters and investors take a pro-active stance they are more likely to avoid problems of interaction with the surroundings and the project later on, when attention is needed to bring the project to fruition and operation.

It should be recognized that the creation of a new production entity changes to the status quo. These changes that are a consequence of its presence will likely be accepted if they are perceived as having a positive impact upon the economy and the health and welfare of the surrounding community. The project designers should invariably undertake some form of environmental analysis, even if it is informal and unsophisticated. The study should consist of an inventory of the surroundings without the project, the impacts of the project and any mitigation measures that may be needed to control or limit impacts. In many areas regulatory or statutory requirements can guide the analysis of the impacts.

An important part of the environmental analysis is keeping abreast of the ideas and concerns of surrounding inhabitants and other organizations. When people are kept aware of what is going on they are more likely to act cooperatively. Unexpected changes are threatening, and in some instances can lead to litigation that ties up a project indefinitely.

Better to anticipate how to deal with these issues constructively. This can lead to efficiencies, for example, in the use of materials, and cooperative coexistence with the surrounding community.

ENVIRONMENTAL PROTECTION IN INDUSTRY

Anticipating environmental impacts of the project in all its phases (planning, construction and operations) can be beneficial to an investment project, leading to improved and more efficient products that will have better acceptance in the market, and to operating efficiencies that can have positive effects on profits.

Product design: A product known for its reliability and ease of maintenance will often be well received in the market. Knowledge of high early failure rate for a product quickly spreads. Products can be designed that are long-lasting (minimized planned obsolescence). Increasingly consumers are looking for products that are designed for recycling. In some countries recycling is mandatory and these requirements will spread, as disposal sites become more difficult to find. Material and energy-saving designs and use of environmentally benign materials can also be used in the marketing program as more people become aware of environmental issues.

Technology selection: Clean technology can prove to be profitable. If a process has large amounts of waste and high rates of emissions it is obvious that much material is being purchased that does not get into the revenue stream. Often there are opportunities to clean up the process and improve profits at the same time. A bag filter system installed on a smelter not only cleaned up the environment (to the great benefit of the community and its workers) but had a payback of only 2 years. Material- and energy-saving technologies can not only keep the environment clean, but can also improve profitability.

Waste utilization: In some instances wastes can be converted into useful products. For example, slag from smelting processes can be used in manufacture of cement-based building materials. If wastes are discharged onto lands or waterways they can often be neutralized to minimize the adverse impacts.

Waste disposal: The most advantageous approach to waste disposal is to eliminate waste where possible. If waste is not generated, the problem of its disposal does not exist. Disposal of many waste materials is becoming increasingly problematic and costly. Better to eliminate materials from the waste stream where possible, rather than seek means and sites for disposal.

Some approaches to waste disposal are based upon the concept of dilution. However, this approach can be problematic as more information becomes available concerning the effects of small levels of pollutants. A better approach is to seek ways to eliminate or contain the pollutants so that they are not recognized as a problem in the future.

Waste storage only postpones the problem, and increases risk of contamination from spillage and other types of mishaps.

Incineration is also becoming increasingly suspect as environmental authorities enact more stringent regulations on air emissions. Burning does not eliminate the waste, but rather spreads it over a wider area. Some of the combustion products may be more noxious than the original waste. There is also the problem of disposal of ash and other residues, which may be highly contaminated from concentration of unburned constituents.

ENVIRONMENTAL ISSUES

Environmental issues to be addressed in the project design can be identified as follows:

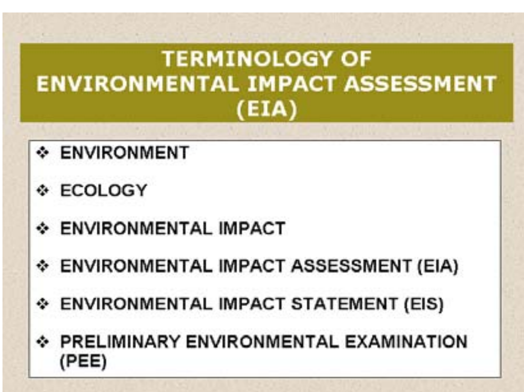
Environmental and socio-economic conditions at the proposed plant site? The process of environmental assessment is first to understand the prevailing conditions at the site of the project in its absence. These are the conditions that prevail at the site and its surroundings - the status of ecological, economic and social systems.

Effects of project on these conditions? The project facilities and operations are conceptually superimposed on the conditions at the site and surroundings to understand the environmental consequences. This is the incremental effect or impact, the difference between the environmental situation with and without the project.

Ecological impacts acceptable under existing environmental regulations? The impacts are considered in regard to existing statutory and regulatory restrictions. Any impacts that exceed such guidelines obviously should be eliminated or mitigated in the project design.

Extra - regulatory impacts acceptable short and long term? If the impacts are recognized as potentially harmful to the environment and appear to be significant, even if statutes or regulations do not currently exist, it is prudent to avoid creating environmental hazards that may be recognized as potentially problematic in the future.

TERMINOLOGY OF ENVIRONMENT IMPACT ASSESSMENT



Environment: Habitats of humans, flora and fauna and their interactions with the natural resources in the region.

Ecology: The study of relations between organisms and their environment. In the human context it is generally considered to have environmental, social and economic dimensions.

Environmental impact: The effect on the status of the environment from human activities.

Environmental impact assessment (EIA): The study of the change in the environmental status as a consequence of the project, the 'with' and 'without project' situations, and assessment of their significance for the existing environment.

Environmental impact statement (EIS): A report based upon the EIA that presents the final status of the environmental impacts, a description of mitigation and other measures, and the situation taking into account such measures.

Preliminary environmental examination (PEE): A preliminary EIA to identify aspects of the environment that are unaffected by the project and those for which further study is justified.

CLEAN PRODUCTION

What is 'clean production'? According to the UN Environmental Programme (UNEP): "Continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment". This definition of clean technology focuses on the risks to humans and the environment. An investment project's objective of satisfactory return on investment is generally advanced with a design that is environmentally benign and efficient in the use of non-renewable resources for which costs will escalate as economies and populations expand.

Grow first and clean up later? "The difficulties of starting an industrial investment project are formidable. Rather than spend a lot of time and resources dealing with plant emissions that have noxious effects on the surrounding environment, these problems can be resolved later, after the enterprise has had an opportunity to 'get off the ground'". This might be the position of project sponsors, but is it a prudent approach?

Allowing environmental problems to get out of hand can have a high cost. The costs of cleaning up later can be much greater than the differential costs for a clean technology. Even if the project's adverse impacts on the environment are not regulated, at some point tighter controls will likely be imposed when the problem is better understood by the surrounding community and the political authorities. Ecological damage and adverse health impacts attributable to the project's operations will ultimately have its economic consequences; the enterprise will probably have to pay the bill. 'An ounce of prevention worth a pound of cure'.

Clean technology is generally good business. It is prudent for project planners to utilize a technology that is non-polluting. Not only will this policy have dividends for the project in terms of its image, but it is often sound business practice as materials and energy are conserved as resources do not enter the waste stream.

Efficient use of inputs reduces operating costs and avoids treatment and disposal costs.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

EIA should be undertaken by the project design team, whether or not statutory or regulatory constraints are imposed. It can be relatively informal when guidelines do not exist, but the objective should be to anticipate and avoid environmental problems. Additional details on EIA are provided in EIA Methods.

Material flow balances (quantities, qualities): Define the production program and material flow balances (quantities, qualities). This is a good starting point as all of the inputs and outputs are identified, including emissions of fluids, solids, gases, noise, light and other radiations.

Other operational impacts: These include plant emissions and other impacts such as esthetic, cultural, economic, social.

Legal and regulatory basis for evaluation: Determine what statutes and regulations apply to emissions and other impacts on the local environment.

Perform baseline study, environmental status quo: This study should cover the existing natural setting, describing flora and fauna and their habitats, the human situation with regard to populations, living conditions, culture, social and economic systems.

Incremental effects on humans, flora, fauna: This covers the impact of the proposed technology on humans, flora and fauna in the surrounding community, the changes in the environmental situation with the project in place as compared with the situation without the project.

Indirect influences of project on the environment: These are impacts that are not directly related to project operations, but that are connected either economically or technologically. Economic ties would involve other economic entities such as upstream and downstream enterprises. Technological impacts cover secondary and tertiary effects, e.g. the impact of soil contamination resulting from project operations on agriculture or recreation in the area.

Consider mitigation measures: Abatement and/or control of adverse environmental impacts should be included in the project plan in accordance with statutes, regulations and prudent business practice. Even if the impacts are acceptable to the regulating authorities, or if regulations do not exist, it is prudent for project designers to try to anticipate what regulatory measures might be enacted in the future and what the consequences will be if emissions from the project prove to be harmful to the surrounding community. Mitigation measures should be considered to reduce emissions to acceptable levels.

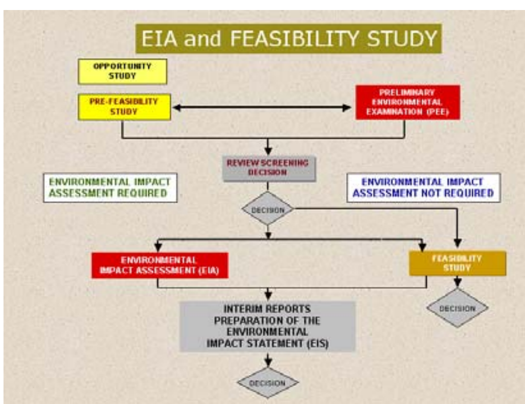
Perform cost benefit analysis including monetized and qualitative environmental impacts: A cost-benefit analysis of the project should ideally be performed, using economic (shadow or accounting prices) for all inputs and outputs, including externalities to the extent practicable expressed in monetary terms. Some of the non-monetary impacts can be analyzed quantitatively and integrated into an economic cost-benefit analysis.

Some impacts are non-monetary and not amenable to monetization (some may be otherwise quantifiable, e.g. the number of specimens of a species affected by an impact). The degradation of non-edible species habitats is not easily expressed in monetary terms. Such effects as aesthetic degradation or infringement on cultural patterns are similarly not easily expressed monetarily. These effects can only be treated qualitatively. There is much literature on the subject.

This will not be practicable for small projects, but should be performed at least qualitatively when the environmental or other external impacts are significant.

Develop environmental plan: This is an action plan that covers design aspects, including mitigation measures, and how the external impacts will be managed. For example, if the project requires displacements of population segments, plans for relocation should be developed to minimize adverse consequences. If habitats of local flora and fauna are to be protected, systems for such protection should be defined and the means of implementation described.

EIA AND FEASIBILITY STUDY



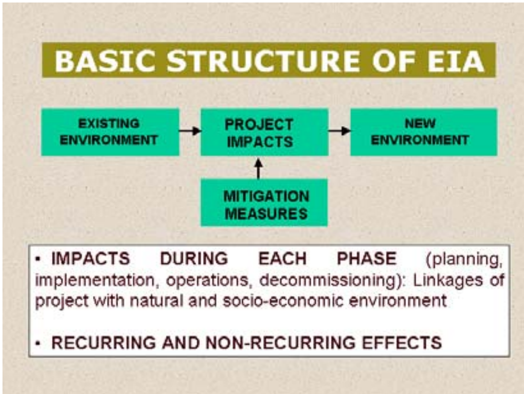
Environmental impact assessment should proceed in parallel with other aspects of project development.

PEE should be performed in conjunction with pre-feasibility or preliminary techno-economic study. This preliminary, but comprehensive, picture of the project should be the basis for project screening, the point at which promoters decide to proceed to further study and development or to put it aside.

If appropriate, EIA should be performed in parallel with a feasibility study. If no significant environmental impacts have been identified in the PEE, the approval process would proceed without reference to environmental matters. If EIA is performed, the final decision should rest on the results of both the techno-economic feasibility study and the EIA. In this case and EIS (statement of impacts and mitigation measures) should be part of the foundation for the investment decision.

Some impacts are non-monetary and not amenable to monetization (some may be otherwise quantifiable, e.g the number of specimens of a species affected by an impact). The degradation of non-edible species habitats is not easily expressed in monetary terms. Such effects as aesthetic degradation or infringement on cultural patterns are similarly not easily expressed monetarily. These effects can only be treated qualitatively.

BASIC STRUCTURE OF EIA

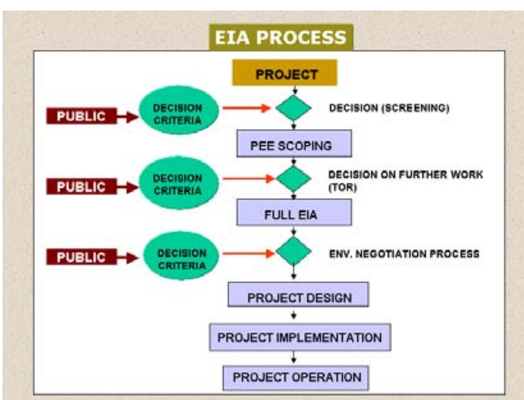


The basic idea of EIA is shown. There is an existing environment. This should be studied and understood to the greatest extent practicable. The project is imposed on the environment. Its impacts should be studied and understood. Based upon the nature of the impacts, regulatory requirements, and good business sense, it may be necessary to plan for mitigations of the impacts. This could involve changes in physical designs, systems designs, operating procedures or installation of capital facilities to limit or control impacts. Capital and operating costs could be affected.

The environment with control and mitigation measures in place should be defined. This is the basis for the EIS, a statement of the environmental problems and how they will be addressed by the enterprise. The EIS includes an environmental assessment and also the effects of mitigation measures proposed by the project.

The necessary measures will usually differ for each project phase (planning, implementation, operations and decommissioning). Some effects are recurring (more or less continuous) and others are one-time effects such as those that occur during construction.

EIA PROCESS



Environmental Impact Assessment (EIA) commences when the project is tentatively approved in the initial screening and there appears to be prima facie evidence of environmental concerns. The diagram shows the process of formulation and approval of EIA and EIS. This activity should be parallel with the techno-economic study of the project. In some cases they will actually merge into one study.

As a general rule, the public - residents of the surrounding community - should be involved in the process as early as possible. In the diagram public intervention is indicated during the initial scoping and negotiations on environmental design factors resulting from EIA. Public hearings in which residents of the area, political representatives and others are permitted to speak on these issues should be held at virtually every major step in the process.

Early commitment and actions by project sponsors to follow good environmental practice will usually have beneficial consequences in terms of community support and customer relations.

PEE scoping: Preliminary Environmental Examination (PEE) is the process of performing a preliminary survey of conditions at the site and identifying areas of potential environmental concern. It is ideally carried out by a multidisciplinary group, with members in the areas of ecology, sociology and economics, but the effort has to be consistent with the magnitude of the project. The result of the scoping effort may result in a decision to prepare terms of reference for a consultant to perform EIA.

Full EIA: If conditions warrant, a full EIA is performed, as described previously. The results of the study are subject to negotiation with regulatory authorities and public interest groups covering design and operational features and relations with the surrounding community.

Project design, implementation and operations: The design and project implementation include features that were negotiated during the environmental assessment process. During implementation and after commencement of operations the actual environmental consequences of both project phases can be monitored. The analysis of field data may lead to an obvious need for design modifications or to further study.

EIA ACTIVITIES

EIA should be considered a scientific activity in the sense that objective observation and interpretation should be the rule. The scientific process is more or less as follows:

Describe: These are recorded data or observations of the environmental situation, described in objective terms.

Measure: Measurement is an indispensable part of the scientific method. Only what can be measured, according to some experts, can be understood to any significant degree. However, aspects of the environment that can not be quantified can at least be 'measured' qualitatively.

Analyze: The measured information is entered into models representing the operative systems in the environment. According to the nature of the model, the 'inputs' produce consequences, or 'outputs'.

Interpret: The results of analysis are subject to interpretation. No model represents exactly the physical, social and economic environment. What the results of analysis mean in the project context is best determined by experts in the field.

Evaluate: Are the consequences acceptable, or manageable?

Communicate: The results of analysis must be communicated to decision-makers and their constituencies in an understandable manner. This should be achieved in the 'full light of day'. Results of analysis that may be unfavorable for the project, if not communicated directly, will probably surface at a later time, when management of the situation may be more difficult.

EXTENT OF ENVIRONMENTAL IMPACTS

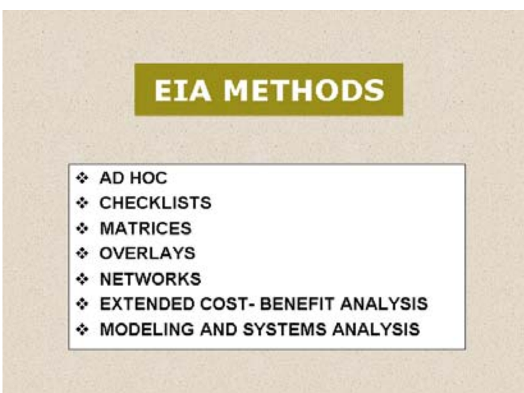
Depending upon the nature of the project, EIA may extend to local, regional or even global dimensions. For massive projects international finance organizations might insist upon an assessment extending to global dimensions. Assessment may be limited to the production site and the surrounding areas for relatively small projects. Assessment for intermediate sized projects may extend to the region, particularly in those areas and directions where pollutants will spread naturally.

Local: Conditions at the production site, and perhaps to impacted adjacent areas.

Regional: Of particular concern are activities that are downstream of the project, where effluents might affect water quality, and in the leeward direction where particulate matter and gases emitted by the project would tend to flow. Some emissions, e.g. radiations, are omni-directional.

Global: For large projects impacts on the atmosphere and oceans might be of concern. A project releasing large quantities of greenhouse gases, for example, would be of concern beyond the borders of the host country.

EIA METHODS



A number of mechanisms have been used widely to facilitate EIA. These devices are intended to present information in an orderly manner so complex relations can be comprehended. More detailed description of IEE and methods of performing EIA for non-quantified impacts are described in the file EIA Methods. An example of an Environmental Impact Assessment for an aluminium smelting plant is provided in the two files Case-Environment: Problem and Solution. (*see Related Documents*)

Ad hoc: Methods that have been developed for a special or particular purpose, with no general applicability. For example, if a rare or endangered species is found in the area, study of its habitat may special methodologies.

Checklists: A number of checklist types have been employed, increasing in complexity of data collection. In each case the environment is examined and appropriate data entered into the checklist.

1. Simple: A listing of environmental parameters
2. Descriptive: (1) + guidelines to measure parameters
3. Scaling: (2) + information on subjective scaling of parameters
4. Scaling-weighting: (3) + information on subjective evaluation of each parameter with respect to other parameters
5. Questionnaire: (1) + linked questions
6. Evaluation system: More advanced checklist, with models for scaling and weighting.

Matrices: A simple interactive matrix has a horizontal list of project activities and a vertical list of environmental parameters. The environmental impacts for each project activity are noted. Activities can be isolated temporally (by project phase) or by function. A quantitative graded matrix is similar to a simple matrix but with a grading system for the magnitude and importance of the impact.

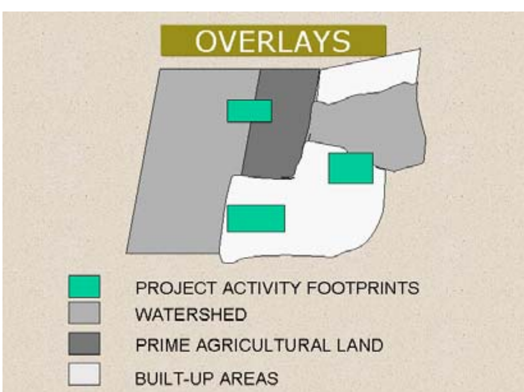
Overlays: Maps of the project area with a series of transparent sheets (overlays) showing characteristics common to all areas.

Networks: Data structures showing primary, secondary and sometimes tertiary levels of impacts.

Extended cost benefit analysis: Includes assessment of environmental costs and benefits with some of the impacts monetized. Some health and transportation impacts have been treated in this way.

Modelling and systems analysis: A model is a simulation of the environment based upon principles of the biological and social sciences. The ecological system is defined qualitatively and quantitatively. Environmental disturbances are superimposed on the model to determine their impacts.

OVERLAYS

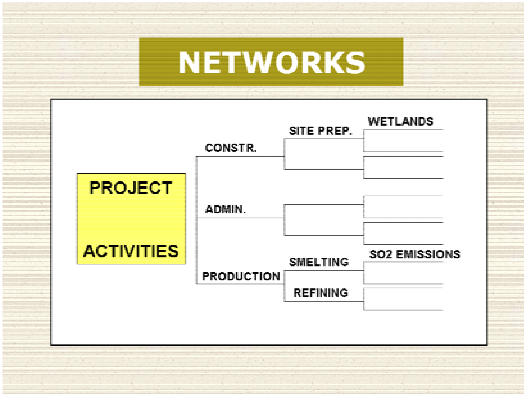


Overlays are basically maps showing significant natural resources in the region and on which impact footprints from the proposed project sites are superimposed. Overlays are usually in the form of transparencies set over an underlying map of the area that resources and impacts can be seen simultaneously.

Natural resource overlays can include aquifer recharge areas, watersheds and waterways, forests, agricultural land, species habitats, etc. Other overlays can show human activities such as high density housing. These overlays help to depict the impact areas on natural resources and human activity.

In the illustration the ‘footprints’ or impact areas for project activities might be included in one overlay, with watersheds, prime agricultural land and built-up or densely inhabited areas shown on separate overlays.

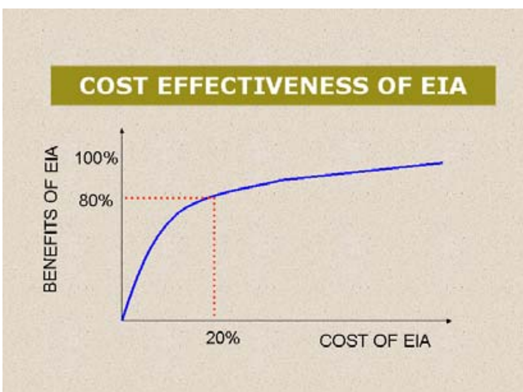
NETWORKS



A network is a data or information structure that presents environmental impacts in a systematic manner. The network can contain primary, secondary or even tertiary levels and beyond.

In the example shown, the project is decomposed into activities. A separate network can be prepared for each project phase (planning, implementation, operations, decommissioning); alternatively the project phase can be at the primary level with activities at the secondary level. Activities may be further decomposed into sub-activities. At some level the environmental features that are impacted by the activity are indicated. This provides a graphical breakdown of all of the environmental issues that should be addressed.

COST EFFECTIVENESS OF EIA



For the project designer the effectiveness of resource utilisation is always of concern. In the case of environmental impacts, at first glance there appear to be only costs and little benefit, although further analysis may reveal a quite different picture.

However, environmental overkill is always a danger. There are diminishing returns as the depth of the analysis increases. In the illustration 80% of the benefits of analysis are realized with 20% of the costs that could be expended if the study continued to indubitable completeness. The study should be complete, but no physical system, and particularly a natural system, can be completely known.

IMPLEMENTATION PLANNING AND BUDGETING

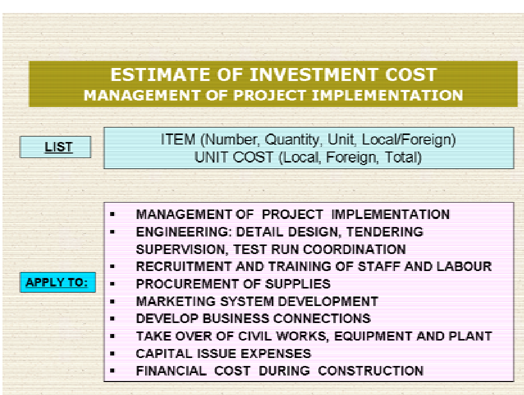
During the planning stage, before the commitment to invest, a preliminary implementation plan is useful to the analyst and stakeholders for costing purposes and to examine issues associated with building the plant - quantities and timing of material, personnel and financial needs to carry out the implementation. This plan can does not require the breadth and depth of detail of the post-decision plan, but should be sufficiently accurate to predict timing of major activities and events, as a basis for financial planning and negotiations.

To bring the project to fruition after a go-ahead decision has been reached requires creation of an implementation management organisation, which would initially consist of a core group - a project manager and support staff - to develop a Project Implementation Plan (PIP). The plan derives from the techno-economic feasibility study in which the basic project parameters are defined. Once the plan is reviewed and accepted by the project sponsors, the implementation team can be filled out.

The PIP covers preparation of the site, construction of all facilities, installations, start-up and commissioning. The timing and interrelations of all activities and events necessary to complete the project are included, with phasing of personnel and material resources and funding.

The implementation of the project includes preparation of the site, construction of all facilities and start up and commissioning of the plant. The project implementation must be planned in detail after the commitment to invest. In the planning stage a preliminary implementation plan is necessary for costing purposes and to examine the needs for materials, equipment and personnel to carry out the implementation.

ESTIMATE OF INVESTMENT COST - PROJECT IMPLEMENTATION



The costs associated with management of implementation should be added to the investment in plant and machinery. These costs may be in addition to the construction costs previously discussed.

An alternative to the method previously suggested of assigning all resources to the jobs, and then calculating the project cost as the sum total of the cost of all the jobs, is the usual procedure of listing the resources by item, unit cost and total cost and then summing them. The disadvantage of relying solely on this method is that the timing, which is important for financial issues, is not included.

In any case, it is necessary to include the cost of all resources utilized during the construction phase. This applies to all the necessary activities project construction and the ancillary activities that are necessary to bring the enterprise to operating condition. Some of these costs are as follows (if not covered elsewhere):

- Management of project implementation
- Engineering: detail design, tendering supervision, test run coordination
- Recruitment and training of staff and labour
- Procurement of supplies
- Marketing system development
- Develop business connections
- Take over of civil works, equipment and plant
- Capital issue expenses
- Financial cost during construction

RELATED DOCUMENTS

EXERCISE

TECHNOLOGY CHOICE

Problem Statement

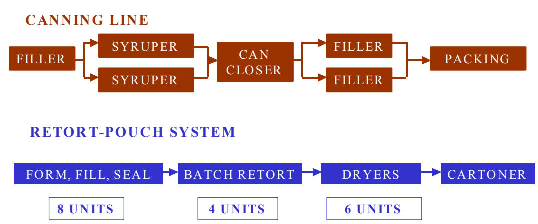
The Tropical Fruit Company is contemplating expansion of their juice packaging line. Two alternatives are being considered, a Retort/Pouch System and a Canning Line. It is anticipated that the useful life of each line will be 10 years.

Both lines must be imported. The canning line is available from a country in the region that has recently industrialized while the retort/pouch line must be imported from an industrialized country. Both must be paid in foreign exchange.

Cans are available domestically but are produced from imported tinplate which constitutes about 60% of their cost. Pouches must be imported at present but there is a possibility that a local manufacturer will soon begin production. It is expected that the price of the plastic pouches will reduce at an average of 5% per annum, as the projected increasing demand will permit economies of scale. The foreign component of pouch cost is expected to be 30%. *All other inputs and investments are domestically produced and the increased availability of these inputs and investments are attributable to this project. This implies that they all contribute to domestic value-added.*[1]*.*

The Development Finance Corporation that is considering support for this project is concerned with the foreign exchange effect, job creation and the most efficient use of scarce capital resources. There is also concern for the demands on the power grid as shortages have been recently experienced due to maintenance problems at the hydroelectric plant and low levels of water in the reservoir.

The opportunity cost of capital in real terms is 10%.



Some of the features of each system are as follows (note that the original data is altered for purposes of this exercise). The project is to be constructed in one year and planning should cover 10 years of operations.

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[1] This assumption concerning other inputs contributing to domestic value-added are simplified for the purposes of this exercise. Ordinarily there would undoubtedly be imported components if the other inputs were properly decomposed into domestic and foreign content.

CAPACITY, INVESTMENT - (Costs in US$ thousands)

DESIGN CAPACITY	360 packages per hour
SHIFTS – 2	16 hours/day, 250 days per year
INVESTMENT COSTS, Foreign exchange	
CANNING LINE	690
RETORT/POUCH	1350
OTHER INVESTMENTS, Local currency	800
AVERAGE EXPECTED REVENUE, per annum	990

OPERATIONAL DATA:

	CANNING	RETORT-POUCH
Number workers per shift	3	7
Electricity Kwh per shift	92.95	1601.9

ANNUAL OPERATION COSTS (US$ thousand), 2xxx

	RETORT-POUCH	CANNING	EST PRICE CHANGE per annum, %
Labour	15.50	7.50	0.00
Electricity	30.97	1.80	4.82
Cans	-	115.20	3.23
Pouches	171.36	-	-5.00
Thermal energy	4.06	3.74	4.82
Transport	223.6	317.0	4.85
Other	10.00	100.00	0.00

Which alternative should be selected?

EXERCISE

TECHNOLOGY CHOICE

Fruit Packaging Case

SOLUTION

Table I shows the comparison between the cash outflows for the two systems of production assuming a 10 year project life after a one year construction phase. Table II shows a financial and economic comparison of the two alternative technologies. Figure 1 shows the Present Value of costs for each alternative vs. discount rate.

RELATIVE ANALYSIS:

Figure 1 shows that the Retort-Pouch (RP) system has lower present value of costs for any discount rate below about 17%. With the hurdle rate at 10% RP shows lower costs. The Net Present Value (NPV) at the hurdle rate also favours RP. Other advantages of RP are as follows: Lower investment per worker (about 38%), lower cost of imported materials and higher overall value-added (assuming only imported inputs based on year 5). The cost in foreign exchange is considerably lower, either on a total impact basis or when discounted at 10%.

The Canning system (CN) shows some advantages when the project is regarded from the national perspective. The use of electricity, of concern to the national authorities as in short supply, is much lower for CN. Electricity consumption for RP is about 17 times higher than for CN. The Value-Added per MWH of electrical energy is much more favourable for CN by a factor of about 16.

By most criteria RP would appear to be the favourable alternative – higher return for investors, lower foreign exchange costs and higher value-added. CN is the favoured alternative mainly on the basis of its demand for electricity. The final decision would have to be based on a formal or informal weighting of the relative benefits of each alternative. The weighting system would be different for each type of participant. The investor would undoubtedly weigh return on investment most heavily while the regulators or licensing agents would place more emphasis on electricity consumption and value-added.

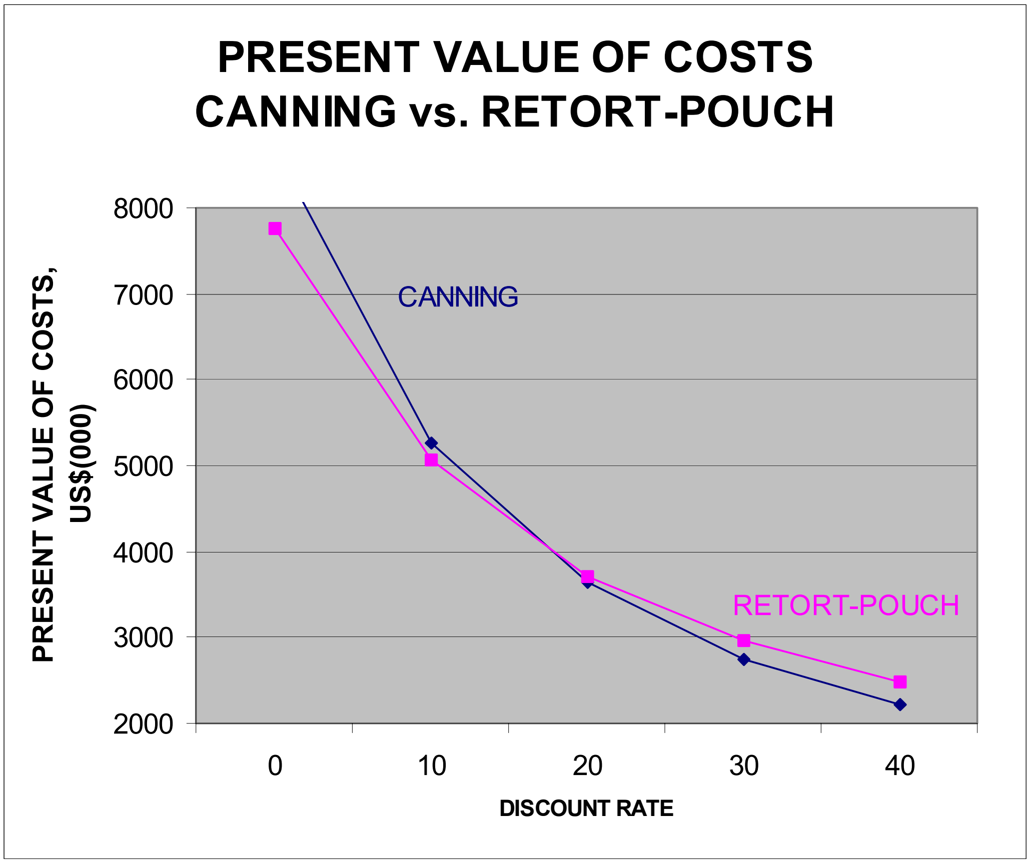
TABLE I: CASH FLOW - CANNING vs. RETORT/POUCH

CANNING											
	0	1	2	3	4	5	6	7	8	9	10
Investment, FE	690.00										
Investment, Dom.	800.00										
Raw materials		75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00
Packaging		115.20	118.92	122.76	126.73	130.82	135.05	139.41	143.91	148.56	153.36
Labour		7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Electricity		1.08	1.13	1.19	1.24	1.30	1.37	1.43	1.50	1.57	1.65
Thermal energy		3.74	3.92	4.11	4.31	4.51	4.73	4.96	5.20	5.45	5.71
Transport		317.00	332.37	348.49	365.40	383.12	401.70	421.18	441.61	463.03	485.48
Other		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TOTAL - CAN'G	1,490.00	619.52	638.85	659.05	680.18	702.26	725.34	749.48	774.72	801.11	828.70
RETORT-POUCH											
	0	1	2	3	4	5	6	7	8	9	10
Investment, FE	1,350.00										
Investment, Dom.	800.00										
Raw materials		75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00
Packaging		171.36	162.79	154.65	146.92	139.57	132.60	125.97	119.67	113.68	108.00
Labour		15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50	15.50
Electricity		30.97	32.46	34.03	35.67	37.39	39.19	41.08	43.06	45.13	47.31
Thermal energy		4.60	4.82	5.05	5.30	5.55	5.82	6.10	6.40	6.70	7.03
Transport		223.60	234.44	245.82	257.74	270.24	283.34	297.09	311.49	326.60	342.44
Other		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
TOTAL	2,150.00	531.03	535.02	540.05	546.12	553.25	561.45	570.73	581.11	592.62	605.28

TABLE II - FINANCIAL AND ECONOMIC COMPARISONS - CANNING vs. RETORT-POUCH

NET FLOW											
REVENUE	0	990.00	990.00	990.00	990.00	990.00	990.00	990.00	990.00	990.00	990.00
CANNING	-1,490.00	370.48	351.15	330.95	309.82	287.74	264.66	240.52	215.28	188.89	161.30
RETORT-POUCH	-2,150.00	458.97	454.98	449.95	443.88	436.75	428.55	419.27	408.89	397.38	384.72
FOREX OUTFLOW											
CANNING	690.00	371.71	383.31	395.43	408.11	421.35	435.21	449.69	464.83	480.67	497.22
RETORT-POUCH	1,350.00	159.31	160.51	162.01	163.84	165.98	168.43	171.22	174.33	177.79	181.58
NPV COSTS											
DISCOUNT RATE		0.00	0.10	0.20	0.30	0.40					
CANNING		8,669.22	5,265.14	3,635.75	2,747.83	2,209.73					
RETORT-POUCH		7,766.67	5,057.08	3,714.48	2,953.38	2,472.72					
DR, PERCENT		0.00	10.00	20.00	30.00	40.00					
COMPARATIVE RESULTS		RETORT/POUCH		CANNING		FAVORS					
NPV COSTS AT 10% DISCOUNT		5,057.08		5,265.14		R/P					
NPV AT 10% DISCOUNT		473.03		264.97		R/P					
NPVR		0.22		0.18		CANNING					
No. WORKERS		7.00		3.00		R/P					
INVESTMENT/WORKER		307.14		496.67		R/P					
OUTPUT, YEAR 5		990.00		990.00							
DEPR. IMPORTED MACH.		135.00		69.00		CANNING					
IMPORTED MATERIALS		41.87		83.74		R/P					
VALUE ADDED		948.13		911.51		R/P					
VALUE ADDED PER											
UNIT INVESTMENT		0.44		0.61		CANNING					
ELECTRIC DEMAND, MWH		800.95		46.48		CANNING					
VALUE-ADDED/MWH		0.59		9.81		CANNING					
FOREX COST		3,035.00		4,997.53		R/P					
DISCOUNTED 10%		2,158.03		2,973.63		R/P					

FIGURE 1 : PRESENT VALUE OF COSTS -
CANNING vs. RETORT-POUCH SYSTEM



USE OF DYNAMIC MODEL TO DETERMINE PRODUCTION SCHEDULE

A dynamic analysis of the production programme can be used to find the optimal (least cost in this case) plan for the project. This type of model can be used when:

* Demand varies in each period
* Costs vary in each period

The type of model illustrated here is a recursive model, i.e., the computations start from the first stage (period) and proceed to the last, with the optimal solution for each stage depending upon the optimal solution for all previous stages and the minimum cost function for the stage under consideration.

Variables:

Z_i amount produced in period I
d_i amount demanded in period I
X_i entering inventory for period I
h_i holding cost per unit of inventory carried forward from period I to period i+1
K_i fixed cost for period I
$C_i(Z_i)$ production cost function given the value Z_i

Stage - each period
State - entering inventory for period i+1
(same as ending inventory for period i)

The decision variable, as indicated above is Z_i, the quantity to be produced in each period i.

The function for determining minimum cost in each period is determined for each possible state (entering inventory) in the subsequent period based upon the relation:

$$f_i(x_{i+1}) = \frac{\min}{0 \leq z_i \leq d_{i+1}} [C_i(Z_i) + h_i(x_{i+1}) + f_{i-1}(x_{i-1} + d_i - z_i)]$$

The last term is added for the minimum cost in the previous period corresponding to the entering inventory of the current period. This derives from the continuity relationship:

$$x_{i+1} = x_i + z_i - d_i$$
$$x_i = (x_{i+1} + d_i - z_i)$$

For example, in stage (period) 2, if $x_3=4$ $d_2=3$ and $z_2=2$, then

$$f_1(x_3 + d_2 - z_2) = f_1(x_2) = f_1(5)$$
$$\text{since } x_2 = (x_3 + d_2 - z_2) = 4 + 3 - 2 = 5$$

EXAMPLE OF DYNAMIC PRODUCTION PROGRAMMING:

Stage (period) i	Demand d_i	Fixed cost K_i	Holding cost h_i
1	3	3	1
2	2	7	3
3	4	6	2

$$C_i = 10 z_i \text{ for } 0 \le z_i \le 3$$
$$C_i = 30 + 20(z_i - 3) \text{ for } z_i \ge 4$$

Assume that the entering inventory in period 1 $x_1=1$.

The fixed cost for each period K_i is added to the variable costs, which depend upon z_1 and x_{i+1}. In each of the following tables the values shown represent sequentially:

$C_i(z_i)$	Production cost for period I
$h_i(x_{i+1})$	Holding cost for inventory carried over to next period
K_i	Fixed costs for the period I
$f_{i-1}(x_{i+1}+d_i-z_i)$	Minimum cost up to and including the previous period based on the current entering inventory (determined from the continuity equation)

PERIOD (STAGE) 1: (In this case $f_{i-1}=0$)

$$(d_1 - x_1) \le z_1 \le (\sum_{i=1}^{3} d_i) - x_1$$

$$(\sum_{i=1}^{3} d_i) - x_1 = (3+2+4)-1=8$$

$$0 \le x_2 \le \sum_{i=2}^{3} d_i = (4+2)=6$$

$C_1(z_1)$		20	30	50	70	90	110	130	$f_1(x_2)$	z_1^*
x_2	$h(x_2)$	Z_1								
		2	3	4	5	6	7	8		
0	0	20+0 +3							23	2
1	1		30+1 +3						34	3
2	2			50+2 +3					55	4
3	3				70+3 +3				76	5
4	4					90+4 +3			97	6
5	5						110+ 5+3		118	7
6	6							130+ 6+3	139	8

In the above table showing the minimum cost production levels in the first period for the entering inventories of the next period x_2, there is only one possibility for each value because $x_1 = 1$ and d_1 are constants, and

$$x_2 = x_1 + z_1 - d_1$$
$$= 1 + z_1 - 3 = z_1 - 2$$

PERIOD (STAGE) 2:

$$0 \le z_2 \le \sum_{i=2}^{3} d_i = 6$$
$$0 \le x_3 \le (z_{2\,\max} - d_2) = 6 - 2 = 4$$

$C_2(z_2)$		0	10	20	30	50	70	90	$f_2(x_3)$	z_2^*
x_3	$h(x_3)$	Z_2								
		0	1	2	3	4	5	6		
0	0	0+0+7 +55	10+0+7 +34	20+0+ 7+23					50	2
1	3	0+3+7 +76	10+3+7 +55	20+3+ 7+34	30+3+ 7+23				63	3
2	6	0+6+7 +97	10+6+7 +76	20+6+ 7+55	30+6+ 7+34	50+6+ 7+23			77	3
3	9	0+9+7 +118	**10+9+7 +97**	20+9+ 7+76	30+9+ 7+55	50+9+ 7+34	70+9+ 7+23		100	2
4	12	0+12+7 +139	10+12+ 7+118	20+12 +7+97	30+12 +7+76	50+12 +7+66	70+12 +7+34	90+12 +7+23	123	6

In the cell for $z_2=0$ and $x_3=0$ ($d_2=2$) for example,

$$x_3 = x_2 + z_2 - d_2$$
$$x_2 = x_3 - z_2 + d_2 = 0 - 0 + 2 = 2$$
$$f_1(x_2) = f_1(2) = 55$$

In the cell for $z_2=1$ and $x_3=3$:

$$x_3 = x_2 + z_2 - d_2$$
$$x_2 = x_3 - z_2 + d_2 = 3 - 1 + 2 = 4$$
$$f_1(x_2) = f_1(4) = 97$$

PERIOD (STAGE) 3

$$0 \le z_3 \le d_3 = 4$$
$$0 \le x_4 \le z_{3\,\max} - d_3 = 4 - 4 = 0$$

$C_3(z_3)$		0	10	20	30	50	$f_3(x_2)$	z_3^*
x_4	$h_3(x_4)$	Z_3						
		0	1	2	3	4		
0	0	0+0+6 +123	10+0+ 6+100	20+0+ 6+77	30+0+ 6+63	50+0+6 +50	99	3

The optimal (minimum cost) solution is determined by a recursive procedure as follows:

$$f_3(x_4) = 99$$
$$z_3^* = 3$$

Three units should be produced in period 3. This implies that the entering inventory for period 3, x_3, (the final inventory for period 2) can be determined as follows:

$$x_3 = x_4 + d_3 - z_3 = 0 + 4 - 3 = 1$$
$$For\ \ x_3 = 1, z_2^* = 3$$

This means that 3 units should be produced in period 2. Then for period 1:

$$x_2 = x_3 + d_2 - z_2 = 1 + 2 - 3 = 0$$
$$For\ \ x_2 = 0, z_1^* = 2$$

The optimal production programme is then:

$$z_1^* = 2,\ \ z_2^* = 3,\ \ z_3^* = 3$$
$$Minimum\ cost = 99$$

MATERIAL QUANTITY AND WASTE FACTORS

EXAMPLE: MATERIALS REQUIREMENT CONSIDERING WASTE FACTORS

Limestone requirements for cement production:

Nominal consumption coefficient: 1.28 Tons/Ton clinker

Based upon short rotary kiln/preheater technology (shaft kiln disqualified due to high volatile content of available coal)

Waste factors (based upon process input) %

Clinker production and handling	5
Clinker grinding and packaging	2
Finished product waste	6

$$ACC = \frac{1.28}{(1-.05)(1-.02)(1-.06)} = 1.46 \text{ Tons / Ton cement}$$

ACC Actual Consumption Coefficient

Production programme: Maximum production 63,000 TPY

Year	1	2	3	4-15
% Full production	50	75	90	100
Limestone requirement, Thousand tons per year	46	69	82.8	92

For example during the first year at 50% production capacity the production requirement will be:

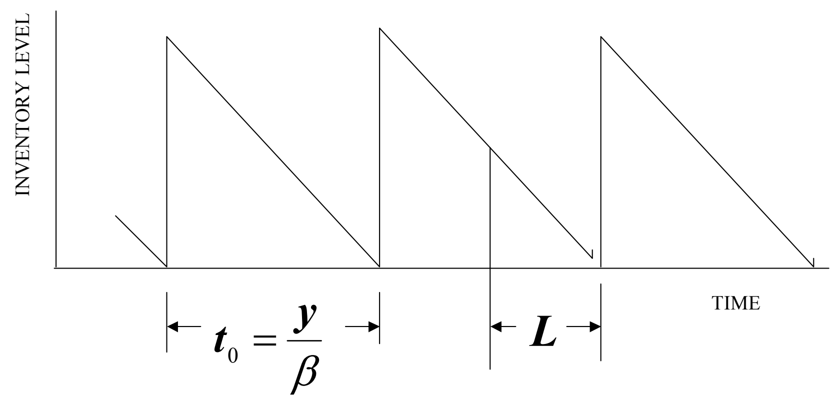
$$Limestone\ \ requiremen\ t = \frac{63000 * 0.5}{0.95 * 0.98 * 0.94 * 1000} = 46.0\, thousand\ \ tons\ \ per\ \ year$$

The total materials requirement for each period will consist of the production (and sales) requirement (including above wastes) plus any build-up of inventories, raw materials, work in process and finished product.

ORDER QUANTITIES

For the purposes of determining the best supplies programme, models can be employed that minimize cost based upon usage rate and holding cost to determine the optimal order quantity.

Single item static model: The objective is to find the Economic Order Quantity, the size of procurements that will minimize the cost of the input item. The parameters are set up and holding costs and consumption rate (quantity of item used in production per unit time.



$$y^* = \sqrt{\frac{2K\beta}{h}}$$

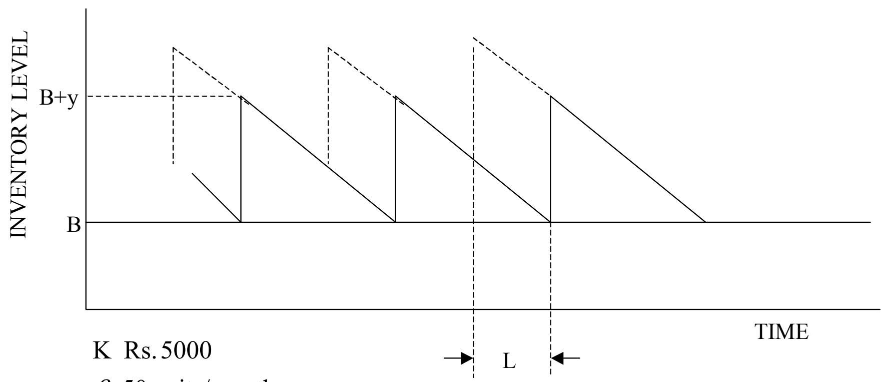
y order quantity

K set up cost

β consumption rate, e.g. units/month

h holding cost, e.g. storage cost per unit/month

Buffer stocks model: This model is similar to the first. There is a minimum level of stocks required to assure continuity of production based upon the lead time for the order. In the example the buffer is set at the 99% confidence level for the lead time (3 standard deviations). This could be set to a lower level depending on the risk tolerance of investors. The maximum level of stocks would include the buffer plus the EOQ and the quantity used during the lead time.



K Rs.5000

β 50 units/month

h Rs.10/unit/month

L lead time 60 days

σ_L standard deviation lead time .33 months

c cost per unit 0.75 (000) Rs

$$y^* = \sqrt{\frac{2*5000*50}{10}} = 224 \text{ units}$$

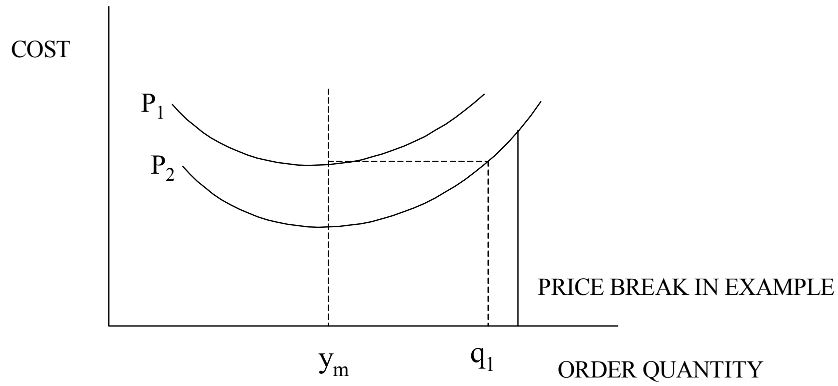
$$\frac{B}{.33*500} \geq 3 \quad B \geq 500$$

$$\text{Maximum storage} = B + y^* = 500 + 224 = 724$$

$$\text{Maximum WC req't} = (B + \boldsymbol{y} + \beta L)c = (500 + 224 + 500*2)0.75 = \text{Rs.}1.293 \text{ mn}$$

Price break model: The supplier offers a price break at a determined order level or quantity. The issue is whether or not the price break offers any advantage for the project. In the example the graph of total cost for the material is shown as a function of order quantity. For low order quantities the cost is high because fixed costs (set up) is included. As quantity increases the effect of the setup cost is reduced but holding costs increase. There is a minimum cost at the optimal quantity or EOQ.

In the example the quantity at which the price break is offered is above the level at which the minimum cost is achieved for the base price. If the price break were at a lower level, say 20 units, then it would be advantageous for the enterprise.



Find q_1 (quantity at P_2 with same cost as minimum P_1 cost)

$$\boldsymbol{P_1\beta + K\beta / y_m + hy_m / 2 = P_1\beta + K\beta / q_1 + hq_1 / 2}$$

y_m is EOQ for P_1 and P_2

Example: Price break at 30 units

$K = 10,\ \ h = 1,\ \ \beta = 5,\ \ P_2 = 1,\ P_1 = 2,\ q = 30$

$$y_m = \sqrt{\frac{2K\beta}{h}} = \sqrt{\frac{2*10*5}{1}} = 10 \text{ units}$$

$$2*5 + (10*5)/10 + (1*10)/2 = (1*5) + (10*5)/q_1 + (1*q_1)/2$$

$$q_1^{\,2} - 30q_1 + 100 = 0$$

$q_1 = 26.2$ or 3.8 (use larger solution)

Price break at 30 units is of no benefit

EXPANSION OPTIMIZATION

The following model seeks the optimal incremental plant capacity expansion programme assuming equal capacity increments evenly staged over time. Benefits produced by any sequence are assumed to be the same: demand is satisfied over the entire time horizon (there is no cost for lost sales).[2]

$$PVC = K(Dx)^a + \frac{K(Dx)^a}{(1+r)^x} + \frac{K(Dx)^a}{(1+r)^{2x}} + \ldots + \frac{K(Dx)^a}{(1+r)^{nx}}$$

PVC	Present value of costs
K	Base cost per unit of production
D	Rate of demand (production) increase per year
x	Years between capacity increments
a	Economy of scale factor
r	Discount rate
n	Number of construction stages

This series (for a fairly large number of stages) reduces to:

$$PVC = \frac{K(Dx)^a}{1 - e^{-rx}}$$

Taking the derivative of this function with respect to x and equating to zero:

$$\frac{\frac{\partial(PVC)}{\partial x} = aKD(1 - e^{-rx})(Dx^{a-1} - K(Dx)^a re^{-rx}}{(1 - e^{-rx})^2} = 0$$

Therefore:

$$x^* = \frac{a}{r}(e^{rx^*}) - 1$$

[2] World Bank EDI Industrial Projects Course Training Manual, Amman Jordan, s. 6, p. 8, 1989

This equation can be expressed approximately as:

$$x^* = \frac{2.6(1 - a)^{1.12}}{r}$$

x^*	-	Optimal time between constructions
$Q^* = Dx^*$	-	Optimal expansion capacity

The optimal expansion capacity increases as both *a* (economy of scale) and *r* (discount rate) decrease. The following table shows a range of solutions:

OPTIMAL CAPACITY EXPANSION HORIZON - YEARS[3]

Economy of scale factor, a	Discount rate % (r * 100)			
	8	10	12	15
0.3	22	17	15	12
0.5	15	12	10	8
0.7	8	7	6	5

For most infrastructure projects have an economy of scale factor *a* of 0.5 to 0.8. The discount factor in many developing countries is between 10-15%. Under these conditions, the model suggests that these incremental expansions should be designed for less than 15 years and more often in the vicinity of 5-10 years. This is generally the case for a wide range of industrial investment projects with similar parameters.

[3] Rounded to next higher integer

SITE ENGINEERING EXAMPLES

WATER PUMPING REQUIREMENTS:

$$Power = \frac{flowrate\ (\frac{M^3}{s}) * \ pressure\ head\ (\frac{N}{M^2})}{1000\ *\ efficiency}$$

$$pressure\ head = \rho gh = 10^3\ \frac{kg}{M^3}\ *\ 9.8\ \frac{M}{s^2}\ *\ h\ M$$

$$= (9.8\ *\ 10^3\ *\ h)\frac{N}{M^2}$$

ρ Density of water, kg/M^3
g Acceleration of gravity, M/s^2
h Height of water column, M

To pump 0.5 M^3/s water 75 M at 80% efficiency

$$Power = \frac{0.5\ *\ 9.8(10^3)\ *\ 75}{10^3\ *\ 0.8} = 368\ Kw$$

ELECTRIC POWER REQUIREMENTS

Apparent power for device: P=EI

E Voltage
I Current

True power for device: P=EI*(PF)

PF Power factor

Installed power:

$$Installed\ power = \frac{CL\ *\ LF}{PF}$$

CL Connected load - sum of apparent power for all connected devices
LF Load factor - percentage of connected load utilized simultaneously in production
PF Power factor – net power factor for all connected equipment operating simultaneously (can be corrected with condensers).

MORE ON SITE SELECTION

MAIN CONSIDERATIONS IN SITE SELECTION

- Cost per square meter
- Site preparation cost
- Infrastructure: Existing and development cost
- Security
- Easements, covenants
- Environmental impact and mitigation costs
- Area and expansion potential
- Geology
- Tax stability

SITE SELECTION REQUIREMENTS

- Size: Generally 5 times building area needed for
  - Sidings
  - Loading platforms
  - Vehicle ingress, egress, parking
  - Warehousing
  - Future expansion

- Topographical map of area for
  - Filling and grading requirements
  - Drainage
  - Siting of buildings, facilities

- Soil conditions
  - Permeability of soil (drainage, waste treatment)
  - Soil bearing capacity, Tons/m^2

  Examples:

	Tons/m^2
Granite rock	320
Gravel and sand, compact	65 - 110
Earth, solid, dry in natural beds	40
Clay, soft	10 – 15
Filling, grading	

- Hydrology
  - Water supply
  - Drainage, effluent disposal

SITE EVALUATION CHECKLIST

- Will building code and zoning regulations permit the proposed installations?
- Are environmental impacts and mitigation measures accepted by the authorities?
- Are there easements or covenants that will restrict the use of the property?
- Who will provide maintenance of necessary infrastructure?
- Can long term commitments be arranged for tax valuation?
- Are security and fire protection assured by the local authorities?

EIA METHODS

ENVIRONMENTAL INVENTORY

The baseline for the EIA is the environmental inventory, which provides a survey of existing conditions at the site. The idea is to understand both the natural and human characteristics of the area. Features and characteristics of natural conditions (climatic, geodesic and ecology) are studied and described. The socio-economic environment includes human habitats (features such as demographics, income distribution, housing patterns, etc.), the economic activity in the region (industry, commerce, employment, etc.), cultural practices and institutions (schools, universities, libraries, social organizations, etc.)

Natural environment

Climatic: Existing weather patterns, direct effects of extreme weather conditions, indirect effects on inhabitants, workers, etc.

Geodedic: Identification of earthquake, flood-prone areas, study of area geology and soil conditions

Ecological: State of existing flora, fauna and habitats

Socio-economic environment

Human habitat: Housing, transportation, communications, recreation, esthetics, etc.

Economy: Breakdown of productive activity

Culture: Patterns of human interactions, practices

Social fabric: Institutions

CLASSIFICATION OF NATURAL AND SOCIO-ECONOMIC IMPACTS

Project impacts fall basically into three categories. Natural resources are consumed such as minerals or water. Emissions can be in the form of liquids, gases, and solids including particulate matter, noise, vibrations and electromagnetic radiation (including light). Other impacts fall into the following several categories:

- Risk of accidents affecting the social and natural environment (during construction, operations, decommissioning or transport of hazardous substances)
- Increase of existing risks. For example, if there is a high risk for certain diseases in the area the risk may be exacerbated by emissions from the plant.
- Displacements – the project may intrude on existing residential or agricultural land, disturb habitats of species found in the area or interfere with cultural and other economic activities.
- Demands on existing infrastructure may overload the existing systems so that other economic and social activities are adversely affected.

- The habitats of flora and fauna and the general eco-system may be disturbed or damaged.
- The project may impose health risks to workers and staff from internal hazardous operations and uncontrolled emissions.

QUANTITATIVE EFFECTS

Some of the environmental impacts can be quantified. Quantitative impacts can consist of (1) quantitative environmental modifications, (2) quantitative financial costs and (3) quantitative economic costs. Financial costs are those that directly affect the project.

Quantitative costs can be internal (cost of waste disposal and mitigation measures) or external (costs, or externalities, incurred by economically or technologically linked activities). These quantitative effects can be explained in the EIA, EIS and also in the economic cost benefit analysis, if performed.

QUANTIFIABLE EFFECTS

Non-monetary effects are sometimes amenable to quantification.

Survey methods: (Effects that can be quantified by the following methods, among others)

Contingent valuation: Survey determines the value that the affected population places on environmental change.

Contingent ranking: Subjects rank environmental change/monetary compensation combinations. A model is developed which establishes change in income that just offsets the utility of environmental change.

Indirect market-based methods:

Hedonic pricing: Imputed values of environmental change are determined by identifying the effect on the market price of economic resources.

Travel cost method: Identifies relationship of cost and propensity to visit sites (religious, recreation, etc.) with different levels of environmental quality. (Applicable to industrial projects if travel patterns to such sites are altered by the project).

QUALITATIVE EFFECTS

Some impacts are non-monetary and not amenable to monetization (some may be otherwise quantifiable, e.g. the number of specimens of a species affected by an impact). The degradation of non-edible species habitats is not easily expressed in monetary terms. Such effects as aesthetic degradation or infringement on cultural patterns are similarly not easily expressed monetarily. These effects can only be treated qualitatively.

ENVIRONMENTAL IMPACT ASSESSMENT

PROBLEM

In the economic transformation of Central and Eastern European countries, a reasonable assumption is that the need to preserve jobs will preclude closing down many medium size enterprises that are either not economically viable or which present environmental problems. At the same time, there are demands by the citizens of these countries to do something about the occupational health and other environmental problems resulting from these enterprises and increasing resistance from the central government to provide the subsidies that allow such enterprises to continue to operate. The question is how to effect a transformation that responds to all these concerns.

One project in a programme to revitalize such industrial enterprises applied an expanded version of cost-benefit analysis to determine the optimal type and level of output from an existing aluminium casting plant.

SOCIAL COST-BENEFIT ANALYSIS

Concept of the analysis

The Guide to Practical Project Appraisal, UNIDO 1986 describes five stages of analysis, each of which leads towards a measure of the social benefits of a project:

1. Financial profitability at market prices.
2. Shadow prices of resources, including accounting for externalities, to obtain the net benefit at economic (efficiency) prices.
3. Adjustment for the impact on savings and investment.
4. Adjustment for the impact on income distribution.
5. Adjustment for the production or use of goods, such as luxury consumer goods and basic needs, whose social values are less or greater than their economic value.

For the purpose of this analysis the focus was on the first two stages, financial and economic efficiency analyses. For the efficiency analysis transfers were eliminated (only taxes in this case) and negative externalities (environmental impacts) were included.

Current situation

The site of the existing aluminium casting plant is in the central part of a plain in a major river basin of Europe. The population of the town and the surrounding area is about 200,000. It is an industrial town situated in a long-established agricultural region. Atmospheric inversions are a typical phenomenon for the town and the valley, especially in the winter.

The plant located in the industrial zone is surrounded by at least 25 factories to the west and 3 to the east. The facilities within a distance of 10 km. include an oil refinery, a cement plant, a glass workshop, a power station and several machine tool manufacturing plants. These facilities cause a high level of environmental pollution that is transmitted directly to the residential districts of the town to the west and to the suburbs and agricultural lands to the east.

The casting plant, built about 15 years ago, consists primarily of one major building with an area of approximately 17,000 m^2. A few smaller buildings are in the vicinity of the main building. The company presently employs about 600 persons.
The basic casting technique used in the plant is the 'VP' counter pressure-casting machine. From a production point of view, the main disadvantage with the factory is the relatively low degree of mechanization and automation, mostly attributable to the wide spectrum of produced castings. From an emission point of view, the core producing and core casting machines lack installations for containment and worker protection.

The plant was originally designed to produce 6,000 tons/year of castings. It can produce more than 5,000 different types of products, including car wheels, parts for electric motors for lift trucks, defence products, etc.

Sales have declined over the past few years. The best estimate for current plant sales is 4,000 T/year. At $3.00/kg of casting, total plant revenue is $12 million per year. Estimated operating costs are as follows:

		Cost per year, $ million
Raw materials		8.0
Labour		1.4
Energy		1.0
Taxes		0.4
Depreciation		1.1
	Total cost	11.9 or 10.8 on cash basis

The return on sales, taking all cost into account, is about 1 percent. The plant appears to be barely breaking even.

Occupational health

The main occupational health hazards in the plant are formaldehyde, phenol, hydrocarbons, carbon monoxide, quartz sand, noise, cold and heat, and others such as UV, gamma and infrared radiations and asbestos. The core producing and core casting machines are the primary source of most of these hazards and account for the majority of the occupational health risks.

The sources and their health risks on a scale of 1 (lowest) to 6 (highest) are as follows:

Source	Risk	Pollutants
Core casting	6	noise, hydrocarbons, formaldehyde, carbon monoxide, phenol, quartz dust
Core producing	5	noise, hydrocarbons, formaldehyde, carbon monoxide, phenol
Sand blasting	1	quartz dust
Core dryer	1	hydrocarbons
Thermic treatment	1	hydrocarbons
High lift truck	1	hydrocarbons
Saw machine	1	noise
Product finish	1	noise

The main diseases observed and possibly caused by occupational exposure are: neurastema, gastroenteritis, back disorders, pharyngitis, cojunctivitis and optitalumcus neuralgia. All the symptoms and diseases are connected with occupational exposure, primarily from the emissions from the core production and casting section of the plant.
The age distribution of internal diseases indicates the possible exposure to chronic occupational risks (in this case formaldehyde, phenol and cold). There is a lower percentage of workers in the age group over 55 than would be expected.
People who worked more than 15 years and who are in the age group between 45 and 55 can be defined as a high internal disease risk group. More than 40 percent of the workers in this category are internally diseased. If the chronic neurological diseases are added to this group, the percentage of diseased persons in this age group exceeds 50 percent of the workforce.

The average sick leave duration in the past two years was 8.7 days; the incidence of illness averaged 135 days per 100 workers per year (normal average is between 80 and 100 days), which is 35 percent greater than the country average. The number of days sick leave averaged 118.4 days per 100 workers per year, which is 11 percent over the country average.

Between 4 and 10 percent of wages are lost each year due to plant-specific illnesses and illness-related attrition, which comprises a loss of about $40-100 thousand per year per 100 workers (based on average wage of $1,000 per month). As illness-related termination of employment typically occurs 5 to 10 years before normal retirement age and an average of 10 occupational diseases exist in the plant, the real occupational costs are between $0.2 and $0.5 million per year per 100 workers (at the time of the study the production section had 133 workers).

Environmental damages

Air pollution in the form of dust and photochemical mist is visible at most times. The conditions are particularly severe during cold winter days when inversions occur over the deep valley where the industrial zone is situated and over the residential areas of the city.
Plant damage from air pollution is visible in many ways. Lichens are totally absent within an approximate radius of 15 km from the plant and average age of pine needles drop from some four years at a distance of 20 km to one year or less at the industrial sites. Damage is also correlated to elevation with most damage in the valley and much less 200 meters higher in elevation.

In total, an area of some thousand km^2 shows damage to vegetation that could translate to a 50 percent reduction of growth rate for conifer trees (the only ones that could be studied at the time of the research).

Water pollution is unknown upstream of the plant site. The streams passing through the city are quite clear 15 km upstream with clean water crustaceans such as Asellus present. Downstream the river is severely polluted, totally anaerobic and thus without fish and other higher life forms for more than 30 km until the river drains into a major river basin. The estimated river flow in autumn was 5-10 m^3/s, which indicates a yearly average of 10 m^3/s.

Ground water in the city is being depleted with resulting water shortages. Some analytical results indicate that ground water is contaminated with industrial wastes, possibly from a waste dumpsite.

Economic assessment of damages

Estimates of monetarily quantifiable effects are considered in the economic assessment:

* Damage to plant production, assuming 50 % growth loss on 50 % of agricultural land within a radius of 15 km of the plant and a production value of $.05 per m^2, is estimated at $10-15 million per year.
* Corrosion, which in most studies of industrial areas is larger than agricultural losses, is estimated to be in the same range, $10-15 million per year.
* Water pollution, at 10 m^3/s and a value of $1/$m^3$ for clean water, is estimated to cost $35 million per year.

The environmental damage from the industries and the city could amount to $60 million per year. The aluminium plant's contribution to this damage is estimated to be less than 5 % of the total.

* The cost of adverse impacts on the health of workers and to the public is estimated at about $0.5 million per year.

Taking into account environmental and health impacts, the total extent of economic loss due to pollution effects of the aluminium plant alone is estimated at $2.5 million per year.

Alternatives:

Clearly, the plant is operating with an overemphasis on production and little concern for occupational health and safety and environmental problems. In light of the financial situation, a three-stage investment strategy is proposed to address these problems.

- Phase 1 : Housekeeping measures, installation of personnel protection equipment and repair of existing equipment such as the ventilating system.

- Phase 2 : Revamp the interior of the plant and introduce source reduction techniques and technologies to reduce worker exposure.

- Phase 3 : Use either source reduction and/or emission reduction and monitoring equipment to reduce ambient pollution to acceptable levels.

The costs for the three phases are as follows ($US million):

Phase	End-of-pipe technologies	Cleaner technologies
1	0.3	0.3
2	1 - 1.5	2 - 3.0
3	3 - 5.0	2 - 3.0
Total	4.3 - 6.8	4.0 - .3
Approx.	**5.5**	**5.5**

The distribution of investment costs in relation to some major processes (US$ million):

Melting	0.1
Core casting	2.0-3.0
Non-core casting	-
Finishing	0.2
Painting	1.0-1.5
Electroplating	0.5-1.0
Subtotal	3.8-5.8
General[4]	0.5-1.0
Total	4.3-6.8 or approximately 5.5

Core casting is responsible for a large part of the occupational health and environmental problems. Half the investment would be required to deal with problems associated with this process.

Problem: Determine which, if either, of the two approaches to environmental mitigation is feasible, provides sufficient returns to investors and environmental and economic benefits for the community.

[4] Ventilation, wall construction, etc.

ENVIRONMENTAL IMPACT ASSESSMENT

SOLUTION

A comparison between investments required for end-of-pipe solutions vs. cleaner technologies indicates that over the three phases the total cost would be similar - probably a little lower for clean technologies. Thus this alternative is strongly recommended. A short-term drawback is the acceleration of investments in phase 2.

A comparison between environmental damage - assessed to be in the range of US$ 2.5 million per annum - and the environmental mitigation cost indicates a payback period of less than 3 years.

Financial analysis

For a planning horizon of 10 years and the revenue and cost structure indicated above, and assuming an opportunity cost of the existing plant assets of $10 million, the cash flow is shown in the following table:

Table 1 - Cash flow relative to total investment - existing project

Year	0	1	2	3	4	5	6	7	8	9	10
Inflow		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Outflow	10.0	10.8	10.8	10.4	10.8	10.8	10.8	10.8	10.8	10.8	10.8
Net flow	-10.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

The financial internal rate of return is about 3.5 % for a 10 year operating phase. If the investment for the project is added as an outflow ($5.5 million) and recurring costs are included for operation of the environmental control equipment, it is clear that the project is not financially viable. In fact, the financial rate of return would be negative.

Economic analysis

For the economic analysis three views of the project are presented: The situation without the project, with the project and the incremental effect (difference between the 'with project' situation and the 'without project' situation.

Without project: Transfers are excluded (only taxes in this case) and negative externalities estimated at $2.5 million per year are included as a cost.

Table 2 - Economic Benefits And Costs Without Project

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Investment	10.0										
Operating costs		10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Externalities		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Net flow	-10.0	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9

There is no economic rate of return for the existing enterprise considering the negative externalities valued at $2.5 million per year (rate of return is less than zero).

Existing enterprise plus project: The additional investment for environmental mitigation of $5.5 million and the recurring cost of $0.5 million per year are included. The negative externalities are reduced to $0.25 million per year.

Table 3 - Economic Costs And Benefits Of The Enterprise 'With' (Including) The Project

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits		12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Investment	10.0										
Environmental investment	5.5										
Operating costs		10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Recurring env. Mitigation cost		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Negative externalities		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Net flow	-15.5	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85

The economic rate of return for the enterprise 'with' the project is still shows a negative return of almost -10 %.

Project (incremental effect): The full investment for environmental mitigation (phases 1-3) is assumed to occur in year 0. Recurring costs of operating the environmental control systems are estimated at $0.5 million per year. The negative externalities are reduced from $2.5 million to $0.25 million per year, which represents a net positive benefit of $2.25 million per year.

Table 4 - Economic Costs And Benefits For The Project Alone (Incremental Effect)

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits		2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Environmental investment	5.5										
Recurring env. Mitigation cost		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Net flow	-5.5	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75

The economic rate of return for the project alone is 29.4 %.

Although, from an economic point of view the project appears to be worthwhile, when it is included into the context of the existing enterprise under the above assumptions, both from a financial and economic point of view the project does not appear to be a good idea. However, one factor that would change the picture considerably is the estimate of the existing investment. In the foregoing analyses the plant is valued at $10 million based upon its original construction cost. However, the plant is 15 years old, and most of the equipment is fully depreciated financially and considerably depreciated technologically. If the opportunity cost of the existing assets were reduced to $2 million, for example, the results would be as follows:

Type of analysis	Internal rate of return, %
Financial, existing enterprise	59.3
Financial, with project	-1.2
Economic, existing enterprise	< 0
Economic, project	29.4
Economic, existing enterprise plus project	2.3

It is clear that diminishing the opportunity cost of the existing assets to $2 million rather than $10 million does not materially alter the fact that the project does not appear to be a good investment either financially or economically. One important factor that has not been taken into account in the analyses is the possible improvement in plant efficiencies that would result from the project (raw materials, energy, labour).

Alternative estimates of environmental damage

Although the estimated occupational and environmental damages are a start, they are nevertheless a rough approximation.

The environmental damages were not systematically estimated. In the environmental report there is no justification for the estimate of damage to agricultural land of $0.5/m^3, nor is there justification for the claim that material damage is of the same order of magnitude. There is no apparent basis for claiming that pollutants from the plant constitute 3 % of the environmental damage in the area (the plant probably produces more than 5 % of the air pollution and virtually no water pollution), nor is there justification that the ambient environmental health effects are equal to the occupational health effects.

A more systematic and transparent approach for estimating benefits and costs should be followed. A full assessment of net benefits would require information about five distinct relationships:

1. The technology and cost of pollution reduction.
2. Estimating the reduction in pollutants from the investment in cleaner production.
3. Modelling the impact of pollutant loadings on ambient environmental quality and the number of people, buildings and agricultural land exposed to the incremental change in ambient air quality.
4. Preparing quantitative estimates of health and welfare effects based upon dose response functions.
5. Estimating the increases in utility or welfare, measured in monetary terms to the extent possible, with actual or surrogate values that reflect the actual economic situation in the country.

It is quite easily suspected that the estimates of damage are too high. For example, occupational damages were estimated assuming the European wage rate of $1,000 per month although the factory workers were receiving at most $200 per month, which is the wage used in the earlier financial analysis. Using $200 per month as the lost wages for occupational health damage would reduce the residual damage estimate from $250,000 to $75,000.

The environmental health damage should be correlated with the welfare (agricultural and material) damages rather than the occupational damages since both health and welfare damages are based on ambient quality conditions. A more plausible estimate, based on environmental damage estimates in the U.S. is that air-related health damages (mortality and morbidity) are three times the magnitude of welfare damages and that water-related health damages are 50 percent of the welfare damages.
Assuming the total environmental damage of $2.5 million, as reported, but that the damage attributable to the plant is 1 % rather than 3 % of the total, the air pollution-related welfare damage would be $250,000 (based upon total air pollution-related damages of $25 million) and the health-related damage would be $750,000 based on U.S. studies. The water-pollution damage would be $350,000, unadjusted, as there is no further information available at this time. These damages total to about $1.3 million. Adding the occupational damage of $0.1 million gives total occupational and environmental damages of about $1.4 million. The residual damage (after installation of environmental mitigation equipment) would be reduced to $0.1 million.

Using the above assumptions and the $2 million estimate for the opportunity cost of the existing assets, the economic results (financial results are unaffected by the change in the estimate of environmental benefits) would be as follows (economic results for the original assumptions are repeated for comparison):

Type of analysis	Internal rate of return, %	Original
Economic, existing enterprise	0.0	< 0
Economic, project	7.5	29.4
Economic, existing enterprise plus project	5.6	2.3

Conclusion

The application of economic cost-benefit analysis reveals the basic dilemma for the plant. Financially, the plant should not continue to operate if an investment of $5.5 million is required to deal with environmental problems. From an economic point of view, even with the most favourable assumptions ($2 million opportunity cost of existing assets and environmental damage reduced to $1.4 million) the plant is marginally unacceptable. This indicates that it would not be a good idea for the government to subsidize the continued operation of the plant, as it would be an expensive way to maintain employment.

The next steps for the plant are as follows:

1. A review of the actual capital value of the plant. However, it is important to note that, although the financial result without the project is favourable, there is little likelihood that the enterprise can continue to function without the environmental investment, which reduces the financial performance to an unacceptable level. Also, the assumption of a low value for the opportunity cost of the assets is valid only for the technological life of the existing equipment (15 years old). The replacement cost of the plant machinery will be closer to and probably exceed the original cost so that the long-term financial outlook does not appear to be favourable.

2. A marketing study should be conducted to determine if a price higher than the assumed $3/kg is possible. At a price of $4/kg the financial rate of return with the project is about 25 %, even with the original asset value of $10 million (taxes are assumed to increase to $1.2 million). The economic rate of return with the project using the same assumption would be about 30 %.

3. A detailed engineering analysis would provide a more accurate estimate of pollution reduction and would indicate how these measures (particularly source reduction) would lower the cost of production and reduce discharge of pollutants.

A project has been designed to execute an area-wide environmental quality management plan. The government would conduct a more comprehensive review of the environmental problems and a detailed assessment of the sources of pollution. It would then prepare a least-cost environmental management strategy, which in all likelihood would identify facilities other than the aluminium casting plant as the first priority for pollution reduction measures.

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