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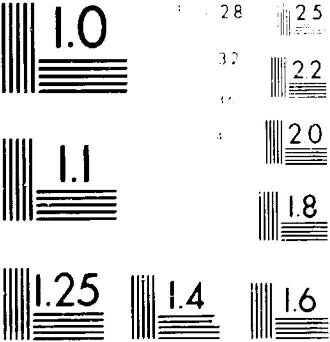

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CAPITAL COST CONTROL OF FERTILIZER PLANTS IN DEVELOPING COUNTRIES

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This document presents major results of work under the element Studies on Capital Goods Industries in UNIDO's programme of Industrial Studies 1982/83.

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(1) /COSTS/ STRUCTURE OF FERTILIZER PROJECTS

CAPITAL COST OF FERTILIZER PLANTS :

- /Ammonia/ plants ;
  [redacted]ity
- /Urea/ plants ;
  [redacted]
- /Phosphate fertilizers process plants
  [redacted]

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ANALYSIS OF THE COST STRUCTURE IN REPORTED [illegible]

5.1 Nitrogen fertilizer projects
- 5.1.1 General remarks
- 5.1.2 Cost structure pattern
- 5.1.3 Comparative analysis o[illegible] Methodology and approac[illegible]

5.2 Phosphate fertilizer projects
- 5.2.1 General remarks
- 5.2.2 Comparative [illegible] plant co[illegible]

5.3 Discussion of results
- 5.3.1 Cost overrun
- 5.3.2 Case studies
- 5.3.3 [illegible] engineering [illegible]

MAIN ISSUES ON HIGH CAPITAL COST OF FERTILIZER PROJECTS IN [illegible]

[illegible] marks. Additional references: /factory establishment/, /financing/, /inflation/, /contract/s, XXX /nitrogen/, /role of UNIDO/.

Preface

This study has ben prepared by the Division for Industrial Studies, Sectoral Studies Branch. It presents an analysis of the developments in capital cost of fertilizer plants in developing countries as well as recommendations on measures to be taken for checking cost increases.

This study is a direct follow-up of the recommendations of the Third Consultation on the Fertilizer Industry to study in-depth the capital cost of fertilizer plants and to present findings for consideration by the Fourth Consultation. The Fourth Consultation is expected to be held in India at the beginning of 1984.

The questionnaire used for the collection of information as well as the main relevant basic data and information are presented in a separate volume as an addendum to this document.

We express our gratitude to government officials, project owners, contractors, consultants, officials of the World Bank and other international and national specialized organizations who were kind enough to answer our questionnaire, give information in personal interviews or discuss the manuscript. For reasons of confidentiality it has not been possible to list the names of all those who contributed to this work.

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Explanatory notes

CE	=	Chemical Engineering Plant Index
CPI	=	Consumer Price Index
DAP	=	Diammonium Phosphate
LPG	=	Liquefied Petroleum Gas
MAP	=	Monoammonium Phosphate
MFG	=	Manufacturing
T/D	=	Tons per Day
TSP	=	Triple Superphosphate

1. INTRODUCTION

The effect of rising construction and equipment cost on the capabilities to build new fertilizer plants has long been an area of concern in developing countries. The Third Consultation on the Fertilizer Industry therefore recommended that UNIDO study in depth the capital costs of fertilizer plants and present its findings for consideration at the Fourth Consultation.

In the process of fulfilling this mandate, UNIDO formulated a plan of work that involved direct formal contacts (in form of questionnaires and interviews) with plant owners, contractors, financing agencies and international organizations involved in the fertilizer industry. The collected relevant information on plants built in developing countries has served as basis for this study.[1/]

This document studies the problem of capital cost overrun and control in fertilizer plants in developing countries. Empirical data and information received from owners of projects implemented within the past few years, and collected through case studies, questionnaires, spot visits, as well as available literature have been used in conducting this work. To provide a framework for a systematic analysis of this information, the first section of the study defines the cost structure of fertilizer projects and describes in detail various cost elements, particularly those that may influence differently the cost structure pattern in different regions. In this context, the principal plant cost components, the contents of which can be determined with some accuracy once the plant technology and particulars are known (i.e. software, hardware and construction), and the cost items usually influenced by the scope of work have been detailed.

It should be stressed that the terminology used in defining various cost components has been based on the need to accomplish a realistic comparison between various fertilizer plants.[2/] This terminology may therefore

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1/ Refer to Annex 1 of the Appendices issued as Volume II of this study.

2/ Definitions of cost components are given in section 2.1 of this study and/or whenever they appear in the text for the first time.

derive to some extent from the one used in other UNIDO documents such as the four "Model Forms of Contracts" especially prepared for the fertilizer industry.

The construction of a fertilizer plant usually involves various functions comprising interrelated activities to be carried out or discharged by different actors. Thus any mismanagement, negligence or misconception on the part of the actors regarding these functions, could lead to abnormalities in the cost structure pattern, and hence, result directly or indirectly in increasing the cost of one or more of the elements. Accordingly those functions and the actors involved have been identified in detail, allowing a closer view of probable factors that jack up the cost in one area or another (section 2).

In identifying areas of excessively high capital cost with regard to fertilizer projects in developing countries, it was essential that a costing basis be established and a reference cost structure pattern be designed. That was achieved by estimating various cost elements (principal plant cost components and the cost items ascribed to them) in terms of the prices or costs of their constituents as indicated by literature. Factors influencing the reference cost structure pattern were also reviewed as far as the principal plant cost components (particularly technology) are concerned. The discussion has been limited here to the capital cost structure of major nitrogen and phosphate fertilizer-processing plants, presented separately as battery limits and as turn-key plant costs (section 3).

To explain the causes of excessively high capital cost of fertilizer projects in developing countries, major cost escalation factors were identified and detailed in terms of their occurrence and control possibilities. Controllable factors (such as delays), foreseen factors (inflation, state policies etc.) and those factors that should be considered at the formulation stage of the project (scope of work, type of contract, financing modalities etc.) were defined in conjunction with various execution functions and as influenced by the behaviour of different actors. Their impact on the total cost and possible means of tuning down their negative effect were also evaluated (section 4).

Based on the discussion and definitions made in sections 1 to 4, the capital cost structure pattern of the reported projects has been analysed. In the case of the nitrogen fertilizer projects on which information and data were available, the analysis has followed two approaches. The first approach used the data and information as received to identify the areas and causes of excessively high cost. The second involved a comparative cost analysis in which the value of all cost elements was converted to a common reference base by using a world price inflation index and conversion factors relating capacity and technology to plant cost. The reference base comprises the capital cost of a standard model complex (gas-based ammonia plant and urea plant of 1,000 T/D and 1,700 T/D capacities respectively) in 1978 prices. The comparative analysis allowed thorough assessment of cost escalation and of cost-escalating factors and their impact on the overall project cost. Furthermore, it allowed a closer estimate of the overrun in plant and in overall costs of each project in comparison with projects in other developing and industrialized countries. The latter approach could not be followed in the case of the phosphate fertilizer projects reported due to the limited number of these projects and the scanty information given on them (section 5).

Based on the analysis of the cost structure, the causes for overrun in the capital cost of fertilizer projects in developing countries were traced back to the procedures and functions ascribed to different stages of project planning and implementation. Such causes as delays, financing procedures and location-related cost factors etc., as discussed in the previous sections, were partly linked to the planning and implementation capabilities of the owner. Ways and means of eliminating these causes were then discussed and presented in the form of general recommendations to be considered by the Consultation Meeting (section 6).

It should be emphasized that no attempt has been made in this study to estimate the effect of capital charges on the profitability or level of return on investment. It is also important to note that the study has been confined mainly to projects of small to large capacities and has not dwelt on small-scale (mini-) fertilizer plants. This is the subject of another study prepared for the Fourth Consultation Meeting on the Fertilizer Industry by the UNIDO Sectoral Studies Branch, Division for Industrial Studies.

2. COST STRUCTURE OF FERTILIZER PROJECTS

2.1 Typical cost structure of fertilizer projects

In presenting a typical cost structure of fertilizer projects, one must differentiate between two distinct investment functions:

(a) feedstock/raw material preparation and transfer facility involving extraction or mining operations, including storage and delivery to fertilizer plant fence;

(b) investment in fertilizer process plants.

Usually these two functions are dealt with separately although not necessarily independently from each other. The first stage may involve another economic sub-sector i.e. petroleum industry in the case of gas and naphtha as feedstock for nitrogen fertilizers, mining industry in the case of phosphate fertilizers etc.

The typical cost structure of fertilizer process plants usually comprises the cost of technology, equipment and civil engineering/erection work pertaining to all production and auxiliary equipment, service implements, spare parts and tools, identified together as battery limits and off-site facility within the plant boundary (inside the fence). The cost of components comprising the above may be referred to as the cost of the technological structure of the plant or the turn-key plant cost (see annex II, table 1).3/

2.1.1 Cost elements of a fertilizer project The capital cost of fertilizer projects in general consists of the following items:

3/ UNIDO Fertilizer Manual (Development and Transfer of Technology) Series No. 13. More details can be found in UNIDO's "Manual for the Preparation of Industrial Feasibility Studies" (ID/206). This term should not be mixed up with the 'turn-key contract' which is a form of contractual arrangement for plant implementation.

i. Battery limits: Plant battery limits usually comprise all the process equipment erected and ready to operate when supplied with specified feedstock and utilities. The total investment of battery limits comprises:

- cost of principal equipment (critical equipment) i.e. columns, reactors, furnaces, compressors, and all other unit processes;
- cost of secondary equipment, including structural metal work, piping system, instrumentation, insulation, electrical installations etc;
- cost of civil engineering and erection work. Battery limits costs may be estimated separately for ammonia, urea, phosphoric acid and sulphuric acid plants as well as granulation plants of finished products.

ii. Off-site facility (supporting and auxiliary units)

This consists of the various equipment and installation necessary for an efficient operation of the plant erected for ready utilization, e.g.

- utilities: production units and/or distribution systems for electricity, water, fuel and compressed air needed by the plant(s),
- feedstock and products storage facility and handling system,
- laboratories and maintenance facility,
- internal roads, communication and material transfer system,
- treatment of effluent and waste system,
- civil engineering and erection work for all these items as well as relevant industrial building, offices.

iii. Preliminary/pre-operation (pre-production) activities

This item includes in addition to the turn-key plant cost (as described in 2.1 above) one or more of the following items, depending on the scope of the project in question:

- feasibility study (including necessary preliminary or detailed investigation),
- site development

- training of operating, maintenance and supervisory personnel,
- preparation for start-up activities (including the initial loading or the first charge loading of the plant as well as expenses associated with trial runs of individual units),
- interest on money spent during construction,
- all indirect site and transport costs of material and equipment used during construction (including those procured on a temporary basis), insurance and fringe benefits for expatriates during construction and commissioning period etc.

iv. Contingencies

This represents exceptional cost elements arising for different reasons while work is in progress and not accounted for at the formulation/planning stage, i.e. delays caused by strike or adverse weather conditions, technical modifications or changes in the scope of work, price escalation, etc.

While the above major cost items represent the core of the capital investment in a normal situation, the total project cost particularly in developing countries may include the following items:

- working capital (especially when a tied loan is involved),
- out-of-plant boundary (essential) infrastructure; roads and railroad sidings leading to the plant fence, harbours and/or extra piers, waterways jetties for handling procured equipment, electrical sub-stations outside the fence (power station not solely for the plant), etc.,
- housing units and related social infrastructure,
- training of marketing personnel, design construction engineers, etc.,
- technical and/or marketing management for a certain period after commissioning and during commercial production.

2.1.2 Principal cost components of a fertilizer plant

The exact cost structure of fertilizer projects varies considerably with location and scope of work among several other factors. The first two cost items mentioned above represent the turn-key cost of a fertilizer plant erected and ready for operation in a particular location. The basic or principal cost components of these two items include:

i. Software technology

The cost of technological services management in conjunction with the following is also a software function which could be conducted either independently or be included in a turn-key contract:

(a) Front-end engineering, process engineering (including know-how and license fees),

(b) Detail engineering

(c) Project management which involves such activities as:

- procurement
- expedition and inspection
- construction supervision
- monitoring and cost control
- commissioning
- training
- planning and co-ordination
- feasibility study (including surveys and field investigation)

ii. Hardware technology

The cost of physical items excluding transportation charges and taxes/custom duties:

(a) Plant and equipment
   - Major (principal) process units plants
   - Others (auxiliary plants, equipment and material) including structural steel and cement, pipe fittings, nuts and bolts, etc.

(b) Pipings, electrical equipment, instrumentation equipment etc.

(c) Spares for all major equipment.

These items could be divided into:

- inside battery limits
- outside battery limits (off-sites).

iii. Construction

This component usually includes the cost of manpower, tools and construction equipment for

- site preparation
- civil engineering work
- mechanical engineering work (erection)
- piping work
- electrical, instrumentation and insulation installation and connections, etc.

Other cost items usually ascribed to the above-mentioned three principal cost components and which are influenced by the location of the plant include

- custom duties, port fees, excise or sales tax imposed on locally purchased materials
- interest and financing cost.

All cost components are usually split up into:

- local currency and
- foreign exchange (usually split up between hard and software technology).

The three basic cost components are very much interrelated and their complementarity when stripped of all other costs including location-rel cost items and contingencies could be used as a practical basis for cc g project costs in different locations. However, it should be noted that . .e cost of construction varies from one location to another. The absolute figures for these basic cost components include overhead and profit of the contractor(s) undertaking the task of executing the project. Cost elements covered by contingencies are usually related to uncontrollable or unforeseen items at the stage of project formulation, cost estimation or contracting such as:

(a) Variation in the rate of exchange,

(b) price escalation due to domestic or international inflations

(c) risks related to:

- delays,
- replacement/repair work in case of equipment failure,
- possible change in scope of work,
- poor management,
- labour problems,
- government policies and regulations,
- political upheavals etc.

Elements of the three principal cost components cannot be affixed a certain percentage. However, an approximate range could be assigned to them once the location and its level of development is known. One engineering contractor figured the breakdown of investment in a fertilizer plant, in normal conditions and in a fairly developed location as follows:[4/]

15 per cent for software technology (not including training or feasibility study)

75 per cent for equipment and construction

10 per cent for normal freight plus provision for risks.

A more detailed breakdown of cost components for an ammonia/urea complex is summarized below for a turn-key plant in a developing country with modestly industrialized infrastrusccture.[5/]

4/ UNIDO "Capital Goods for Petrochemical and Fertilizer Industries in the Developing Countries", Sectoral Studies internal document, (1979).

5/ Supplied by a contractor bidding for a job in a developing country.

	Cost item	Percentage within each cost item	Percentage of total cost
i.	Software	100	12
ii.	Hardware	100	49
	Main process units	77	
	Off-site equipment	21	
	Spare	2	
iii.	Construction	100	29
	Civil work for process units	14	
	Civil work for off-sites	4	
	Mechanical erection	68	
	Construction tools	9	
	Operators	5	
iv.	Others:	100	10
	Buildings	40	
	Freight and Transportation	60	

On a battery limit basis the 90 per cent portion of the investment (i, ii, and iii) specified above may comprise 50 per cent as the cost of principal and secondary equipment and 40 per cent for site, installation and erection cost. The above-mentioned cost does not include taxes/custom duty and interest on borrowed capital but it incorporates the overhead and the profit of the contractor.

All cost elements which are attributed to the scope of work and to the items related to location and financing are very much dependent on the capabilities, sincerity and interest of the different parties involved in the formulation and implementation of the project.

2.2 Execution functions (detail of major activities determining the plant cost)

In determining the cost of the plant, each of the principal components discussed earlier (software technology, hardware technology and construction) must be computed. To achieve that, the execution functions related to these components need to be detailed in order to identify the relevant activities required for that particular project according to its scope and definition.

In general the main activities contained in various project execution functions can be calculated or estimated once the scope of the project is defined. However, the cost of each activity may vary between different projects because of several other factors, such as management capability, contractual modalities etc. which lead to cost escalation and/or time overrun.

2.2.1 Engineering

The overall engineering function involves the direction and co-ordination of relevant activities in different areas of work:

- process design, including flow sheets
- mechanical design and specification
- system engineering, including job design
- specification for storage systems
- loadsheets/basic engineering data for control instruments, ancillaries, utilities, etc.
- data sheets, giving design criteria for special equipment and supplementary functions
- civil engineering design
- supervision of construction.

It is to be recalled that some engineering activities will be carried by engineering consultants, others by vendors, main contractors, sub-contractors and process licensors. For equipment, particularly package equipment, consultants/construction contractors will present specifications, analytical and mechanical designs for vendors.

2.2.2 Procurement

Procurement is the process of purchasing, expediting, inspecting and shipping material and equipment in the quantity and according to the quality specified by the engineering function for delivery at the time specified on the job schedule. Thus an important task in project implementation will be to optimize the utilization of all procurement resources within the approved budget.

For efficient performance and better results, extensive knowledge of world-wide market conditions is a very important asset, together with up-to-date experience and knowledge of major suppliers, particularly for critical fabricated items, machinery and bulk material. This will also include full awareness of the codes and regulations applicable to material and standard fabrication and techniques.

2.2.3 Construction

There are two major modes followed in the execution of a construction job: first, departmental execution, whereupon the owner/consultant management is assigned to supervise a construction team or teams and/or sub-contractors to carry out the work assisted by a few hired technicians and experts for specialized tasks; second, field operations which are carried out by one main constructor who hires his own sub-contractors and teams as needed with or without the approval of the owner. In either case, support for specialized work may be provided by the vendors' servicemen. Inspection of work quality is usually carried out by the consultant or by a third party (outside specialized agency).

The most important activity in the construction function is management, its objectives being to construct the plant within the defined schedule and estimated cost, while ensuring the desired quality of all parts for optimum operation.

In fertilizer projects, management is usually expected to provide efficient execution and thorough control of the elements of the work and to ensure co-ordination and integration of these elements throughout all phases of execution. In general the project plan defines or describes the major functions pertaining to the realization of the project e.g. engineering, procurement, construction and commissioning.

Construction management usually involves four major activities: construction administration, technical services, sub-contracts and safety programmes.

An important part of construction administration is the administration of field personnel (labour, welfare, accommodation etc.), relationship between sub-contractors, industrial relations in general etc. The other important task is field cost control.

The technical service activity involves various tasks:

i. Construction engineering: which deals, among other things, with field work specifications (welding, etc.), inspection procedures, warehouse and office accommodation, availability of utilities for work, etc.

ii. Planning and scheduling: defining the duration of construction with master schedule and critical path diagrams, identifying equipment/material delivery periods, loading of manpower by class and craft, checking actual job progress against bar charts, etc.

iii. Building-up of construction cost for intensive cost estimates.

iv. Integrating all class activities: to permit the establishment of an overall construction progress curve which can be used in verifying job progress and in defining mechanical completion and start-up dates; manpower loading for each class of work, required material delivery sequence, adjusted schedules and incurred changes, work achieved expressed as budget hours, etc.

2.2.4 Commissioning

It is the process of preparing the plant for production as quickly as possible insuring its running at maximum capacity. This requires that the personnel assigned to its operation, maintenance and technical support be fully trained. The cost of training a client's (purchaser/owner) personnel is usually debited to the overall technology cost.

Commissioning is an operation which can only start once considerable and advanced preparation and start-up planning have been done to get the plant ready to operate. Some of the typical operations have to be carried out about

6 months prior to charging the feedstock. For complex-series plants, as is the case for fertilizer projects, this period can be longer, extending to 12 months at times. By then, the technologists, operators and maintenance personnel have had their training and are ready to take over and assume their roles.

Pre-commissioning involves "dummy" run of individual sections. This comprises test running[6/] of moving equipment but initially without any feedstock. In case of a pump, for instance, water may be used as a testing fluid even though the pump is designed for other applications.

When the plant is ready to take in the feedstock, a sequence start-up is then taken in hand and after commissioning has proceeded successfully, the product begins to appear at the far end. However it must be noted that any plant, no matter how experienced the contractor may be, does run into operating troubles, the so-called teething troubles. Their nature varies from plant to plant and there can be no set manual to prescribe solutions. In each case, however, considerable experience and ingenuity is required apart from "cool thinking" and the situation must be studied in depth to come to the right solution.

Usually the overall cost of this function is incorporated in the technology cost. But sometimes certain pre-operational cost items are charged independently (i.e. initial charge-load of the plant, training cost, cost of failure, etc.).

It is important to point out that another function is usually added in the case of developing countries: preliminary investigations for cost estimation in relation to the above mentioned functions. Sometimes preliminary or detailed investigations are carried out within the context of a feasibility study. The cost of this combined activity is then absorbed in the overall cost of technology. Often however, as in the case of this exercise, it is treated separately or in conjunction with pre-operational cost.

6/ This is an activity performed prior to the function of putting the plant on stream with "test runs" which are usually related to the optimization of performance and performance guarantees.

2.3 The principal actors (parties) and their role in determining or influencing the capital cost of fertilizer projects

Although the activities of the main functions detailed in the last section determine the bulk cost of a fertilizer plant and any overrun incurred, there are other non-technical cost elements ascribed to those functions which may be responsible for some overrun. Notwithstanding the effect of force majeure or uncontrollable incidents, the factors usually responsible for overruns can be attributed to the behaviour, strategies, and management capabilities of different actors involved in the implementation of a fertilizer project.

The principal actors involved in the construction of fertilizer plants are: the client (owner), the contractor and the financial institution. Other actors who may not be involved directly, but could share the responsibility for any overrun are the consultant, the vendor, the licensor, and the State.

The role of the various principal actors in the implementation of fertilizer projects is discussed below:

2.3.1 The client (owner/purchaser): In developing countries, the owner can be the State, a private firm, a mixed sector company (public and private sectors forming a joint venture) or a joint venture with a foreign company as shareholder. The efficiency and performance in establishing a fertilizer plant is usually influenced by the level of development of the country in question and the technological capabilities of the management assigned to administer the various functions. In general, there are three modes in discharging these functions:

(a) When management has had good experience, especially after one or two equivalent/similar projects. In this case, a departmental execution is expected using hired staff and/or sub-contractors to perform defined tasks. Negotiated sub-contracts for supplies and services may be on a lump sum or an open cost (semi- or fully reimbursable) basis.

(b) When management has sufficient experience in reviewing and in following up similar jobs, but for some reason, like scarcity of local manpower (especially when there is a concentrated developmental programme going on internally), the owner prefers to engage a principal contractor to handle the job. The main function of the client management is then to supervise the work of the principal contractor and deal with him directly.

(c) When the owner has no experience and does not have full management capability at the time, full supervision is needed (this is usually the case with the first major job or when the country is at an early stage of development). The client hires an engineering consulting firm to deal with all contracting activities on his behalf.

The following remarks which among others deserve being emphasized concern the owner's responsibility with regard to cost overrun:

i. Incomplete planning and formulation exercise may bring about incorrect cost estimates and unrealistic schedules.
ii. Vague invitation to bid can result in a vague response and extreme difficulty to compare bids. This is the case in a first project when the owner has no competent consultant or project manager.
iii. Negotiating a contract is an art that involves considerable skill and technical know-how. If the owner is not well prepared technically, or does not know in advance the background of the contractor, (probably through a pre-qualification exercise), he may end up with an unsuitable contract that brings about overruns in cost, delays, low standard and probably tedious arbitration. The owner's capability in negotiating a contract involves also his knowledge of the type of contract he wishes to have in the light of his realistic assessment of the local situation and his technical capacity, realizing the cultural difference between his staff and the contractor's team.
iv. To administer and carry out the execution of the plan, an effective management is needed. Failing to have an efficient project management, the owner may not be in a position to set and follow up on such important parameters as: co-ordination procedures, schedule, cost control, monitoring with the view of affecting speedy corrective measures in connection with deviations from the scope of work.

v. Delegation of authority and elimination of routine administrative procedures constitute a major basis for efficient project management in respect to cost overruns.

2.3.2 <u>The principal contractor and/or the engineering company</u>

The principal contractor has the main function to co-ordinate and control all activities related to project execution (engineering, procurement, construction/erection and commissioning). The contractor may adopt any of the following modes of operation:

(a) Full utilization of his head office to perform all activities and the assignment of his own field office for direct and full engagement in all phases of the execution programme.

(b) Overall management and co-ordination of all activities which may be sub-contracted to specialized firms, vendors and engineering companies.

(c) A combination or variation of the two modes mentioned above.

Sometimes the mode of execution outlined in (b) above is assigned by the client to an engineering company who will perform on a management contract basis, engaging sub-contractors and supervising their work while following up on purchasing/training/commissioning, etc.

The main functions of the engineering company is to carry out the process engineering (unless this activity is performed by the process licensor or by a specialized engineering outfit), the mechanical engineering and detail engineering design (including those for buildings and other civil engineering work, pipework, electrical facility etc.). Another important function of the engineering company is to carry out detailed studies on the feasibility of the project and to draw up tender specifications. In many cases, as a consultant to the client, the engineering company will be engaged in selecting (and negotiating the contractual terms with) the principal contractor or sub-contractors. This task involves the evaluation of contractor/vendor bids and at a later stage the follow-up and supervision of all relevant activities on the owner's behalf.

The most important asset of the principal contractor is his capacity and experience in technical and administrative management. Within the framework of a turn-key type of contract, it is the principal or the general contractor who assumes all responsibility for the design and construction of the project. In some cases, he may have to assume other activities related to the financial function, for example, arranging and/or managing credit facility.

Quite often international chemical engineering companies which are usually from industrialized countries, especially the most capable ones, act as prime contractors instead of just being the client's consultant. Some of them have some relationship or legal ties with manufacturers of equipment goods and/or are engaged in process development and licensing activity themselves. This can influence their decision in respect to the selection of technology for the project where they are called to act as consultants.

Apart from the high overhead and profit incorporated in his bid, the contractor may place high contingencies against probable risks or when his liability in conjunction with performance guarantees is severe. This will tend to raise the contract cost, causing escalation. Other incidents may be associated with the capability and the integrity of the contractor.

Some contractors, especially those linked with licensors and vending shops may select an obsolete technology or procure equipment which necessitates frequent spare parts replacement. This may involve the purchase of large stocks or entail a higher expenditure with the placing of frequent orders and at a high price since such parts are generally of proprietary nature. The situation is even more critical during commissioning, when large stocks of spares, frequent failures, delays due to replacements and repairs, and waste of feedstock and auxiliary inputs take place.

The estimated cost given by engineering contractors in tenders is not always realized while placing the actual purchase orders. This may have no serious repercussions on the owner in the case of a turn-key lump-sum contract, but for open-cost contracts, the cost overrun can be significant. Even when a clause is inserted in an open-cost engineering contract for overruns (e.g. ceiling price), it can be couched in such words and phrases and with so many conditions that at the end the contractor gets away without sharing the cost overruns. Similarly, it is very rare that a penalty clause incorporated in every purchase order for late deliveries is ever invoked.

Some contractors may place their bids with a minimum of investigation and preparation since such a task entails high expenditure that will not be recovered if the contractor loses the tender in keen competition. This can result in a waste of time during negotiations, or sometimes in a not too clearly defined contract with numerous and vague conditions and in which case penalties for delays and excessive costs do not outweigh the losses of the inexperienced client.

Other sources of cost overrun for which the contractor may be partly or indirectly responsible can be viewed as follows:

i. Some contractors will exchange notes on one particular project to decide on and pave the way for a pre-selected contractor from among the bidders even at a higher than normal cost.

ii. Training and retraining of operators and personnel may be considered as an important task to be carried out by contractors. But the shortfall in proper training can be traced to the methodology employed by the contractor if close consultation with the client or his knowledgeable representative has not taken place. In some cases too much lecture-room activity is allowed rather than in-plant operation, particularly if commercial production is on and a minimum interference or secrecy have to be attained.

2.3.3 The vendor

Suppliers of equipment and material for the fertilizer projects are usually companies which manufacture implements for other areas of work that include sometimes distinct engineering activities. Some of the manufacturers rely on the outside contracting/engineering firms to supply them with design and specifications, while others have developed their own engineering capacity (directly or through subsidiaries) to carry out this task and/or to handle contracts as a whole.

In some instances, vendor shops have to rely on information and design jobs with special operating techniques which are subject to a patent. Then the most stringent modes of co-operation are expected between process engineering licensors, engineering/contracting firms and vendors in order to allow a smooth operation of the contract for the benefit of all including the client.

Well known vendor shops, particularly those specialized in certain critical implements such as gas compressors and turbines, special types of reactors like reformers are few, hence very much in demand and sometimes have a very tight delivery schedule. Thus aside from the quality of their work, a client may be penalized unintentionally if he happens to place an order during peak load time at the vendor's shop. It is here that at an extra charge higher shop capacity and faster action on an order can be induced, in order to avoid overruns associated with delays. Of course associated with this function will be higher transportation and on-site delivery cost to meet the deadline, a feat usually handled in co-operation with the vendor but subject to other factors which may involve other actions.

2.3.4 Patented process licensors

While a great number of items and machinery can be supplied in accordance with a commercial agreement, many are subject to specific conditions not only in connection with performance but also with their design and technology proprietary conditions and stipulations.

The phenomena of polarization of supply for certain items and material required for fertilizer plants may be noticed. Processing units and compressors are good examples where a limited number of suppliers provide the industry on request. The same is true in the case of electric generators and steam turbines, instrumentation etc. In most cases, the patent holder will make his own conditions pertaining (and subject) to many items and factors including financial arrangements, technological services (e.g. spares, operation and inspection) that might burden the project with cost higher than usual when it comes to supplying developing countries. This is very true in the case of countries with financial constraints or low technological capacity. The latter case arises when the supplier feels that his liability for performance guarantee is too prohibitive not to have his costly constant supervision and maintenance during the guarantee period. Of course, this is the case when the patent licensor is linked to the vendor in some form. As a matter of fact in any contract, severe liability conditions usually render an added cost whether they are tied to performance or schedule.

The case of package design in relation to a patented technology is another issue that might place some burden on the fertilizer project owner. Sometimes the license holder specifies not only the vendor shop but also the contractor to carry out the work. The secrecy agreement that includes severe conditions with respect to modification and/or usage as a base for future jobs by the same client limits the freedom of the latter, even when improvement is essential to save on operating cost.

The last but not least factor to be explored in this respect is the socio-political factor, since in some cases the secrecy agreement is influenced by a political decision that may limit the choice of vendors/contractors on the basis of their nationality and affiliation rather than just their technical, financial and managerial capability.

The processes for fertilizer chemicals are now well known and, for basic fertilizer compounds, no longer protected by licenses. Nevertheless, the process engineering remains complex. The competition between engineering companies in this respect is based mainly on their capability in handling fertilizer projects in a particular size range. For some, research and development directed toward increasing plant capacity might offer monopolistic stature in the market. Furthermore, the cost of R & D activity would be debited to the new projects even when these projects are not benefiting from that particular technology.

2.3.5 Financing institutions

For the developing countries, financial credit for fertilizer projects may be supplied by private banks, agronomical/industrial groups, or by the

State. An important credit facility to many developing countries is that associated with all or some of the foreign exchange portion of the investment. Almost all industrialized countries exporting capital goods have established systems for export aid involving any of the following modalities:

- State to State loans,
- export credit granted directly to public or private organizations concerned,
- facilities for financial institutions to offer low fixed-rate credits, e.g. preferential rate discounts, reduced interest rates,
- insurance and guarantees covering credits offered by exporters and banks against commercial (and political) risks, inflation, exchange rate changes etc.

For all these arrangements certain conditions are imposed depending on the developing country involved, the merit of the project and its competitiveness in relation to the industrialized country's relevant export materials, volume of export in relation to the overall project requirements, other parties involved in the project, technological interest of the exporting firm(s) and their capabilities etc.

Some developing countries may seek financial credits which require the participation of several financing institutions. Often when no principal institution takes on the responsibility of the financial arrangements, prompt payments to the suppliers and the contractors involved in the project may not be effected resulting in delays and problems. A dynamic relationship between financing institutions and engineering firms and vendors is necessary to expedite the work.

2.3.6 The State

To ascertain the involvement of the State in the establishment of fertilizer projects, it is imperative to distinguish between the role that the government of an industrialized country may play in influencing the cost and that of the government of a developing country.

The government of a developing country is sometimes the owner or co-owner of a project; hence it is a client to whom services will be rendered by the other actors. But in general the government of a developing country is responsible for all developmental activities including the general system of economic and social infrastructure or the co-ordination of all promotional activities including the financing of development of industrial projects. In either case the government of a developing country is directly involved in project implementation. On the other hand, the government of an industrialized country is involved in the financing or sometimes technological facilities which are made available to developing countries.

i. The government of the developing country. In this case, the responsibility of the State in bringing about unintentional cost escalation and overruns may be identified with:

(a) Poor project planning and inadequate implementation procedure (para. 2.3.1),

(b) general level of development of the country, particularly with respect to inadequate socio-economic infrastructure,

(c) state policies such as taxes, port fees, foreign exchange, imports regulations, technology policy, indigenization policy etc., which may affect the project cost

ii. The government of the industrialized country. The involvement of an industrialized country in the implementation of fertilizer projects in developing countries is usually indirect and it can be of various forms:

(a) When a State-owned contracting firm is involved in a consultancy activity or in a supply/engineering construction activity.

(b) When a country loan is granted by the State to a developing country.

(c) When the State has the prerogative in determining the level of its export and procedures pertaining to the transfer of technology to other regions

(d) When the State provides cover for the risk of contractors undertaking a job (with or without financing facility).

The responsibility of the State (government) of an industrialized country in bringing about higher cost of fertilizer projects established in developing countries can then be attributed to one or more of the following, depending on the degree and nature of its involvement:

- complicated administrative procedure with regard to management of the State-owned contracting firm,
- conditional or tied-up loans that limit the choice of contractors and sources of equipment,
- restrictions made with respect to patented technology (usually design package) to be handled for fabrication and/or utilization by expatriate firms from other regions, as well as conditions imposed on product marketing and/or use of patented technology in a repeated job,
- sanctions on guarantees to cover risk for contractors of its nationals working in certain regions considered as unfavourable by the government of the industrialized country.

3. CAPITAL COST OF FERTILIZER PLANTS

As is the case with most basic chemical processing plants, the capital cost of fertilizer plants is usually influenced by the scope of work. Important components of the scope of work are related to the feedstock and plant capacity.

For fertilizer projects, the choice of feedstock is made after considering its opportunity cost and other uses, while the capacity choice follows market trends and potentials. The combined effect of feedstock and capacity factors cannot be overlooked or overemphasized. R and D activities pertaining to fertilizer process units have been directed mainly toward achieving economy of scale.

The cost of R and D activities will escalate the capital cost of fertilizer plants not only in terms of licensing fees for new patents and relevant and necessary training programmes (as part of the software) but also with respect to the innovated pieces of equipment dictated by the patent both for battery limits and off-site facilities. However, in recent years, the influence of new development on the capital cost of fertilizer plants has not been as significant as the effect of inflation. On the other hand, the additional cost ascribed to technology items for projects built in developing regions has been appreciable.

The following sections examine the capital cost of fertilizer plants with particular reference to the effect of feedstock and capacity, being the two major aspects of technology that affect the cost of battery-limit and the turnkey plants.

3.1 Ammonia plants

Ammonia production is a highly capital-intensive operation. Technological developments in recent years, especially with new designs using centrifugal compressor, resulted in higher capacities at lower production cost. In terms of feedstock, ammonia production by steam reforming of natural gas, naphtha and other light hydrocarbons led to even better economics. However, the fact remains that although technological development and increase in scale resulted in a steady decline in ammonia production cost, the sharp increase in feedstock and construction cost since 1972 has maintained production cost at a high level, particularly in regions where subsidized or low priced feedstocks do not exist. It is to be noted that the increased construction cost was caused by:

- increased material and labour cost, partly due to abnormal inflation trends,
- need for energy recovery equipment,
- physical requirement of more stringent pollution control regulations.

Some studies made on the subject implied that cost-saving techniques in ammonia plant engineering and construction industry should have offset rising labour and material cost between 1974 and 1978. But it is unlikely that greater efficiency will continue to offset rising construction cost in the future.7/ This does not mean that technological improvements are not expected. Furthermore it is unlikely that improvements during the late 1970s could have reversed the upward trend of rising construction cost all over the world. In this respect, of major interest have been further increases in scale with the view of achieving more cost saving. But such achievements would have to be assessed in the light of increased distribution cost.8/

3.1.1 The effect of capacity on capital cost

By 1978, the world's largest single ammonia plant was rated at about 1,600 T/D. Larger capacities have not been popular although designs were available for 2,000 T/D plants, the economies of which have not yet been substantiated. Scale economies which have been very popular since the mid-1960s or since the use of the centrifugal compressors start with 550 T/D.

7/ Nichols, D.E. et al: "Assessment of Alternatives to Present-Day Technologies with Emphasis on Coal Gasification". Paper presented at Sleenbock Kettering International Symposium on Nitrogen Fixation, Madison, Wisconsin, 1978.

8/ Economy of scale and the merits of small (mini-)fertilizers is a subject of another UNIDO paper to be published soon.

Three standard ammonia plant designs have been highly in demand since the early 1970s: 550 T/D, 900-1,000 T/D and 1,300-1,500 T/D. Information received from engineering construction firms in 1978[9/] with respect to the economy of these plants provided the following rough capital cost estimates for natural gas-based plants in a U.S. Gulf Coast location:

Capacity metric ton/day	Battery limit cost $ million	Cost per annual ton[10/] of ammonia capacity
550	35	193
1 040	48	140
1 360	69	154

It can be seen from the above presentation that the 1,040 T/D capacity is the optimum economy of scale.

The majority of the plants built during the past decade have been in the 900-1,040 T/D capacity range. The 550 T/D capacity is regarded as a common economic minimum scale for plants using centrifugal compressors (lesser capacities are also used), a type of plant usually selected for small markets. The larger capacity plants (over the optimum size) are usually selected where site development costs are high. In the latter case, thoughts have been directed toward having two-train plants of 900 T/D capacity rather than one larger capacity train plant (1,500 T/D or more).

The above mentioned remarks regarding the relative increase in cost for different standardized capacity plants hold true for all plants having steam reforming units irrespective of the feedstock (natural gas, LPG, naphtha, refinery gases, coke-oven gas, and methanol as a source for methane, the major hydrocarbon used for ammonia synthesis). However, for hydrocarbons heavier than naphtha i.e., fuel oil used for ammonia production, a partial oxidation process is imperative. Such a process entails higher capital cost since an air separation plant is required to provide the necessary oxygen and nitrogen.

9/ UNIDO: Fertilizer Manual, 1980 (Development and Transfer of Technology, Series No.13).

10/ Assuming annual capacity = 330 x daily capacity, same price for gas as feedstock and other operational factors constant.

There are few plants built to produce ammonia by partial oxidation of heavy oil or coal. As a matter of fact most of the existing partial oxidation units have been designed to use heavy residual oil from specific refining processes, the main aim being to achieve higher recovery of valuable lighter fractions. The heavy fractions usually have higher sulphur contents and thus need expensive equipment for anti-pollution reasons. This will vary from one type of crude oil to another, so that a tailor-made design is necessary. This is why designs for partial oxidation processes and equipment have not been standardized. Incidentally, such plants are usually tied up to large refineries.

3.1.2 The effect of feedstock on capital cost

Natural gas has advantages over all other feedstocks, wherever available of course, not only because of its process technology but also because its extraction/production and transportation activities cost less. In comparison to natural gas, the technology of other feedstocks may present a higher cost by a factor of 1.14 for naphtha, 1.6 for heavy oil, and 2.00 for coal.[11/]

Wherever natural gas (associated or unassociated) is available, gas-based ammonia plants are the most economical, provided the investment for exploration and gas recovery is not added to the capital cost of ammonia plants. It is logical to assume that such additional cost will not be incurred because gas production is mainly associated with energy needs,[12/] and only the cost of transferring the fluid (gas/liquid) can be added to the cost of ammonia plants, or at least charged to the price of feedstock.

At present feedstock prices constitute a major portion of ammonia production cost (over 50 per cent of total production cost in some areas). Of course the cost of feedstock is closely related to the volume of reserves in any location and to the economy of its alternative uses. In general, the

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11/ Based on information made available to UNIDO in the preparation of the Fertilizer Manual.

12/ About only 3 per cent of the total world production of natural gas destined to ammonia production, and about 0.5 per cent of the existing world refining capacity used to provide feedstock for ammonia processing units.

opportunity cost of natural gas, the most widely used feedstock (about 71 per cent of the world-wide ammonia feedstocks, followed by naphtha with about 15 per cent), favours its use in oil-rich developing countries located rather far away from high energy consuming markets. The next best feedstock is naphtha if ammonia plants are located close to oil refineries.

Low-cost natural gas available in developing countries usually exists in remote locations where construction cost is usually high. Some studies have indicated that the cost of ammonia plants in such locations can be higher by 50 per cent than that encountered for similar plants in industrialized locations. This is due to the need to provide auxiliary and supporting facilities or to improve the existing infrastructure, in which case the added cost will be charged to the plant.[13/]

In oil/gas-rich developing regions, higher than usual capital cost due to added auxiliary and supporting facilities may be encountered if less elaborate heat and energy recovery facilities are used, since the feedstock cost is low. But the more effective way to tune down the effect of high capital investment cost is by improving capacity utilization.

3.1.3 Capital cost of ammonia plants of standardized capacity

For the purpose of establishing a basis for comparing capital cost of ammonia plants, a 1,000 T/D ammonia plant is considered in this study. Based on technical information and proper cost estimates for such a plant capacity on the U.S. Gulf Coast, battery limits of a natural gas-based ammonia plant would have an investment cost of $50 million and the turnkey plant cost would be $75 million during the period 1977/1978.[14/] Not included in this estimate are the following:

13/ UNIDO Fertilizer Manual (Development and Transfer of Technology, Series No. 13).

14/ Ibid.

- interest on capital during construction,
- import taxes or custom duties,
- feasibility studies/training programme/start-up expenses,
- contingencies,
- power generation facility, water facility, etc.,
- infrastructure such as housing, roads/harbors outside the plant, fence, etc.

For other ammonia plant capacities with similar provisions and conditions, the estimated cost of a turnkey plant is:[15/]

$52.5 million for 550 T/D plant
$99.0 million for 1,360 T/D plant.

According to the same source, a 1,000 T/D turnkey ammonia plant in the same location, during the same period but with different feedstocks should cost as follows:

Naphtha based plant	$ 85.5 million
Heavy oil based plant	$120.0 million
Coal based plant	$150.0 million

To use the above as a yardstick in estimating ammonia project cost in different locations, not only the location factor on investment (and consequently on production cost) has to be considered, but also the escalation since the base year (1978) and the variation in capacity. For instance, a battery limit investment cost for a 1,000 T/D in a said location in 1979 was estimated at $60 million (or a turnkey plant estimated at $90 million).[16/]

15/ UNIDO Fertilizer Manual (Development and Transfer of Technology, Series No. 13).

16/ Ibid.

3.2 Urea plants

Although ammonia is the most important basic material for nitrogen fertilizer, its direct application as fertilizer is surpassed by that of its derivatives, e.g. urea, ammonium nitrate, ammonium sulfate, ammonium phosphate, particularly in the developing regions. Urea is the most important form of nitrogen fertilizer produced in the developing countries.

3.2.1 Capital cost of urea plants

Most common urea plant capacities range between 500 and 1,700 T/D. Battery limits estimates made in 1978 place the cost of such plants in western industrialized regions in the range of $13 million to $27 million respectively.17/ The same exercise calculates the production of bulk urea to cost approximately:

Plant capacity (T/D)	500	1,000	1,700
Plant cost ($ m)	19.5	31.0	40.2
Storage facility ($ m)	1.5	3.0	5.1
Total investment ($ m)	21.0	34.0	45.3
Production cost ($/ton)	117.8	11.22	105.01

3.2.2 Capital cost of ammonia-urea complex

The estimated turnkey plant cost of a 1,000-1,725 T/D gas-based ammonia/urea complex in developed regions (US Gulf Coast) was computed in 1978 as follows:18/

Ammonia plant	75.0 $ million
Urea plant	40.2 $ million
Storage facilities	5.1 $ million
Total	120.3 $ million

17/ UNIDO Fertilizer Manual (Development and Transfer of Technology Series No. 13).

18/ Ibid.

In developing regions, the same project would encounter a much higher cost. It was suggested that such a project would cost over $300 million if it was established in a remote location in a developing country and that about half this amount would be related to the construction of the plant, its auxiliary and supporting facilities, while the rest would be for other items and activities, such as additional infrastructure, housing colony, ocean freight/local handling etc.19/ Cost items which may be encountered in all regions but to a much lesser extent in the industrialized countries include:

- ocean freight/local handling
- physical contingency
- escalation during a 42-month construction period
- interest during construction
- pre-operational expenses.

A 1979 study suggested that a complex similar to the one mentioned above would cost about $150 million in an industrialized country, $230 million in a developing country with fairly good infrastructure and $320 million in a remote location.20/

In another study (1975), an estimate was given in connection with the construction of a fertilizer complex, indicating the high magnitude of investment in developing countries in 1975.21/ That included estimates for turnkey plants (with utilities and storage facilities) as follows:

1 000 T/D ammonia plant:	$107 million
1 720 T/D urea plant:	$67 million
600 T/D phosphate plant:	$125 million

A more recent estimate was given for a complex to be constructed in a developing country with modestly developed infrastructure. The complex

19/ UNIDO Fertilizer Manual (Development and Transfer of Technology Series No. 13).

20/ W.F. Sheldrick "Investment and Production Cost for Fertilizers", a paper for the 7th Session of FAO Commission on Fertilizers (Rome, January 1979)

21/ UNIDO, ID/WG.236/2: Supporting information on eight issues which might be selected for consideration at the First Consultation Meeting on the Fertilizer Industry.

concerned comprises a 550 T/D gas-based ammonia plant and a 1,050 T/D urea plant. The breakdown of cost items for the whole complex was approximately as follows (in $ million):22/

	Plant	Spare parts	Freight	Construction	Total
Ammonia	68	2	8	29	107
Urea	24	1	2	12	39
Off-site	30	2	3	31	66
Total	122	5	13	72	212

Thus the software and hardware for such a plant would be about $127 million. Construction and freight cost for the complex would be $72 million and $13 million respectively. This represents an estimate for a turnkey plant in 1981/1982 prices.

3.3 Phosphate fertilizers process plants

The two major raw substances for the manufacturing of nearly all commercial phosphate fertilizers are naturally existing phosphate rock and chemically produced sulphuric acid from various sulphur resources including natural gas extracted sulphur, mined or deposit sulphur, and compound sulphur.23/ Phosphoric acid resulting from the reaction of sulphuric acid and phosphate rock constituents, is by far the major source of phosphate fertilizers. Although to a much lesser degree of importance, the runner-up to phosphoric acid derivatives is expected to be nitro-phosphates.

Notwithstanding the direct application of phosphate rocks and the use of other phosphate compounds as a source of phosphate oxides for fertility, the major phosphate fertilizers fall into two major categories:

(a) Fertilizers derived from phosphoric acid. The important ones are:
- Triple superphosphates (TSP)
- Ammonium phosphates, e.g. monoammonium phosphate (MAP), and diammonium phosphate (DAP)

(b) Nitrophosphates

22/ Based on information provided by a consulting engineer to ECWA.

23/ Details on reserves, production, processes and economics may be found in UNIDO Fertilizer Manual (Development and Transfer of Technology Series No. 13).

3.3.1 Capital cost for phosphate fertilizer projects

Capital cost for phosphate fertilizer projects comprise two distinct yet complementary investment mechanisms: one pertaining to phosphate rocks mining and benefication, and the other pertaining to unit process plants and granulation. Investment in phosphate rock mining operations differs according to the location, e.g. open cast mining or underground mining, etc. In the first, site preparation, stripping and mining operation (usually done concurrently), pumping for the transfer of the rock matrix to the benefication plant as a slurry is a very expensive item.

For good quality rock, investment for simple benefication can be below $50 per annual ton of product capacity. For a new mine in a remote location where all infrastructure has to be provided, investment can exceed $200 per annual ton of product capacity.[24/] This is usually the case since phosphate rock deposits are often located in remote and difficult environments where social and development infrastructures need to be established mainly if not solely for the project i.e. housing, power plants, water supply, roads, etc.

The investment cost for mining phosphate rocks in industrialized sites range between $50 and $80 per annual ton product capacity[25/] depending on the quality of the rock and whether in an industrialized or a developing country.[26/] For a developing site, where engineering cost would be rather high and the project encounters additional infrastructure cost, $100-150 per annual ton of product capacity will be required.[27/] In a remote location, the investment for developing a similar mine might reach $450 million of which

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24/ Sheldrick, W.F., "Investment and production cost for fertilizers", FAO sponsored paper presented to the 8th Session of the Commission for Fertilizers, 31 January-3 February 1983.

25/ Ibid.

26/ Morocco was considered in this range along with Florida and North Carolina in the United States.

27/ Assumption is made in respect to an average mining capacity, most likely to be of 3 million tons of phosphate rocks per year.

$250 million might be assigned for essential infrastructure including a long railroad stretch to the site. This would place the investment at $160-167 per annual ton capacity.

The breakdown of the cost of investment in the principal production units for 600 T/D phosphate fertilizers in 1975 (in an industrialized country) was quoted as follows:[28/]

i.	Battery limits:	
	Sulfuric acid unit	$11.6 m.
	Crushing unit	$ 3.0 m.
	Phosphoric acid unit	$15.4 m.
	Granulation unit	$13.3 m.
ii.	Off-sites facility	$59.1 m.
	Total	$102.4 m.

As was the case with ammonia fertilizers, the capital investment in phosphate fertilizers process plants went up very steeply during the early 1970s as compared to the escalation that took place in the latter part of that decade. A rough estimate placed the rise in the cost of investment in phosphoric acid plants between 1970 and 1975 at 32 per cent (average, 6.4 per cent annually) and at 5.7 per cent annually during the second half of the decade.[29/]

In a more recent study investment in a phosphate fertilizer process plant was estimated as follows:[30/] (US$ million 1982 based on a cost estimate of several World Bank assisted projects):

28/ UNIDO "Capital Goods for the Petrochemical and Fertilizer Industries in Developing Countries", Sectoral Studies internal document, 1979.

29/ Based on information made available to UNIDO in conjunction with the preparation of the First World-wide Study on the Fertilizer Industry (1976).

30/ Ibid.

	Industrialized site	Developing site	Remote location
Phosphoric acid: (1000 T/D: 100% P_2O_5)			
Plant investment	123	210	282
Total investment[a/]	153	233	307
Triple superphosphate (TSP) (1200 T/D bulk: 46% P_2O_5)			
Plant investment	39	45	48
Total investment[a/]	62	70	75

a/ Total investment = plant investment + working capital.

In certain areas, especially where sulphur is expensive and price could be a prohibiting factor, nitrophosphate is produced using nitric acid instead of sulphuric acid to aciduiate phosphate rocks. This route, in comparison with the phosphoric acid route, would be competitive in a country where a relatively large fertilizer market exists and more so where cheap domestic sources of ammonia are found. Such a situation prevails mainly in Europe where ammonium nitrate as a fertilizer is also very much in use. Among developing countries only a few are indulging in the production of nitrophosphate fertilizers. But most likely the prospect of pursuing this process further depends on the export potential of that particular country for this type of fertilizer, a situation that usually requires abundance of both good rock phosphates and inexpensive hydrocarbon source for ammonia production.

In view of the above, not much time has been devoted to the evaluation of investments in this type of fertilizer. However, reference should be made to a FAO study[31/] in which a recent capital cost estimate was made for a 1,000 T/D ammonia plant with downstream nitrophosphate plant complex to match. A summary of the FAO cost estimate (in $ million, 1982 prices) follows.

	Plant investment	Total investment
Industrialized site	354	380-386
Developing site	463	510
Remote location	555	614

31/ Reproduced by UNIDO document ID/WG.406/1, October 1983.

4. MAJOR COST ESCALATING FACTORS

Project costs escalate all over the world but the extent of escalation is particularly marked in the developing countries. Various escalating factors will be discussed hereunder in this respect but it should be emphasized that the exact contribution of each factor from project to project and from country to country is not easy to quantify. One way to do so is to have a proper project audited after the project has been completed.[32/]

The major cost escalation factors and their effect on the overall cost may include any number of cost elements as a result of mismanagement of, or problems associated with different project execution functions either because of an uncontrollable situation or due to actors behaviour. A broad discussion of these factors is presented in this chapter.

4.1 Inflation

As a rule, the price of any item increases with time, as a result of inflation. It is therefore only natural that the capital cost of fertilizer projects increases with time. Such an increase should be foreseen and estimated by the owner and the contractor. Both parties stand to suffer if this factor is not taken into consideration.

To predict its impact, an inflation or price index is employed to estimate the increase in cost over a period of years. Ideally the inflation index should be based on actual data for the cost of fertilizers and other chemical process plants and equipment over a given period. However, detailed data are seldom published. Furthermore, there is always the possibility of an exceptionally high rate of inflation locally or internationally as it occurred during the period 1973-1975 when much higher escalation of prices was noticed than could be conceived and built into the estimate of the project during

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32/ The World bank introduced a system of performance appraisal of a project some months after the project is completed. Such an appraisal can be quite objective and realistic if it is carried out by an independent (third) party and if the project authorities are co-operative in furnishing all the relevant information.

the planning stage. In addition, the use of an inflation index to convert prices over a long time span (over a period of 10 years) may not give accurate results.

In industrialized regions, several price indices have been established at the country level for a particular group of implements. Some developing countries have also established price indices reflecting their local conditions. The various indices established were based on different hypotheses regarding the activities and cost of products involved. In the USA, for instance, some of the well known indices are designed to reflect the rate of escalation of specific construction activities, commodities or industrial plants such as petroleum refineries (as is the case with the Nelson Refinery Index). Basic to most indices are material and labour costs; sub-divisions in regard to material (i.e. specific equipment, construction material, etc.), and relevant services (i.e. engineering, etc.) are also considered in some indices.

Various inflation indices in the same country are within range reflecting the escalation trend (Table 1). Still it is important to realize the limitations of their validities imposed by the effect of market forces and technological changes. In order to overcome these limitations, modification and adjustments are needed to suit a particular situation (specific plant). Because of this limitation, the inflation indices established for one region cannot be employed in another region or even in another country of the same level of development. In other words the location factor must be linked or incorporated into the inflation index, otherwise faulty estimates can result (Annex II, Table 2).

Table 1. Comparison of various cost indices
(basis: 1970 = 100) a/

Year	CE plant b/ index	CPI - all c/ items	Earnings d/ in MFG
1971	105	104.3	106
1972	109	107.7	113
1973	115	114.4	121
1974	132	127.0	131
1975	145	138.6	144
1976	153	146.6	155
1977	162	156.1	169
1978	174	167.9	199
1979	190	187.2	199
1980	208	212.4	216
1981	135	234.1	238

a/ Indices predicted for the USA.
b/ Chemical Engineering Plant Index.
c/ Consumer Price Index.
d/ Earning in Manufacturing.

Price indices applicable in the case of fertilizer projects on a world-wide basis were built for the past decade. They appear to fall in the same range as the world price index for equipment, at least in the case of ammonia plants. Compared with the indices most applicable in the USA, there are as expected some discrepencies which are viewed in the following:

	World index	Range of 3	UNIDO's reported indices 33/ Ammonia plants	Phosphoric acid plants
1970	100	100	100	100
1973	-	115-121	124	-
1975	163	139-145	-	132
1976	-	147-155	169.5	-
1977	176	156-169	-	147
1978	193	168-199	-	-
1979	207	187-199	-	-
1980	260	202-216	(200)	(175)
1981	-	(234-238)	-	-
1982	273	-	-	-

(Figures between parentheses are approximate or projected)

33/ UNIDO, "Capital Goods for the Petrochemical and Fertilizer Industries in the Developing Countries", Sectoral Studies internal document, 1979.

4.2 The time factor: project execution period

An important factor that needs consideration when comparing cost of fertilizer projects in different locations is the time factor or the project implementation period. The importance of this factor stems from the fact that the location cost factors involve dynamic values which may change not only during the life of the project but also over a prolonged period of project execution, especially in countries where vast developmental programmes are being pursued or dramatic inflation rates are prevailing.

The completion period for a major fertilizer project may be two to three years in an industrialized country and perhaps three to four years in a developing country. In addition, there can be an additional period of one to two years from the date of completion of the feasibility study to the date of commitment during which time various approvals for relevant activities have to be obtained such as financing, problems related to local and foreign exchange, calling and awarding contracts. Thus the total period may be as long as 6 years from the date when preliminary cost estimates are called and awarded to the mechanical completion of the project. Accordingly, there can be an additional 3-year period in completing a fertilizer project in a developing country compared to that in an industrialized country. This assumes of course that a project in an industrialized country does not undergo the same type of formalities in obtaining approvals and establishing procedures or in awarding the contracts. Notwithstanding the effect of inflation during the extra years and the losses due to commercial production down-time, still there will be cumulative financial costs to be added.

As it has been stated elsewhere in this text, the relationship between the delay in executing a project and the cost escalation can very well be interpreted in terms of inflation.

4.2.1 Time-table for project execution

For medium and large ammonia urea complexes the minimum average time period for engineering, fabrication and erection activities may be 36 months from the day the contracts (main ones) are signed, even in some industrialized regions. (Chart 1)

Except for expansion jobs, small projects and certain, well prepared and managed projects in industrialized regions, an ammonia/urea complex has rarely been implemented in 24 months. There are many cases in industrialized regions where such projects require 30 months if established in a non-green site.

In developing countries, the following time-tables may be applicable when normal and fair conditions prevail.

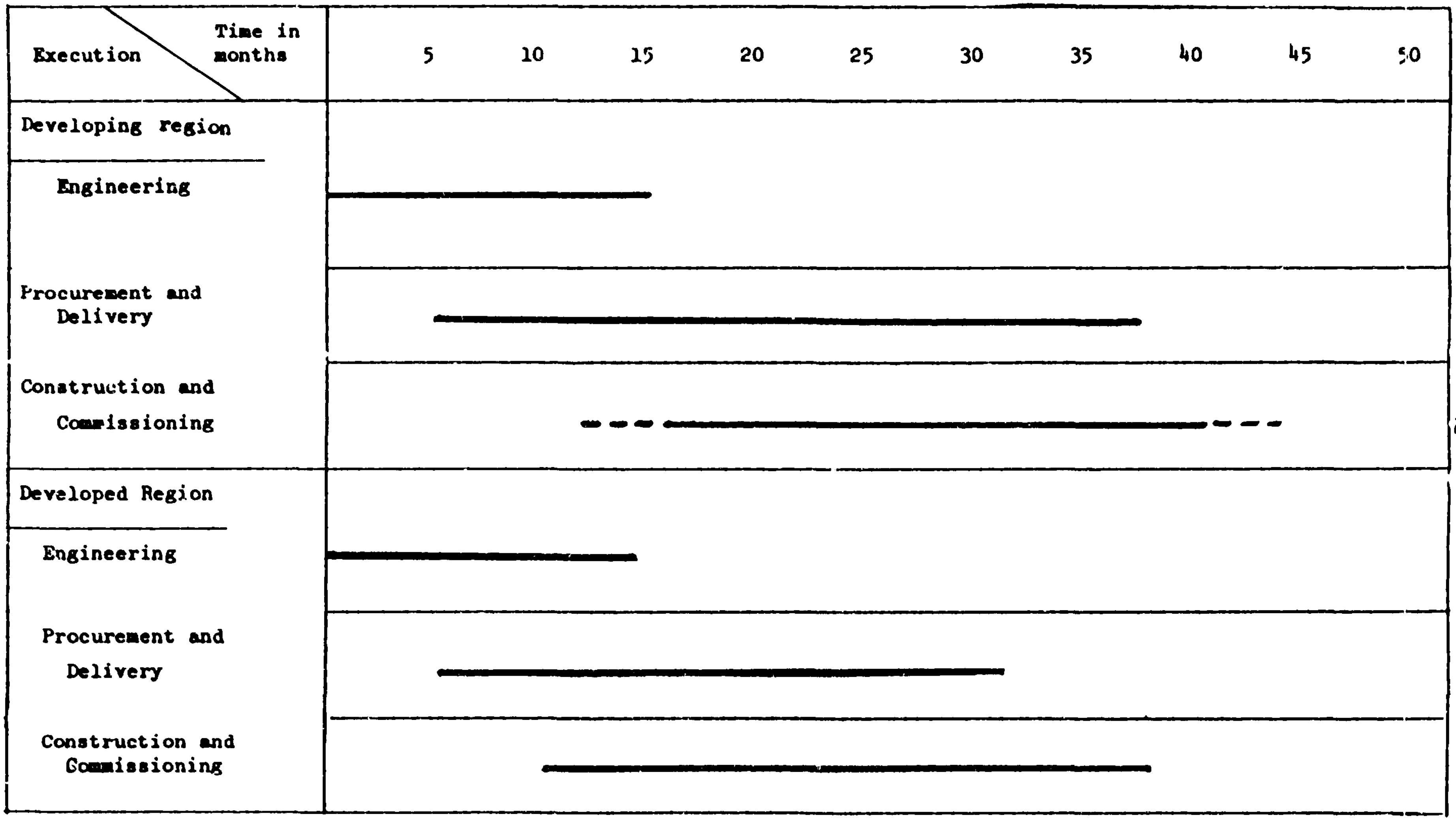
- 24-30 months for an expansion job and for a small size complex in a well industrialized location.
- 30-42 months for a medium/large size (single train) complex in a well industrialized location.
- 40-48 months for a large size complex in an undeveloped location and greenfield site (remote location: see chart 1).

The time-table depends on so many factors including management efficiency, State administration, effectiveness in speeding up relevant programmes and procedures, etc. Furthermore, the time-table given above does not cover the period required for surveys/investigations,[34/] the preparation of feasibility studies and evaluation before decisions are made. It covers rather the period from the day the contracts are signed. The time needed to cover other activities from the day the project is conceived, before and after it has been committed until the signing of the contracts could take anywhere from 6 to 30 months, depending on the degree of sophistication and efficiency of the organizations concerned and on the clarity in defining the project. These activities, which may overlap sometimes if planned properly, include:

- preparation of feasibility studies and undertaking of relevant investigation and surveys;
- evaluation and approval of the project in the light of available resources after discussing financial arrangements and implementation procedures;

34/ This activity may be carried out by the contractor during the construction period and concurrently with engineering work, particularly if the contractor's liability is severe and he likes to satisfy himself. This mainly applies to soil investigation, water analysis and essential inputs for design purposes, etc.

Chart 1. Time table for the construction (execution) of ammonia/urea (medium/large capacity) complex in different region.



1) Thickness of the line indicate volume of work, dotted line may represent some activities, i.e. site preparation, external infrastructure development, start up/training and failure delays etc.
2) Assuming fairly well developed location (site) in the developing country.

- preparation of tender documents in the light of the implementation procedure (mode of implementation) and given technical stipulations;
- invitation for bidding, probably preceded by a pre-qualification exercise to select prospective contractors;
- bidding and evaluation of bids;
- contract negotiation and signing;
- consultation with the managements concerned and various local administrations regarding any of the above points, necessary preparatory or complementary activities, synchronization and co-ordination of resources, inputs and relevant infrastructures and services.

The information collected in line with this study indicates that with the exception of two large projects (one in an industrialized region and the other in a developing region), all took longer for their implementation than originally envisaged by the owner and in general exceeded the period defined above (Chart 2, chapter 5).

4.2.2 Delays

Delays in project execution can be attributed to many factors, among which the most important ones can be:[35/]

- poor management usually associated with a shortage of skilled manpower, inexperience, administrative problems in connection with industrial relations and co-ordination modalities, etc.;
- inefficient or overworked engineering contractors and vendor shops, late deliveries of equipment, faulty fabrication causing delays in design work and commissioning, etc.;
- highly active area in the vicinity of the project resulting in port congestions, constraints in (or overloading of) infrastructure;
- lengthy procedures in decision-making regarding some relevant activities on the part of the actors involved;
- political instability and labour problems;
- change in the scope of work;
- others, i.e. weather conditions, etc.

35/ See chapter 5.

4.2.3 Time-phasing of cost

To phase out the project expenditure over the implementation period is not an easy matter, as this depends on the type of contract, the financial arrangements, and the scope of work involved. In general, it would be logical to assume that there is a peak year when the bulk of the construction takes place once most of the equipment has been delivered. This can then be considered as the base year for adjusting the overall cost.

Ideally most orders should be placed within the first six to twelve months after signing the contract assuming that all the engineering and procurement costs (software and hardware costs) have been fixed except perhaps freight/transportation charges and probably the cost of engineering supervision and inspection during construction (if an unstable rate of inflation is expected).

At the beginning of the second year, at least 50 per cent of the construction cost should be fixed, including an accurate evaluation of all construction material and labour cost. This may leave the cost of a probable third year or more.

In a study on project management,[36/] various functions in project implementation were assessed in terms of their duration and finalization within the whole execution period (Figure 1). The results indicate that the bulk of the engineering and procurement work should be finished within the first 75 per cent of the total time allowed for the job. By then more than 60 per cent of the construction work should be completed. In terms of budget, the same study points out that probably by then 80 per cent of the total cost will be spent (Figure 2).

36/ E. Stallworthy and O.P. Kharbanda, "Total Project Management", a paper to be published.

FIG. 1 Work progress for major project execution function

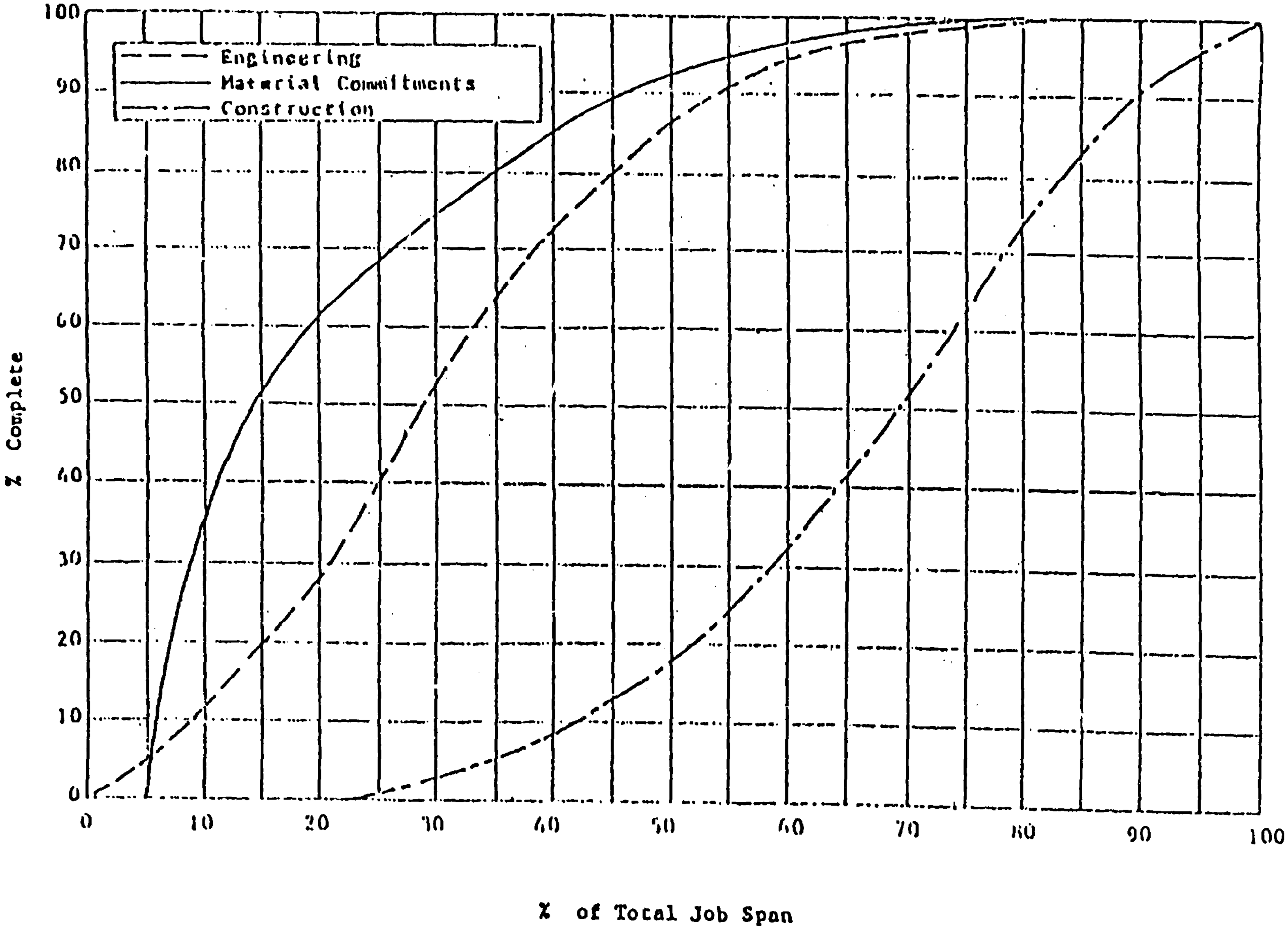


FIGURE 2

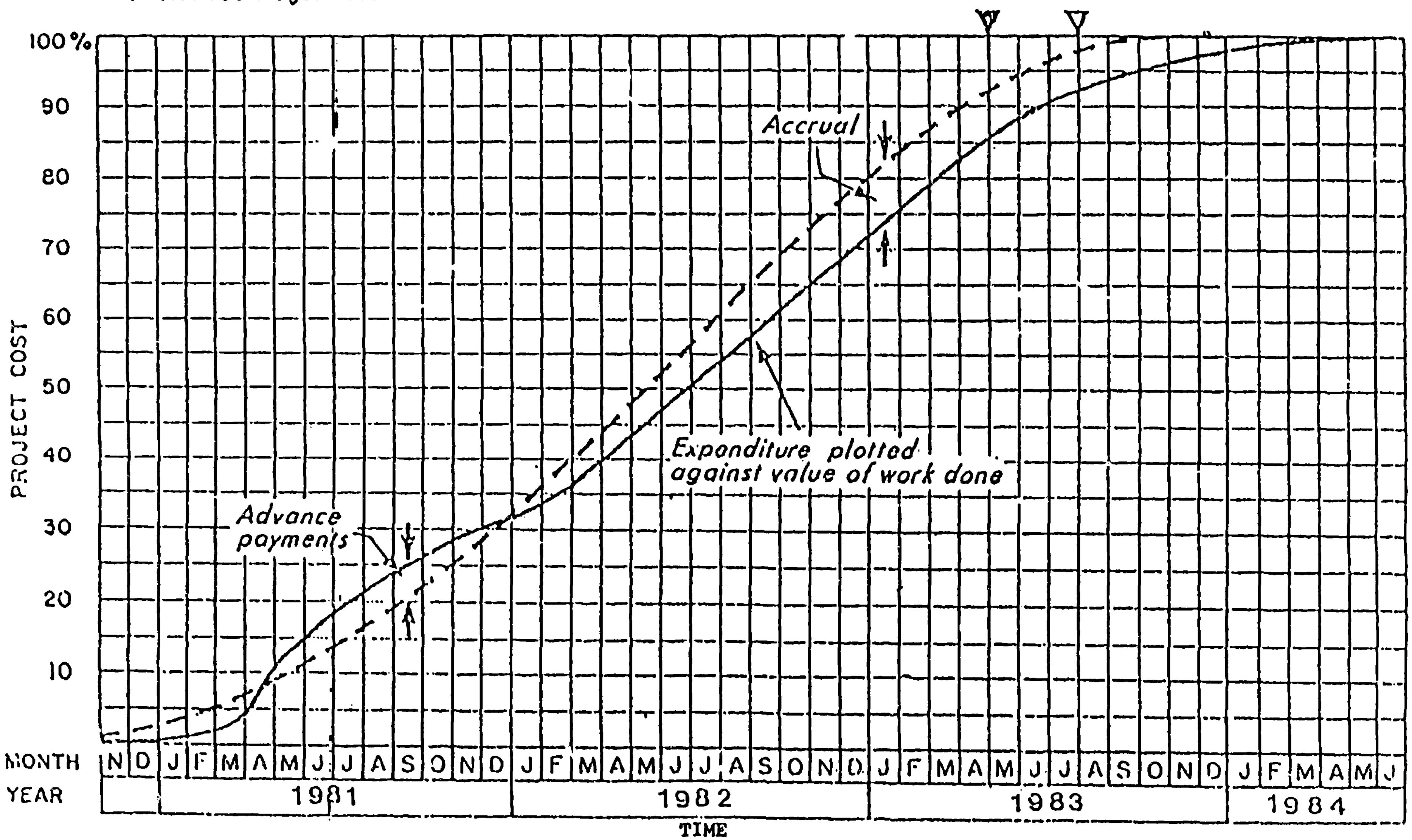
PROJECT PROGRESS: Value of work done

---Value of work done

_____ Payments

Target date ready for start-up

Revised target date



From the above description one arrives at the following schedule (in per cent) for a project that takes 40 months to be completed:

Work completed	Engineering	Procurement	Construction	Budget spent or committed
during first year	75	50	-	30
during second year	20	45	30	40
during third year	5	5	60	20
Balance	-	-	10	10

4.3 Location of project

The location of a fertilizer project can have a major bearing on its cost. Several attempts have been made to quantify the effect of location on the project cost but they did not come to a satisfactory solution. Meanwhile, empirical data based on previous projects of similar design and at various locations have been employed,[37/] but the impact of this approach has been insignificant since no two projects are ever identical.

In any case most of the useful empirical data are in the hands of international contractors and constitute one of their most valuable assets. Occasionally some of these data get published but usually in a rounded form, as a location index, to give an approximate cost for a project in a particular country as compared to another one in a different region.

Such indices cannot be used in any way to establish in absolute terms the effect of location on the final cost of a project. To arrive at that, especially in respect of a fertilizer project in a new location, it is necessary for the owner and/or contractor to establish a suitable cost base using information at the micro level. This includes among others:

- Transport facilities and cost,
- Local fabrication capacity,
- Availability of craftsmen: various categories,

37/ Refer to Annex II, tables 3 and 4 of the Appendices issued as Volume II of this study.

- Wage level and productivity,
- Power and water availability and cost etc.
- Availability and cost of construction equipment and material
- Local taxes and duties.

Collecting and analysing such data requires considerable time and effort but it is important to do it before a realistic cost estimate can be made. Insufficient homework in this respect is bound to lead to considerable time and cost overruns beyond the original project estimate, while a realistic cost estimate may show from the start that a project is not viable.

4.3.1 Location index: Published data pertaining to location indices are usually prepared on the basis of historical records, in respect to certain type of activity and of plants in specific regions. For a proper analysis, such an index should be split up in "scope factor" and "execution factor". Otherwise certain assumptions should be made.

Studies on the subject have revealed some discrepancies in plant cost (capital investment) even when plants of the same capacity and characteristics are constructed within the same region but these discrepancies may not be as large as those observed for plants constructed in completely different locations (Tables 2, 3 and 4 of Annex II).

One study[38/] has indicated that the major cost items influencing these discrepancies would be:

- Freight and insurance for capital goods and material shipped from industrialized regions where they are manufactured for a developing location.
- Abnormal requests for spare parts needed to continue operations with minimum interruption in case of failure and with minimum delay for purchasing order and delivery.
- Construction sub-contracts; most of the technical capabilities, work force, equipment and construction material have to be imported, cared for and stored at high cost.

38/ Referred to in the UN/ECWA study on Export Refineries (1979) (ECWA internal document).

The same study illustrated investments for the construction of a large petroleum refinery which is somewhat similar to that of an ammonia plant as follows (in $ million, 1976 prices).[39/]

	Middle East location	Industrialized region/location[a/]
- Equipment/material	111	108
- Freight insurance	52	6
- Construction contracts sub-contracts	188	149
- Spare parts	12.3	5.2
Total	363.3	268.2
- Pre-operational and other costs	77.7	26.8
Total investment	441	295

a/ The figures represent cost average of various cost items in three different regions.

According to the above figures, the location factor for a Middle East refinery location, as compared to a similar one in an industrialized region, would be 1.36 for the first four cost items. By adding the other cost items, the overall location index may go up to 1.5. However, it was noted that the overall location index may be much lower i.e. 1.26, in a Middle East location compared to an industrialized country with a relatively high location cost index.

Other studies on the location factor indicate a similar range, particularly for the production cost of basic chemicals including some petrochemicals, ammonia, urea, etc.[40/] But there are only a few studies in which the effect of location on different cost components of fertilizer projects is identified.

39/ Cost structure of a petroleum refinery may be somewhat similar to an ammonia plant.

40/ UNIDO's Second World-wide Study on Petrochemicals: Process of Restructuring, ID/WG.336/3, 1981.

Information[41/] on the capital cost of a nitrogen-fertilizer complex erected in a developing country indicates that more than 50 per cent of the overall capital cost was spent on items which are more expensive in such countries than in an industrialized country:

	Cost item	$ million	Percent of total
1.	Plant facility and construction	145	47.2
2.	Additional cost items	103	33.6
	- Ocean freight/local handling	12	
	- Physical contingency	18	
	- Escalation during a 42-months construction period	53	
	- Interest during construction	13	
	- Preparation expenses	7	
3.	Out-of-boundary cost item:	51	16.6
	- Harbour, etc.	31	
	- Water supply line	6	
	- Housing colony	14	
4.	Other cost items:	8	2.6
	Total	307	100

A 1979 study[42/] suggested that the location factor for a medium to large size fertilizer complex would be 1.53 for a developing country with fairly good infrastructure and 2.13 in a remote location, in comparison to a well industrialized region.

In an up-dated version of the study presented to the participants of the Eighth Session of the Commission on Fertilizers organized by FAO, 31 January-3 February 1983 in Rome),[43/] the investment cost for fertilizer plants in three different site locations was compared. Table 2 illustrates the results using as a base the case of a N-fertilizer project (1,000 T/D gas-based ammonia plant and 1700 T/D urea plant) where the cost of battery limits would be $140 million (1982) in an industrialized country.

41/ UNIDO's Fertilizer Manual (Development and Transfer of Technology Series No. 13).

42/ W.F. Sheldrick, "Investment and Production Cost for Fertilizers", a paper presented at a Session of the FAO Commission on Fertilizer (Rome, January 1979).

43/ Ibid.

Table 2. Overall cost of fertilizer projects in different locations

Type of site	m $ 1980	m $ 1982	Factor (1982)
(a) Industrialized site: "Normally, in an industrialized country but it could also occur in a developing country which already has a well-developed fertilizer industry and/or similar industrial project and infrastructure".			
Average	-	231	1.00
Approximate range:	200-240	200-250	-
(b) Developing site with some infrastructure: "Some facilities do exit but more infrastructure would have to be provided".			
Average	-	323	1.40
Approximate range:	240-360	250-350	-
(c) Developing site: "A remote location without infrastructure",			
Average	-	405	1.75
Approximate range:	350-450	350-450	-

A sound assessment of the suggested generalized location indices is rather difficult to make, mainly because of the many assumptions involved regarding the different interrelated factors. A simple approach is attempted to establish guidelines for a theoretical cost structure for fertilizer plants constructed in developing regions, as compared to the corresponding cost structure in an industrialized region.

4.3.2 Simplified approach for building cost structure pattern

To illustrate theoretically the effect of location on the cost structure pattern, a simple comparative analysis is presented below on the main components and their effect on the cost of turn-key plants built in different regions:

Within the context of this study, two contractors (X and Y) reported that the principal cost components after all directly linked cost items (freight, custom duties etc.) have been prorated and included, might assume the following content in a turnkey plant estimate in the industrialized regions:

	Contractor X	Contractor Y	Average
Software	20%	20%	20%
Hardware	40%	50%	45%
Construction	40%	30%	35%
	100	100	100

These figures do not seem to correspond to the data reported in this exercise.44/ However, in the pursual of deriving a comparable cost structure pattern, the above average is used. For the sake of simplicity, it is assumed that the proposed site for the fertilizer plant is a fully industrialized area and that in the developing country it is completely undeveloped,45/ while making an attempt to synthesize the three principal cost components into the capital cost in two extreme cases:

- industrialized site in an industrialized country
- Undeveloped site in a developing country.

Other assumptions as well as the result of the analysis are included in the following paragraphs:

Software

Assuming that in both cases all the software work is carried out in the industrialized country (usually the home country of the main contractor or of the front-end engineering supplier), the absolute cost in respect of the

44/ Please refer to table 5.

45/ It is not necessary that all the sites in an industrialized country be fully industrialized. Conversely, not all the sites in a developing country are undeveloped. Thus one can have a remote site in an industrialized country which needs all the infrastructure. On the other hand, an industrialized site in a developing country may already have most of the infrastructural facilities.

battery limit plant with the necessary utilities (off-sites) should be identical in the two cases. At the present stage of development of most developing countries, the environmental standards are generally lower than elsewhere, so that there could be some slight savings in software obtained locally. This, however, may be compensated by the slight extra cost for 'adapting' the design to tropical or other such conditions in the developing country. On the whole therefore, the software cost in both cases (a) and (b) may be considered identical.

Hardware

For the sake of comparing the share of hardware in total costs, two typical situations will be considered:

(a) Hardware entirely imported

This is likely to be the case for a developing country with practically no fabrication facilities nor manufacture of electrics, instrumentation or other ancillary equipment.

(b) Hardware partly imported (50 per cent)

It will be assumed further, for purpose of illustration only, that the imported hardware from an industrialized country delivered at the site of the fertilizer project in a developing country costs 75 per cent more[46/] than hardware delivered in an industrialized country, to cover:

- additional freight and insurance (including transportation to the developing country site)
- import duty and other clearing charges (in excess of duties and excise tax levied on plants purchased and installed in an industrialized country site).

46/ Information on projects reported in the study indicates that the maximum cost (in two extreme cases) for the relevant two cost items is about 68 per cent of the hardware cost, although the indigenization content is not clear. This percentage excludes such items as interest/currency fluctuation and escalation, preliminary and pre-commissioning expenses, contingencies, etc.

In a developing country, local hardware may be assumed to cost, in the initial stages of development of the fabrication/manufacturing industry, 15 per cent more than in an industrialized country. The net result is as follows:

- Basis: Hardware cost in the industrialized country = 100
- Cost in developing country:

	Case (a)	Case (b)
	175	50 X 1.75 +
		50 X 1.15 = 145

It is also assumed that specification, quality and delivery period for the imported as well as the local materials are the same. The delivery period being reckoned as the time for delivering all equipment to the project site.

Construction

This cost element is the hardest to quantify in the case of a fertilizer project in an industrialized country. Furthermore it can escalate considerably and even get out of hand when delays occur. Construction cost comprises mainly labour cost plus construction equipment/tools (labour cost, basically is a function of labour wage and productivity).

It is easy to ascertain the prevailing wage structure for various categories of local labour in a developing country. Certain categories of craftsmen, for example, qualified welders especially for high pressure work, are seldom available locally and therefore will have to be expatriates and of course this will add considerably to the cost of construction.

The second element, productivity, is very difficult to measure/quantify, especially at the micro level in developing countries where hardly any data exist. Productivity is an abstract term and cannot be measured, except in comparative terms and only under completely controlled conditions.[47/]

In the absence of detailed information, a few assumptions have to be made in order to produce a construction cost pattern in developing countries. In the first place, and for comparison purposes, it is not too unrealistic to assume that the construction cost is entirely composed of man-hours.[48/] In addition, manpower includes also expatriates such as skilled craftsmen and supervisors. Third, local wages (and productivity) are lower than in an industrialized country. Hence, the combined effect of wages and productivity on the local labour cost element will tend to be similar to that in the industrialized country.

To draw an approximate construction cost pattern in a developing country, it is assumed that the expatriates constitute 30 per cent of the total working force and that the cost of their man-hours is at least twice as high as in an industrialized country to provide for travel, accommodation and other expenses incurred in locating the expatriate personnel at the fertilizer porject site in the developing country.[49/] On this basis, the total construction cost can be the following:

47/ Productivity comparison at macro level, e.g. tons steel/man/year, could be deduced from data available in the annual reports of steel manufacturing companies, assuming that the developing country in question has a steel plant. But such data when translated to a construction site can be very misleading. There is also an additional factor in many of the developing countries which are interested in providing maximum employment for a given investment. This, of course, can disturb productivity comparisons doublefold. If for the same job and over the same period the work force is double, productivity will be halved automatically, even before the job starts. Once the job has started, productivity drops are induced further by greater manpower than needed.

A more realistic assessment of the productivity for a planned project in a given country is past experience, but for a first construction project no feedback exists, one has to resort to guessing since after completion of the first construction job, the estimate becomes considerably more accurate. This is one of the major strengths of reputable international contractors who use their experience in various countries to build up their data bank.

48/ Reference should be made to world indices on chemical plant construction and fabrication of its capital goods.

49/ Expatriate fringe benefits and remunerations can be very costly, particularly if the contractor charges high overhead for assumed or relevant backstopping activities of these expatriates at his head office.

Industrialized country	Developing country
100	70 + (30 x 2) = 130

This assumes that the construction time is identical in both cases although this seldom happens.

Overall plant cost

On the basis of the foregoing analysis, information and assumptions, a simple synthesis of the total cost of identical projects (same scope and no additional facilities) in a developing country as compared to one in an industrialized country would be as follows:

	Industrialized country	Developing country case (a)	Developing country case (b)
Software	20	20.00	20.00
Hardware	45	(1.75 x 45)= 78.75	(1.45 x 45)= 65.25
Construction	35	1.30 x 35)= 45.50	(1.30 x 35)= 45.50
	100	144.25	130.75

(This assumes the same completion time for both projects in the developing as well as in the industrialized countries).

Thus the capital cost of a fertilizer plant in a developing country, if completed on time, should be 1.31 - 1.44 times that of an identical plant in an industrialized country. Hence, the overall cost of a N-fertilizer plant of standardized capacity in a developing region should have cost $157.3 to $173.5 million in 1978 (without contingencies). However, because of considerable delays in the case of a project in a developing country, this factor becomes much higher. Should the project in the developing country be delayed by two years (as indicated by most of the projects reported), the cost may escalate to 86.55 per cent and 78.1 per cent respectively when compared to that in an industrialized country (using 15 per cent per year - simple interest).

According to the above, in the developing countries, the cost portion for the software, hardware and construction may be put at 14 to 15 per cent, 50 to 55 per cent and 31 to 35 per cent of the total cost respectively.

In the above simplified approach, the effect of indigenization on reducing the overall cost should be noted. In other words, indigenization can reduce the cost of a project in developing regions by at least 10 per cent when 50 per cent of the equipment, tanks, pipes, etc. are built locally.

4.3.3 Areas of high cost in conjunction with location

In the above presentation, freight and insurance together with the stripped cost of technology and physical work for a turnkey plant were the only elements considered. Other items which can cause further escalation in project cost in conjunction with location include:

- spare parts,
- infrastructure outside plant boundaries,
- training.

Spare parts

There are few cases where additional cost is incurred with spare parts:

(a) At the time of giving a quotation on international competitive bidding, the vendors of plant machinery offer the most attractive prices to secure the purchase order. Any spare parts purchased at that time will also be quoted on very favourable terms. However, once the plant is commissioned, any subsequent requirement of spares is at times quoted and supplied at a very high price. Since these parts are generally of proprietary nature and the client does not know their specifications, material of construction and other details, he has no option but to pay these high prices or suffer a shut-down of his plant. It has been noted that the rate of inflation on spare parts can be 30 to 50 per cent per annum. After three to five years, the vendor may claim that the spare part is no more on the manufacturing line and the cost can go as high as the original price of the whole machine.

(b) At times, the developing countries are supplied with obsolete technology and plant machinery. When the client approaches vendors to purchase spares/replacements, he is informed that this part is no more in production and has been replaced by a new one. This new part can be several times more expensive than the original one.

(c) If the client wants to avoid long delivery periods for spare parts, he has to carry a heavy inventory. This in itself is another costly undertaking.

(d) The commissioning of some projects takes more than 12 months, from the date of mechanical completion to commercial production mainly because of equipment failures. In such cases, replacement of all or part of the major equipment may be necessary. This causes delays and adds to the project cost. Such failures are also expensive because of the waste of material incurred by repeated trials for corrections and adjustments before the plant is finally put on stream. Down-time in production can be very costly because of interest, pay-back period, loss of the potential market, inflation etc.

Infrastructure

Many of the fertilizer projects in the developing countries are at a greenfield site in a remote location. The site may have been chosen because of raw material, in order to supply products to that particular area, or in many cases, on the basis of political and socio-economic factors when the main objective is to develop backward regions and provide employment. In the latter case the infrastructural facilities can include:

- township,
- rail and/or road link,
- hospital,
- school,
- transport, etc.

These facilities may add substantially to the total cost of the project and may well be double the cost of the plant itself (or even more). Strictly speaking, the cost of infrastructure such as those mentioned above, should not be considered as part of the project cost. Instead it should be considered as part of the general cost incurred to develop backward regions and should therefore be financed by a development fund allocated for that purpose by the State. This also applies to infrastructure to be provided at the beginning of the construction, mainly to serve the fertilizer project, to benefit other projects that may be set up in the region later on. For that reason, it is not fair to debit the entire cost of such infrastructure to the fertilizer project alone.

Training

This activity is usually essential for owners in developing countries. The cost of this activity depends on the level of development of the country and the capabilities of the owner's team. At times this cost is multiplied because the training is ineffective. The latter situation arises due to different circumstances:

(a) The introduction of new technologies requires retraining operators and maintenance personnel. Sometimes the training given by the contractor to the owner's employees is below standard, for various reasons: one of the problems can be that the trainees spend much time with theory but are not allowed to operate the plant as its units are in commercial production and nothing should interfere with the production. Another important problem is associated with communication barriers,50/ trainees and trainers having different backgrounds and languages. In such cases, additional cost may be encountered for on-site retraining, possibly during commissioning when downtime in production can be so costly.

(b) In many cases, especially when the State owns the plant in a developing country, a training programme is also required to up-grade the local capabilities and allow for higher indigenization in future projects. Such a programme may not concern only engineers but technical and marketing management staff as well which of course adds further to the normal cost.

50/ A major problem associated with imported technology is language. The situation becomes more acute when some of the technicians from different countries cannot communicate effectively with the owner's staff. This leads to misunderstanding and delays in executing certain tasks (L.M. Liayo: paper presented at the UNIDO Technical Conference, Beijing, March 1981).

4.4 State policies

Notwithstanding the effect of developmental strategies in regard to State-owned projects, State policies (fiscal and others) can have a major influence on the capital cost of a fertilizer project. Among other factors, this is due to:

- import duty: levied on imported hardware
- excise duty and sales tax on local hardware
- environmental regulations that impose costly anti-pollution equipment
- labour law in which some stipulation may affect productivity
- import regulations and directives
- port fees and unloading priorities concerning strategic goods.

The magnitude of these items, varies of course from country to country. Hence it is not possible to quantify and generalize their effect on capital cost. Each case must be considered in depth to determine the financial implication of these factors on the overall cost of the project. The costs arising from State policies are, of course, obligatory and therefore must be carefully ascertained and included in the total project cost. Any item which was not provided for in the original estimate because of negligence or oversight will, of course, contribute later to the cost overrun.

Other State policies of importance in this context are those associated with administrative procedures and indigenization. In certain cases bureaucratic administrative procedures can affect delays, particularly when approvals for any activity are awaited. The situation is all the more critical in the case of State-owned projects.

Apart from the issue of establishing State-owned projects primarily on a social benefit basis, the other major issue is indigenization which can cause cost escalation if not carefully studied. It is quite natural and understandable for developing countries contemplating to set up new fertilizer projects to aim at a maximum indigenization both for hardware and software technology, including activities connected with construction. This is an important objective of any country development plan. But the indigenous element of a project must be decided after an exhaustive exercise at the micro-level to determine realistically the permissible local content of the project execution. Predicting a broad policy may prove unrealistic and lead to overruns during the actual execution.[51/]

Indigenization at an early stage of development is bound to add to the project cost. But that must be considered as the 'entry fee' that the developing countries have to pay to learn the art. Once this is achieved, the cost level should come down to the international level.

4.5 Changes in scope of work

Many of the fertilizer projects in developing countries have suffered because of changes in mid-stream. Change is always expensive. The later the change occurs, the more expensive it becomes. Even if a firm resolves to make no changes, changes can still come for a variety of reasons. Mistakes in detailed design can have devastating results, giving rise to as many changes and delays as the poor definition of the project would do in the first place.

4.6 Mode of financing

The mode or type of financing used (or available) for the fertilizer project can greatly influence its total cost. As shown in tables 3 and 4, the incidence of interest ranged from 6 to 20 per cent for the major ammonia/urea projects in developing countries, for which detailed data were available on the cost structure. The highest figure is in the case of a project C which suffered nearly 100 per cent cost overrun. Such overruns play havoc with the viability of the project.

51/ In the case of a fertilizer project in India, which is one of the case studies prepared for the present report, an in-depth analysis revealed that "the decision to achieve maximum indigenization in procurement of equipment... was taken without advance preparation ... such ad-hoc decision ... led to inordinate time and cost overruns. It is extremely necessary to have a time-bound national programme for progressive indigenization..." (Bureau of Public Enterprises, Government of India: "Barauni Fertilizer Project", June 1980).

Interest on the capital employed constitutes a major cost element at least until production starts. Any delay in completion has a snow-balling effect, because as soon as a project is committed for execution, the interest will be charged, even before physical implementation activities start moving.

Interest rates have been steadily going up, but the quantum depends largely on the source of finance. Usually, the interest rate particularly for development projects in developing countries can be as low as one-third of the prevailing commercial rate. Such preferential interest rates apply to financing from developmental institutions which are State-owned or from such international agencies as the World Bank.

The mode of financing sometimes includes loans or aid from the contractor's country of origin. This usually happens on a government-to-government basis, but it can also happen when a loan is obtained through normal banking channels.

Ideally the foreign exchange required for a fertilizer project should be free foreign exchange. This allows for the purchase of imported equipment from the most economical sources. In the case of tied credits, the owner and/or contractor has no choice and the price can be unduly high. A certain fertilizer project in India was in such a situation as revealed in a study to investigate the time/cost overrun for that project.52/

In support of this argument, the case of a successful fertilizer project in the same country (the expansion of the Indian Explosives plant at Kanpur, India) was considered. This is one of the Indian case studies where the management was fully aware of tied financing problems. Another factor which was considered in this respect by the planner and the implementation

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52/ "The present study has revealed that dependance on suppliers with tied-up credits leads to higher project costs as also delays in completion time. Since the equipment supplied on such credits are, at times, costlier as well as inferior tho those procured with free foreign exchange, it would be advisable that for future projects, the equipment should, as far as possible, be procured with free foreign exchange." - (Bureau of Public Enterprises; New Delhi: 'Baraundi Fertilizer Project', June 1980 p. 57).

management of this project is the importance of tying up the financial resources quickly and at an early stage.[53/]

4.7 Mode of execution: management and type of contract

The mode of execution of a project is in fact the type of management and execution procedure desirable to effect successful completion of the project in the shortest period and at the lowest possible cost. Poor management could cause delays and/or overrun in cost no matter which actor is involved (client/consultant or contractor).

Generally speaking, there are two broadly defined modes of execution in respect to the establishment of a plant: the employment of a single contractor on a 'turnkey' basis or the owner carries out the task himself (departmental execution). These are the two extreme cases and in practice, several variations exist in between the two extremes, each with its own merits and shortcomings regarding the cost and the economics of the project.

It is not possible to make a categorical statement as to which of the two modes, or the variations thereof, is the desirable one. Each case must be studied in depth and on its own merits. However, in the case of an owner undertaking the fertilizer project for the first time ever, the trend has been to entrust the entire job to single contractors on a turnkey basis. This has proved to be sometimes expeditious and more economical in the long run.

Departmental execution for an owner in case of a first project will most likely overrun both in time and cost. The reasons for this situation can be numerous. In the first place, the responsibility may be split among several agencies and sub-contractors and hence suffer from constant disagreements and less co-ordination, leading to loss of time and considerably escalated overall

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53/ "Raising financial resources of this magnitude is a very time consuming process involving protracted negotiations and having to confirm to numerous formalities. Despite these, the short time frame within which the financing arrangements were completed was largely due to the active support and co-operation extended by the Indian Government, Reserve Bank of India, financial institutions and commercial banks who recognised the need for urgency in executing a fertilizer..." (Chem. Eng. World, 16, 61-2, Dec. 1981).

cost. At the end, the 'savings' claimed in the case of departmental execution may be completely wiped out. The 'savings' may actually be fallacious to start with anyhow, for the owner may not take into account the REAL cost of his men. The argument being that they are there anyhow. But the problem extends also to how this manpower can be utilized after completion of the fertilizer project.

To elaborate further on the impact of the mode of execution on the cost and economics of fertilizer projects, the major features including risks of various contracting methods are summarized below.

4.7.1 Turnkey lump sum contract 54/

Such contracts enable the owner to set a fixed budget for his project. The scope should be specified and defined in detail to allow for a close cost estimate in the first place and enable him to thoroughly evaluate different bids. At the same time this method of contracting requires that the bidders carry out a thorough investigation prior to their bidding, a task which is costly. The extra cost will be charged to the contract total cost along with additional provisions to protect the contractor against any risks as a result of changing conditions during the execution period.

The cost of this type of contract involves a fixed cost for software, hardware and construction as follows:

- material and equipment cost delivered to site (including shipping charges),
- field equipment and tools, etc.
- licence fees,
- field supervision and labour,
- home office engineering, procurement of construction services,
- overhead and profit.

54/ For details see UNIDO's Model Form of Cost Reimbursable Contract for the Construction of Fertilizer Plant, ID/WG.306/1.

To protect himself against any risks and performance liabilities, the contractor usually includes in the fixed cost of his bid contingencies for possible error in quantities of material take-off and its effect on construction time, cost escalation and currency variations, other unkown or unforeseen eventualities, etc.

This type of contract requires minimum supervision from the owner who establishes his price the day he signs the contract. However, he is required to prepare, invite and evaluate all bids. Such a task may also be time-consuming. Furthermore, in such a contract, the possibility for any change in scope is reduced but if it happens, it can be costly. In the meantime all contingencies included in the contractor's price will add to the real cost of the project. It is important to note that it will be to the advantage of the contractor to finish his job in the shortest time possible, thus also benefiting the owner.

This type of contract is suitable for new owners with limited experience and technical capacity.

4.7.2 Cost-plus (semi-reimbursable) contract

This type of contract, also referred to as semi turnkey contract, may come in different forms, the most popular being with a fixed fee (lump sum) home office/engineering services plus reimbursable (presumably actual) costs for material and construction. In other words, it is a contract with fixed cost for software while hardware and construction are charged at cost when the time comes. The owner in this type of contract may have a non-binding project cost estimate and the overall (final) price may not be known to him until the mechanical completion of the plant is reported. And even then, some uncertainty regarding commissioning cost may remain. Furthermore, unless he has the technological capacity and the management team to supervise and control the work of the contractor, he may not be in a position to detect possible excessive overruns in time.

With this type of contract, a contractor may prepare an "open book" estimate for the project in a short period of time and with minimum expenditure, allowing the execution to go on with minimum delays and provision for contingencies. At the same time the owner will need less efforts to evaluate the bids and will definitely have maximum participation in the project execution. He will be able to verify actual cost and contingencies with a chance of reducing them by making changes when needed at a low cost and through prompt decisions.

In this type of contract, developing countries can pursue a process of indigenization. In certain cases, the owner team arranges to undertake the construction themselves or sub-contract locally civil engineering, detail design, procurement of locally facbricated materials and take some responsibility in supervising and or/or learning the state of the art in international procurement and construction work. But lose coordination with contractors may lead to non-synchronized activities causing delays that can be associated with engineering design, purchasing orders or procurement, delivery of equipment and/or commissioning of the plant.

4.7.3 Fully reimbursable cost contract[55/]

In this type of contract, the contractor is reimbursed on a man-hour basis, usually against salaries plus overhead, auditable burdens and profit. A fixed fee covering the last three items and whatever may be associated with management is possible plus the salaries at cost. Of course this means that software, hadware and construction functions are executed on an open-cost basis.

Of course in this type of contract a non-binding project cost estimate necessitates a sizable knowledgeable owner team or qualified experienced management. Such contracts are very popular with large multinational chemical and petroleum companies, which are in a position to determine the validity of the cost and control the contractor via different means for optimum delivery in quality, cost and time.

55/ For details refer to UNIDO's Model Form of Cost Reimbursable Contract for the Construction of Fertilizer Plant, ID/WG.306/1.

The second type of contract (semi-reimbursable or cost-plus) is becoming more popular in developing countries which have gained some experience in this field and are taking wider responsibility in project execution. To achieve better results, variations on this type of contract are being introduced, including:

- guaranteed maximum price,
- ceiling price with sharing of over/under-sums, where both owner and contractor are having a stake in bringing the cost down,
- reimbursable with lump-sum option, in which case lump-sum on certain portions of the work will be fixed after an open book estimate is prepared and the work started.

In selecting any of the above methods, the owner has to be in a position to determine his capabilities and priorities to achieve his goals, namely, completing the project as soon as possible and at the lowest possible cost while realistically estimating the cost. In all cases the issue of coordination is important and it has to be shown how to avoid any cost overruns resulting from delays as mentioned in the previous section.

5. ANALYSIS OF THE COST STRUCTURE IN REPORTED PROJECTS

Within the context of this study questionnaires were sent to owners and contractors of fertilizer projects (Annex I). Twenty-two answers were received, some of them incomplete, containing information on projects implemented during the past few years. Sixteen of the projects concerned nitrogen fertilizer plants while only four dealt with phosphate fertilizer production facilities. Two projects covered utilities for already existing projects.[56/] A few other answers contained general information and views regarding specific projects and were written by consultants, contractors and financial institutions involved in the implementation of fertilizer projects in developing regions.[57/]

Summaries of the 22 projects reported are included in Annex I. Relevant information on 20 projects was extracted and is presented in this chapter in tables 3, 4, 5 and 7, as well as in charts 2, 3 and 4. Each project reported is identified by an alphabetical letter. In presenting the characteristics on the projects by one or more actors, some assumptions had to be made, based on publications to fill some gaps when data were missing or omitted and judged important for the analysis. However, this approach was not possible in the case of five of the detailed projects (3 N-fertilizer and 2 P-fertilizer projects) because of the scanty information reported on them. Accordingly it should be noticed that the analytical part of the work concerns mainly 14 N-fertilizer and two P-fertilizer projects.

With the purpose of identifying the areas of high cost overrun the procedure followed in the analysis comprised two steps:

(a) Whenever possible cost structure patterns of each project were analyzed in absolute terms to identify the shortfalls of the implementation procedure which may have led to overrun.

56/ See Annex of the Appendices issued as Volume II of this study.

57/ Ibid.

(b) The cost structures of similar or equivalent projects were compared to illustrate the relative effect of specific items on high capital cost in fertilizer plants.

In the course of this analysis, various issues were reviewed in connection with the reasons for high cost and the possible modalities to avert their occurrence.

5.1 Nitrogen-fertilizer projects

Although the discussion in this section covers 16 nitrogen-fertilizer projects for which some information has been available, the analysis was mainly centred on 13 projects to which enough information and comparable features were provided.

5.1.1 General remarks

With the exception of two N-fertilizer projects reported in the developing countries (one was a small expansion job), none of the others finished on time. Delays ranged from 26 to 300 per cent over the period estimated by the owners. Excessive delays were accompanied by high cost overrun ranging from 20 to 200 per cent over the owners' estimates (Table 3) as presented in Chart 2 (vz. Chart 1).

It can be noted from these two charts that probably some project execution programmes were scheduled in accordance with conditions that may have been too strict for developing countries. Unrealistic prediction of the period required for the implementation of some projects could have led to incorrect cost estimates even when normal escalation provisions had been included; hence overruns happened. The effect of a too tight schedule was more severe for some projects when their execution period extended beyond 1980 and an unexpectedly severe inflationary situation in world economy prevailed.

Another problem associated with the extension of the execution period may have come up if purchasing orders were not made at an early stage, although the execution schedule may have been normal or realistic. The negative impact of this problem is more acute when a reimbursable type of contract is involved, as it seems to have been the case in projects P and C, as well as project N which is in an industrialized country (Table 3, Chart 2).

5.1.2 Cost structure pattern

Table 4 shows how the cost structure pattern of different projects differ, even in their principal cost components (i.e. cost of technology and physical structure for a turn-key plant). However, it seems that there is a general trend as to the range of the three principal cost components in developing regions when compared to that perceived in industrialized regions (Table 5). The explanation for variations can be viewed in the following paragraphs:

(a) The high cost of hardware compared to that of construction can be explained by the fact that unskilled labour employed in construction costs very little when compared to skilled labour required by the capital goods industry, particularly since most capital goods are imported from industrialized countries where skilled labour incorporated in the hardware portion costs very much.

(b) The software portion of the cost is much less than the average when the project is an expansion or a repeated one, and when the owner (country) has a rather advanced engineering services capacity.

(c) A too low software cost in comparison to hardware gives the impression that a turn-key contract is involved, in which case part of the engineering work may be debited to equipment by the vendor or contractor. This is especially true for patented engineering/design packages connected with fabrication, or if an off-shelve design work is used, particularly in a repeated job.

(d) High costs in software compared to construction indicate that engineering supervision and inspection during construction has been absorbed in the software package rather than being charged to construction. The reverse is also possible when high cost and exaggerated fringe benefits of expatriates (especially if their stay is extended beyond normal) are charged to construction.

Thus it is natural to see such variations in the cost of these items. Compared to the overall project cost,58/ these cost items constitute 48 to 74 per cent (except for one project) with an average of 62 per cent (Table 5, item 1). The variation in the percentages of these cost components may be attributed to two factors: the effect of inflation on cost of technology (particularly hardware) and the difference in local costs (particularly labour cost) built in the construction cost at each location.

The rest of the cost is taken up by other cost items in the following average proportions:

- Freight/insurance (maximum 11.5 per cent)59/	6%
- Custom duties and taxes (maximum 11.5 per cent)59/	6.7%
- Site development (maximum 4.2 per cent)	2.5%
- Interest (maximum 21.5 per cent)	12%
- Contingencies and pre-operational/preliminary charges (maximum 19.4 per cent)	10.7%

For some projects it has appeared that freight/insurance charges and custom duties were integrated in the hardware cost and that site preparation cost was integrated in the construction cost. Furthermore, in a few cases, other cost (i.e. interest, contingencies, etc.) may have been already included in the overall cost of the main items since they were not reported separately. This situation has made it very difficult to attempt a comprehensive and comparative analysis. Thus adjustments were made by integrating the following items to reach further and closer assessments (Table 5, item II).

- Freight/insurance charges and custom duties/taxes (sales or excise) were integrated into the hardware cost.

58/ Exluding out-of-boundary (off-fence) infrastructure, i.e. housing, railway siding, etc.

59/ Custom duties/taxes compared to hardware cost averaged 18.75 per cent; freight/insurance charges compared to hardware cost, 16.75 per cent. The sum of the maximum custom duties/taxes and freight/insurance charges reported separately for two different projects if prorated and combined constitute 40 per cent as compared to the average hardware cost for all projects.

- Site preparation was integrated into the construction cost.

As a result, the following conclusions could be drawn:

i. The total adjusted cost of technology and construction in relation to the overall project cost range from 58 to 84 per cent (except for one project) with an average of 74 per cent for the large/medium projects and 76 per cent for all projects in developing countries. This means that approximately 25 per cent of the overall project cost may be attributed to contingencies, interest, preliminary and pre-operation charges and foreign exchange rate fluctuations. The developing countries which had the highest percentage of such charges (more than 25 per cent) were those affected by a major price escalation and particularly high interest rate.

ii. Modified hardware cost (including freight, custom duties etc.) in developing countries constitutes a major share of the total cost of the 3 principal cost components, ranging from 50 to 77 per cent (average 60 per cent), as compared to 28 to 36 per cent for projects reported in industrialized countries. At the same time, construction cost (including site preparation) ranges from 10 to 30 per cent (average 23 per cent), except for one project where construction cost was more than twice its hardware cost. The reason for the latter case may have been due to its lengthy construction period that extended well beyond 1980. Although this particular project was supervised by a consultant and had a fixed cost contract, its high overrun both in terms of cost and time makes it a unique case deserving further consideration. The average cost for construction in industrialized countries was twice that of developing countries, i.e. 46 per cent.

iii. Almost all the medium/large-size projects that encountered higher than average construction cost seem to have had the bulk of their execution period after 1980 (Chart 2). The same group of projects was also characterized by its lower than average hardware cost; a case which could indicate that the purchasing orders for equipment have been placed at an early stage, most probably prior to 1980, while construction dragged on at an inflated cost for a longer period than originally estimated (Chart 2).

Table 3 Summary sheet of N-fertilizer plants implementation, particulars and cost

	Project	A	B	C[1]	E	H[2]	I	J	K	L	M[3]	N	O	P	S[4]	[illegible][5]
A.	Major units (feedstock)	G	n.s.	F	N	N	N	F	N	F	G	n.s.	n.s.	G	G	G
	a. ammonia capacity (t/d)	930	900	1200	540	415	900	1350	600	900	1000	1350	1000	1000	1360	600
	b. urea capacity (t/d)	1600	1100	1500	940	680	1500	1800	1000	1550	1725	1000	1500	1725	1090	750
	c. other processing units	-	-	yes	-	-	-	-	-	-	-	-	-	-	yes	yes
B.	Overall cost $ m	426	283	532	181	96	228	445[8]	92	187	208	288	201	276	170	106
	Foreign exchange portion	252	825	159	115	29	111	101	23	73	153	15		178		
C.	Plants cost $ m		244[6]			96	139[7]		46		208	288		144	155	
	a. ammonia		175			47	63		25		126	186		59	63	15
	b. urea					34	29		15		46	72		31	29	7
	c. others	-				-	-		-		-				(**)	
	d. utilities		42			15	43		6		11	12		41	63	7
	e. storage		27				4				25	18		13		(*)
D.	Date of completion (m/y)	12/81	7/82	2/83	8/80	6/81	10/80	12/81	8/75	m 78	EA/78	E/79		E/81		1975
	Date of commercial production (m/y)		1/83		9/81	9/81	3/81	6/82	11/76	EA/79	M/79		5/82	6/82	E 78	1979
E.	Implementation procedure[9]	c-ii	a	n.s.	c-ii	c-ii	c-ii	c-ii	c-ii	b-ii	b-ii	b-ii	c-ii	b-ii	b-ii	c-ii
F.	Overrun cost (percent)	71	00	96	20	10	22	n.s.	163	n.s.	00	n.s.	200	25	(-9)	283
	Execution period in months	80	72	80	67	24	n.s.	68	109	48	33	51	72	48	40	120
	Overrun in time (percent)	40	50	100	70	00	n.s.	26	180	33	(-10)	42	300	33	4	233
G.	Region	DC	DC	DC	DC	DC	n.s.	DC	DC	DC	DC	IC	DC	DC	IC	DC

Abbreviations: n.s. = not specified or given; EA = early in the year; E = toward the end of the year;
M = middle of the year, m/y = month/year; DC = developing country; IC = industrialized or developed country
G = gas; N = naphtha; F = fuel oil

* storage and other expenses = 68 per cent

** other units cost and most likely inclusive of all other expenses is $ 15 m.

Explanatory notes to Table 3

1. The project was not complete at the time of the survey. Its time and cost are estimated at the time the questionnaire was made (almost 5 months before envisaged date of completion). Its units include a sulphur removal plant (58 t/d) and a methanol plant (24 t/d).

2. It is an expansion to an existing plant.

3. It is built on the same site as an existing plant.

4. It includes an ammonium nitrate plant (1000 t/d).

5. It includes a phosphoric plant (250 t/d), TSP plant (1400 t/d) and DAP plant (880 t/d).

6. The plant cost does not include other expenses than software, hardware and construction cost (including freight/insurance, site development, interest/escalation, duties).

7. Plant cost represents software and hardware only excluding other expenses even construction, but obviously includes freight/insurance.

8. The overall cost as it appears represents the reported project cost in IR (10 IR/$), and it includes a non-disclosed or unspecified (itemized) cost of approximately $66 m, which might represent added costs for additional infrastucture, working capital, over-estimates, site preparation, housing, contingencies, pre-commissioning expenses, etc.

9. Implementation procedure covers: I - actor(s) involved in the implementation:

   a) owner + sub-contractors/vendors (negotiable contracts basis): full departmental;
   b) owner + main contractor (responsible for sub-contractors/vendors);
   c) owner + consultant + contractor(s); and

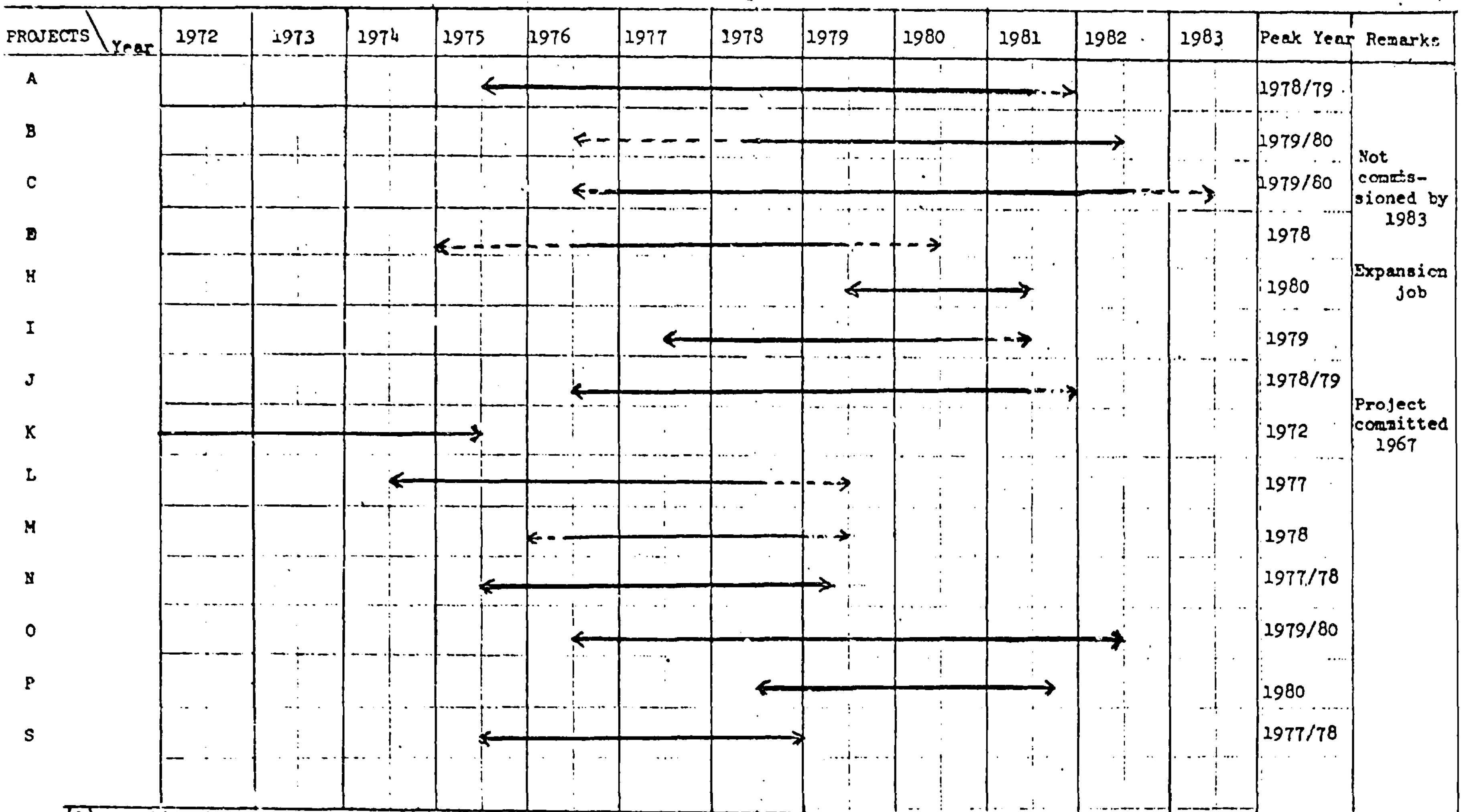
   II - type of contract(s) involved:

   i) Turn-key lump sum basis (fixed cost).
   ii) Semi-turn-key (basis-reimbursables): cost plus or fixed fee (usually for engineering/consultancy services) plus reimbursables (usually for equipment and sometimes supervision manpower).
   iii) Fully reimbursable or open cost.

Table 4 N-Fertilizer plants - Breakdown of investment ($ million)
(Principal cost components and other cost elements)

		A	B	C	E	H	I	J	K	L	M	O	P	S
1.	Software	62	36	38	33	10	23	54	22	22	32	6	37	28
2.	Hardware	103	102	171	72	53	115	117	28	145	74	58	108	48
3.	Construction	79	36	59	10	10	31	25	14	20	105	125	51	94
4.	Freight/insurance	13	8	n.s.	20	n.s.	n.s.	}44	}5	n.s.	9	n.s.	19	n.s.
5.	Duties and taxes	42	n.s.	9	n.s.	11	n.s.	}	}	n.s.	n.s.	n.s.	9	n.s.
	Sub-total (a)	299	182	277	135	84	169	240	69	187	220	189	224	170
6.	Interest	36	25	103	12	11	33	}108	}16	n.s.	}47	n.s.	}33	n.s.
7.	Price escalation	17	29	-	-	-	-	}	}	n.s.	}	n.s.	}	n.s.
	Sub-total (b)	352	236	380	147	95	202	348	85	187	267	189	257	170
8.	Site development	17	10	6	5	1	-	n.s.	2	n.s.	9	-	7	-
9.	Preliminary/pre-operation charges	}41	incl.	81	27	n.s.	n.s.	n.s.	2	n.s.	12	n.s.	12	n.s.
10.	Contingencies	}	22	12	2	-	26	65	3	-	-	12	-	-
	Sub-total (c)	410	268	479	181	96	228	413	92	187	288	201	276	170
11.	Housing colony	}16	-	-	-	-	-	-	-	-	-	-	-	-
12.	Railway sidings power station	}	-	4	-	-	-	32	-	-	-	-	-	-
	Total	426	268	483	181	96	228	445	92	187	288	201	276	170
13.	Working capital	-	15	-	-	-	-	-	-	-	-	-	-	-
	Total	426	283	532	181	96	228	445	92	187	288	201	276	170

CHART 2 Execution Time Table for the reported N-fertilizer projects.



(1) x Solid line represent confirmed time (period) for peak-work, and/or bulk of contract activities.
(2) Dotted lines represent uncertainty in regard to activities due to lack of definit date on schedule.

Table 5   Data sheet : Cost structure pattern of reported projects

	Most popular medium-size projects executed during 1975-82 in developing regions						Small size projects executed in developing regions			Large size projects executed in developing regions		Large size projects executed in industrial countries	
Project	A	B	I	L	O	P	E	H	K	C	J	N	S
1. Software - hardware - construction $ m.	244	174	169	187	189	196	115	73	64	268	196	211	170
a. % software	25.4	20.7	13.6	11.8	3.2	18.9	28.7	13.7	35.3	14.2	27.6	15.2	17
b. % hardware	42.2	58.6	68.0	77.5	30.7	55.1	62.6	72.6	43.8	63.8	59.7	35.0	28
c. % construction	32.4	20.7	18.4	10.7	66.1	26.0	8.7	13.7	21.8	22.0	12.7	49.8	55
2. a. Software $ m	62	36	23	22	6	37	33	10	22	38	54	32	28
b. Hardware + freight + taxes $ m.	158	110	115	145	58	136	92	64	33	180	161	83	48
c. Construction + site preparation	96	46	31	20	125	58	15	11	16	65	25	125	94
d. Total $ m.	316	192	169	187	189	231	140	85	71	283	240	229	170
e. % software	20.0	19	14	12	3	16	23	12	31	13	23	14	17
f. % modif. hardware	50.0	57	68	77	31	59	66	75	47	64	67	36	28
g. % modif. construction	30.0	24	18	11	66	25	11	13	22	23	10	50	55

5.1.3 Comparative analysis of project cost

Methodology and approach

Variations in the cost structure pattern of the reported projects could be attributable to the scope of work, the period of execution, and by location. In order to make a sound comparative analysis of the capital cost of these projects with the view of identifying the abnormalities in their cost structure pattern, it is imperative to establish a reference point as a basis for comparison. To achieve this, a common base for estimating the capital cost of each project was determined by the following approach:

(a) Using specific factors relating to feedstock and capacity of process plants to investment cost,60/ the turn-key plant cost of each project was transformed to that of a standard configuration complex which has been most popular and well assessed in publications i.e. gas-based ammonia plant (1000 T/D capacity) and urea plant (1700 T/D capacity with essential utilities and storage facility.61/ In cases where information on feedstocks was missing, three alternative cost patterns were developed, assuming the feedstock for that particular project to be natural gas, naphtha or fuel oil respectively.62/

(b) To reduce the effect of inflation on investment for projects implemented at different periods, 1978 was chosen as base year and in each case, the third year of the execution period was considered the peak year because prices should have stabilized by then. The world inflation index was used to adjust the project price. It should be pointed out that this index has some limitations however since it:

60/ Refer to section 3 in this paper.

61/ Turn-key plant cost in this context comprises the total cost of software, hardware and construction for ammonia and urea processing units as well as essential off-site facility, but excluding cost of preliminary and pre-production activities, cost of financing and other functions related to location, i.e. freight/insurance, taxes, site preparation, etc.

62/ This was done in the case of projects B, O and N. It should be pointed out that the factor used in transforming the cost of ammonia plant fuel oil-based to that of a standardized configuration and capacity, gives very approximate the results of lower or higher capacity.

- ignores the effect of market forces;
- cannot reflect technological changes; and
- does not take into consideration productivity, training programme requirements, development levels in various regions and at a said period of time.

(c) Other cost items which were set aside to reduce the effect of location on the cost of a turn-key plant were dealt with separately by grouping them in one lump-sum cost adjusted to 1978 and added to the turn-key plant cost, resulting in a readjusted overall cost of the project.

(d) The readjusted turn-key plant cost and the ratios of principal cost components (software, hardware and construction) as originally reported for each project (Table 6) were employed to produce the readjusted cost pattern.

(e) For some projects, where enough information was available, the methodology summarized in points (a) and (b) above was followed to readjust individual plants investment for further comparison.

The result for this exercise are presented in Table 6.

<u>Comparative analysis of capital cost of reported projects</u>

In applying the methodology outlined above with the view of having a common basis for comparison, the following projects were considered for full analysis:

(a) Projects implemented in developing countries: eight medium/large capacity ammonia-urea plant complexes, and two small capacity ammonia-urea plant complexes.

(b) Projects implemented in industrialized countries: two large/medium capacity ammonia-urea plant complexes.

Table 6 Turn-key plant cost and total cost of N-fertilizer projects adjusted to a common base for comparison purposes ($ m)

Project	A	B	I	L	O	P	E	K	C	J	N	S
1. Turn-key plant cost[1/] as reported	244	174	169	187[4/]	189	196	115	64	268	196	211	170[4/]
2. Turn-key plant cost adjusted for standardized configuration	244	192[2/]	155	136	189[2/]	196	147	83	158	116	191[2/]	154
3. Adjusted turn-key plant cost at 1978 prices	227	142	145	149	176	145	147	133	147	108	191	154
4. a) Adjusted software cost	58	29	20	18	6	27	42	46	21	30	29	25
b) Adjusted hardware cost	96	84	98	115	54	80	92	58	94	64	67	44
c) Adjusted construction cost	73	29	27	16	116	38	13	29	32	14	95	85
5. a) Total other costs as reported 3/	166	94	59	-	12	80	66	28	211	217	77	-
b) Adjusted to 1978 prices	155	70	55	-	11	59	66	45	197	202	77	-
6. Adjusted project cost (3 + 5 b.)	382	212	200	149	187	204[5/]	213	178	344	310	268	154

1/, 2/, 3/, 4/ and 5/ see next page.

Notes for Table 6

1. Turn-key plant cost includes software, hardware and construction cost for main units (ammonia and urea) plus off-sites (storage utilities and other auxiliary units). Not included in the hardware freight/insurance charges, or taxes and custom duties. Not included in the construction site preparation.

2. Feedstock was not specified and was assumed to be natural gas. (In the text other feedstock alternatives were considered and cost was adjusted for naphtha and fuel oil-based ammonia plants, by converting both to gas-based plants. This was done for projects for comparison purposes and as possible alternatives).

3. Other cost items reported include: freight/insurance, taxes/custom duty, interest/foreign exchange rate discrepancies, site preparation, contingencies and pre-operation expenses. Not included are outside-the-fence infrastructures (housing, railway siding, power plant).

4. Represents project cost rather than turn-key cost. It could very well be that these figures represent a turn-key cost plus contingencies but no information available to justify this assumption.

5. For project P, additional unspecified cost items of $20 million were reported. In making the analysis, these items were assumed to be for working capital. If it is not, then it could be added in item 5 of Table 6 and hence after adjustment may increase the total project cost to $219 million.

In the course of discussion, another project implemented in a developing country with medium/large capacity ammonia-urea plant complex (project M) was reviewed as thoroughly as its reported information permitted. Meanwhile, project J which is a small expansion job linked to a small capacity complex in a developing country, was not considered in this analysis except for its implementation procedure.

Projects executed in developing countries

In reviewing the adjusted cost patterns of these projects as presented in Table 6, the following conclusions were drawn:

i. Six projects depict close structure pattern in their adjusted turn-key plant cost, and four of them have also a close range in their overall cost, as can be noted in the following presentation (in US$ million):

Project-cost	B	I	L a/	P	E	C	Average b/	Percentage
Turn-key plant	142	145	149	145	147	147	146	100
Software	29	20	18	27	42	21	26	18
Hardware	84	98	115	80	92	94	94	64
Construction	29	27	16	38	13	32	26	18
Overall project	212	200	149	204	213	344	-	-

a/ Information on project L is not clear in regard to the overall project cost and the cost items involved.

b/ Cost in the millions. Underlined figures represent significant deviation.

ii. The adjusted cost structure pattern of the other four projects that underwent full analysis reflect a wide range of abnormal cost, although some cost elements seem to be comparable to the above averages:

Project-cost	A	O	K	J	Average	Percentage
Turn-key plant	227	176	133	108	161	100
Software	58	6	46	(30)a/	35	(22)
Hardware	(96)	54	58	64	68	42
Construction	73	116	(29)	14	58	36
Overall project	382	187	178	310	-	-

a/ Figures in parantheses represent data which seem to fall within the normal range of average cost.

iii. Except for that of projects J and K, the turn-key plant cost for all projects seems to be in general rather high. However, with an average of $146 million, the turn-key plant cost of eight projects (including J and K) may not be too far from the theoretically accepted average of $120 million for similar complex in 1978 prices (established for a complex in an industrialized region).

iv. Project K was implemented during the late 1960s and early 1970s, and hence its cost may have been fixed by 1970, the year that marked the beginning of major escalations in the cost of fertilizer technology. Further, the implementation of this project took a much longer time than usual (almost 9 years) before it was commercially operative. These two factors may explain the abnormalities in this project cost structure pattern, a fact which may disqualify it as a typical sample for thorough analysis. However, its high software cost in comparison with its hardware cost deserves further consideration. High software cost can be explained by the fact that when the project was conceived (in the mid 1960s) local technological capabilities were still at an early stage of development and engineering services had to be imported. In addition fertilizer process technology was still being patented. Lower hardware cost may be lower when local engineering industry is well developed.

If so, indigenization may also reduce software cost. Thus one may conclude that the high cost of software is due to high fees for patented technology which was used also for local manufacturing of some equipment (hardware).

v. Project J seems to have a very low (below average) turn-key plant cost even when compared to similar projects in an industrialized country. This can very well be due to an early purchasing order given in the first few weeks of its implementation period (prior to 1978). This fact was, however, not taken into consideration when readjusting the cost.

vi. In general the variation in the turn-key plant cost is not so severe except in the case of projects A, J and O to a certain extent. The minor variations in the turn-key plant cost can be attributed to contracting modalities (contract method and terms), technological level and degree of sophistication, escalation in cost mainly due to delays, especially when a reimbursable contract is involved.

vii. The overall cost of all projects falls into three broad ranges, e.g.: below $150 m (as in the case of project L): $175 million to $215 million (as in the case of six projects with an average of $197 million) and above $300 million (as in the case of three projects), all in 1978 prices. The variation in the overall project cost may be attributed to factors related to the location, management/administrative procedure and capabilities, and financing cost particularly that part which is related to delays. An important factor affected by location is the cost of social and economic infrastructure beyond the plant fence. But only few projects encountered seem to be affected and in general its portion should not be exaggerated as noted in the previous section.

viii. Three projects (namely A, C and J) seem to depict great abnormalities in their overall cost when compared to the above estimated averages. In the case of project J, abnormal figures also prevail in its turn-key plant cost. However, some discrepancies in the cost of individual (ammonia and urea) plants were noticed but such discrepancies are not severe in the individual plants of projects B, I and P as can be seen below:[63/] It is obvious that projects A, C and J are highly overpriced. The three of them encountered delays in their execution and none of them was on stream before 1982. As a matter of fact, project C had not yet been commissioned by the end of 1982. However, it is important to point out that project C involves additional process units[64/] which ought to add a little to the cost, but definitely not much to the execution time. Furthermore projects C and J have advantages over project A because the latter was constructed on a green field site. The other disadvantage encountered by project A was its conditional (tied-up) loan that limited the choice of contractors and consultants. Such a case led to disputes and a change of management which in itself was a costly and time-consuming feat.

ix. A major issue raised in respect to overruns encountered by project A appears to be linked to the planning of its implementation programme. Three important factors were cited in this respect:

- The project was implemented during a peak general developmental period in a country that had scarce technical inputs.

- Limited technological capability adversely affected the choice of contract and management which were both responsible for overruns.

- Site improperly selected.

x. In the case of project C overruns may be attributed to problems faced during implementation, partly due to the limited experience in management and control, but mainly due to pre-commissioning problems associated with equipment failures (and replacement) during start-up operations. Furthermore the change in scope of work resulted in late placement of purchasing orders for equipment not originally provided for (orders of equipment defined in the original scope of work were placed in 1975) which led to an increase in overall cost. The delay in

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63/ Refer to paragraph on individual plant cost for various projects in different regions.

64/ In addition to the ammonia and urea plants the complex comprises also a sulphur recovery unit (58 T/D) and a methanol unit (24 T/D).

construction work which dragged beyond 1980, led to a greater increase in cost than the modest escalation margin included in the original estimate.[65/]

xi. For project J the high overall cost was attributed mainly to delays caused by many factors. Some are associated with:

- poorly planned implementation scheme (not too clear scope of work, timing of project implementation during the countries' peak period of development, and

- unsuitable contracting procedure (chosing an open cost contract with no clear definition of escalation clauses, selecting a contractor without competitive bidding, not having own authorized management ready for fast knowledgeable action and proper assessment and control).

Other overrun factors are associated with complicated and cumbersome State administrative procedures that caused delays in placing purchasing orders and in delivery of material. Furthermore, the scarcity of essential inputs within the country resulted in an ineffective mobilization of essential resources which, if properly utilized, could have minimized delays and high cost. Unforeseen events (such as a labour strike) were also cited among the reasons for delays.

In the three projects above, delays caused not only escalation in cost, but also resulted in added interest. Furthermore, a significant portion of the cost overruns could be attributed to high custom duties and freight charges in the case of projects A and J. Additional cost above the technology physical structure cost comes close to 100 per cent of the latter project (almost 50 per cent of the overall project cost).

xii. Project L seems to be completed within the period expected for similar projects in developing countries. The owner expected to have it finished in three years but instead it took four years before commercial production commenced. However, no overrun in cost was reported and the

65/ According to the World Bank report on the project (see annex III).

adjusted figures appear to confirm this point, although the project was constructed in a greenfield location. The overall cost of the project as it appears in table 6 should be viewed with care because it is exactly the same as the turn-key plant cost and the information received did not give any explanation or include further details.

xiii. Project E appears to have encountered a minimum cost overrun but excessive time overrun.66/ This is possible if the project was implemented during a price-levelling period as far as chemical plants are concerned (1974-1978). Still the turn-key plant cost of project E seems to be slightly high, as does its overall cost. Thus it is quite possible that the project was originally over-estimated since the owner insisted on its minimal cost overrun. The real abnormal situation noticed would be in respect of the high cost of software and low cost of construction. The only explanation to be offered on this point is that the cost of construction supervision by expatriates has been charged to the software, with all engineering services being imported at high cost while the cost of local unskilled labour was very low.

Projects executed in industrialized countries

Two reported projects with nearly the same ammonia/urea complex capacity,67/ were constructed during the same period in two industrialized countries; one, project N encountered a delay in execution of 42 per cent to finish in early 1979; the other, project S, was delayed by only 1.5 months (over the scheduled 40 months) to finish late in 1978, but at almost 9 per cent lower cost than originally estimated. Both had almost the same cost for software, but hardware and construction costs were different.

The implementation procedure had been the same for both projects e.g. the owner engaging (and supervising) a major contractor for the whole work. The contract of project S was on a fully reimbursable cost basis while the other

66/ Project E encountered a very long delay of 70 per cent (finishing in 67 months instead of 40 months as envisaged).

67/ Ammonia plant capacity: 1,350/1,360 T/D, urea plant capacity 1,000/1,090 T/D.

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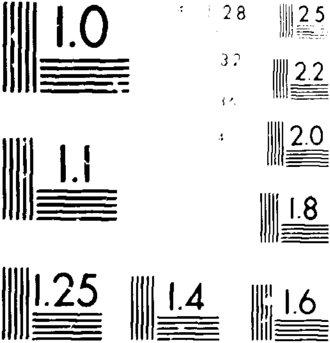

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was on a cost-plus basis (fixed cost for engineering and reimbursable for materials).

In reviewing the cost elements for both projects one may conclude that the country of project S is more advanced in engineering industry, but that the cost of labour is high in both countries as manifested by the high cost of construction and its high share of the total turn-key plant cost. The level of development of the country of project S can also be noted in the short (almost normal) period that the project was executed with no excessive provision for financial cost, site preparation, freight/insurance etc.[68/] The low cost of hardware compared to that of project N testifies that the country of project S has a well developed engineering industry.

Although not much detail was given regarding the itemized cost of project S, it can still be assumed that all items other than the stripped technology-physical structure cost have been included in the three major cost items, because of the fact that the owner reported his satisfaction with the project which suffered no overrun. If this is the case, the overall cost for project S seems to be quite reasonable and within the predicted range for similar projects in the industrialized countries.[69/] However, if the given cost does not include all cost items and contingencies, then project S could have had an overrun. But the owner reported that the project cost was within the estimate. Furthermore, the cost of process units and off-site facilities (outlined earlier) seems to be reasonable.

It could be assumed that the owners' management for both projects was keen to handle a reimbursable contract without the help of engineering consultants. However, for project N a prime contractor was commissioned with several sub-contractors/vendors to handle various activities, i.e. basic design, procurement, commissioning etc. Furthermore, the owners' project team was not prepared to follow-up properly and was not in a position to monitor various activities.

68/ Assuming that all these costs and contingencies are absorbed in the reported total cost.

69/ As mentioned earlier, the cost of a turn-key plant of standardized ammonia/urea complex in an industrialized country should be about $1,200 million in 1978 prices. With an estimated 25 per cent increase for contingencies, the overall project cost should be about $150 million.

The major reason cited by the owner of project N for the overrun was the delay in procurement and civil engineering design. The main problems faced through the contract seems to have been the ineffective co-ordination of the different activities and the loose industrial relationship between all parties involved. This was noticed in the debating issues related to technical problems claimed by the owner e.g. design errors and manufacturing faults for certain units and equipment, and delays encountered in procurement, civil engineering design, etc.

The management of project S which encountered almost no overrun seems to have been well equipped to handle an open-cost contract which brought down the cost of the project by 9 per cent and a minimum delay of 1.5 months. This delay was attributed to problems associated with untimely access to feedstocks. The contract was on a turn-key basis.

Notwithstanding high financing cost (interest rate) and other than procurement and engineering costs, project N seems to have cost almost 24 per cent more than project S although both have been implemented during the same period. The difference might be more, considering the fact that project S includes an additional 1,000 T/D nitric acid plant.

Individual plant cost for various projects in different regions

Table 3 illustrates the variation in turn-key plant and overall cost for all projects for which enough information was reported. However, in the case of projects B, N and O no information was given in respect to the type of feedstock. Accordingly in readjusting the costs as they appear in that table, natural gas was assumed as feedstock for these three projects. Had the feedstock been different, the following cost structure pattern would have resulted (costs in US $ million):

Feedstock		Project		
		B	O	N
Naphtha	Turn-key plant	174	174	173
	Overall	244	184	250
Gas oil	Turn-key plant	136	138	132
	Overall	206	149	209

It appears from this that with fuel oil as the actual feedstock, these three projects would fall within the range of average turn-key plant cost and the overall project cost under normal conditions. However, this may not be the case of project O in a developing country because its cost was as low as that usually encountered in a well developed location.

To compare the overall cost of projects in different regions, individual plant costs (reported for some cases) were adjusted using the methodology outlined earlier. The results are tabulated below:

Adjusted Individual Plant Costs

(US $ million 1978 prices)

	Project					
	B	I	P	M	N	S
Ammonia	89	87	85	126	99	51
Urea	72	54	55	46	79	40
Off-site	60	60	65	37	59	63
Overall	220	201	205	208	237	153

As can be noted, there is no conformity to allow deriving an average. Furthermore, conclusions cannot be drawn since plant costs in different projects may have included different cost items ascribed in each case on a different basis. However, some general remarks can be made:

- Except for project M, the cost of process plants and off-sites seems to be very close for projects in developing countries having the following percentages in the overall cost: ammonia plant cost: 41 per cent, urea plant cost: 29 per cent, off-site cost: 30 per cent.
- Low cost of off-site in project M may refer to local capabilities in building storage tanks etc.
- The comparison with the theoretically established costs (paragraph 3.2.3) is not possible in the absence of details regarding cost elements ascribed to the individual plant cost.

Chart 3 - Possible reasons for overrun in cost, as reported by owners and some contractors

	A	B	C	E	H	I	J	K	N	O	P	T	U	Average cause
A. <u>Excessive costs</u>, due to														
1. Heavy development programme in the vicinity	x	x								x				23%
2. Contractual stipulation in respect to strict performance requirements	x											x		14%
3. Conditional (tied-up) loans	x													7%
4. Out-of-boundary socio-economic infrastructure	x		x								x			23%
5. High interest rate	x	x				x		x			x			38%
6. High taxes and/or custom duties on procured materials	x		x					x						23%
7. High cost for site preparation (green field)	x	x						x						23%
8. Expenses in conjunction with change in management	x							x				x		23%
9. High contingencies and pre-establishment expenses	x													7%
B. <u>Extra costs</u> associated with unrealistic estimates and/or unclear scope of work														
1. Cost related to changes in specifications, site etc. at a late stage	x		x			x				x	x	x	x	54%
2. Excessive expenditure for additional services and equipment not provided for originally	x			x	x					x	x		x	46%
3. Supplementary inputs for lengthy commissioning and start-up operations				x										7%
4. Excessive number and high remuneration of expatriates				x						x	x			23%
C. <u>Escalation</u> in conjunction with														
1. Inflation pertaining to reimbursables (usually in open cost contracts)	x				x	x		x			x			38%
2. Currency fluctuation (rate of exchange, etc.)					x			x	x	x				
3. Delays	x	x	x	x		x	x	x	x				x	69%

Chart 4 Possible reasons for overrun in time (delays) as reported by owners and contractors

Project:	A	B	C	E	H	I	J	K	L	M	O	P	T	U	Average
A. Management constraints	0	0		0	0		0			0	0	0	0	0	0
a. Inexperienced management	X	X		X	X		X			X	X	X	X	X	71%
- owner		X			X		X			X	X	X	X	X	
- consultant	X			X	X		X				X			X	
- main contractor	X						X			X					
- sub-contractors				X	X		X						X		
b. Ineffective co-ordination		X					X				X		X		28%
c. Communication gap				X											
d. Shortage of skilled manpower												X	X		
e. Limited delegation of authority															
f. Late appointment of the engineer				X			X								
B. Constraints during construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a. Late completion of design work							X			X	X			X	
b. Late delivery of equipment	X		X	X	X	X	X	X	X	X	X	X		X	86%
- imported equipment		X		X	X	X									
- local equipment						X	X	X		X					
- not specified	X			X				X	X		X				
c. Delays in civil work/ erection				X							X				
d. Changes in scope of work						X		X			X		X	X	
e. Financial problems (arrangements for payments)				X							X		X		
C. Constraints during commissioning		0	0	0	0	0		0	0		0				
a. Power failure						X		X							
b. Untimely provision of					X			X	X				X		
- feedstock					X				X						
- utilities/services								X					X		
c. Manufacturing errors/ repairs + replacements	X			X				X	X						
d. Unspecified			X												
D. Unforeseen matters	0				0		0	0	0	0	0				
a. Change in management	X					X		X		X	X				
b. Ind. relations problems					X			X	X						
c. Accidents									X		X				
d. Political/labour unrest							X	X			X				
E. Others	0	0				0									
a. Heavy dev. programmes	X	X				X									
b. Port congestion						X									

5.2 Phosphate fertilizers projects

5.2.1 General remarks

As can be noted from table 7, some information was reported by owners on two projects only, comprising integrated plants with major process units and off-site facility, e.g. projects D and Q. However, project Q where the plant has been under construction since 1981 is expected to be commissioned by the end of 1984, and its commercial production operation may not be under way before 1985. As such it has been impossible to assess the degree of overrun and major causes for such an overrun. The main problem of some concern cited by the onwer is technical and related to the design of off-site facilities. It is not clear how this problem affects the cost, although one can imagine some bottlenecks or delays through corrective measures, a situation that may not materialize before all units have been put on stream. Of course with a highly qualified owner team the matter can be solved with minimum delay if the off-site design has been critically reviewed at an early stage.

Project F is a very small job consisting of the installation of one small process unit and a 100 per cent delay over the estimated period was reported with no reference to any cost overrun. It is possible that no overrun is involved since the project was contracted on a lump-sum basis in which case the contractor must have added some contingencies to cover himself against any escalation in prices. It is to be noted in this respect that this process unit, installed on a developed site and annexed to an existing production facility has not yet been commissioned. The local contractor whose construction work, according to the owner, seems to progress very slowly was expected to be finished in July 1983. It can be concluded that for an expansion work, a local contractor may be able to handle the job, probably with some overrun in cost due to delays or to a faulty cost estimate. With a lump-sum contract such a contractor should bear the consequences.

Project R also concerns the installation of one small process unit attached to an existing project. The departmental execution was possible because of the experience gained in the original plant, although the owner reported that some technical problems materialized in connection with work standards. However, the owner remarks that productivity and late delivery of

Table 7 **Summary Sheet of Phosphate Fertilizers Projects Implemented in Developing Countries.**

Projects	D		F		Q		R	
a. Production units and off-site cost:	Capacity (1)	Cost (2)	Capacity (1)	Cost (2)	Capacity (1)	Cost (2)	Capacity (1)	Cost (2)
Sulfuric acid	2600	43	-	-	1500	157	300	8.9
Phosphoric acid	940	71	220	9.4	1200	69	-	-
STP	1040	36	-	-	-	-	-	-
MAP	1000	32	-	-	-	-	-	-
DAP	-	-	-	-	165	49	-	-
Off-sites	-	44	-	-	-	123	-	-
Others	-	-	-	-	-	-	-	-
Total	-	226	-	-	-	-	-	-
Overall cost	-	(309)	-	9.4	-	(400)	-	8.9
Foreign Exch. portion	-	42	-	-	-	280	-	5.3
b. Breakdown of cost	Cost	Percent	Cost	Percent	Cost	Percent	Cost	Percent
Software	48	18	-	-	30	7.5	-	-
Hardware	79	38	-	-	221	55.2	-	-
Construction	68	28	-	-	149	37.3	-	-
Freight/Tax	7	(included)	-	-	-	-	-	-
Site preparation	23	(included)	-	-	-	-	-	-
Pre oper. Expenses	23	9	-	-	-	-	-	-
Interest	19	7	-	-	-	-	-	-
Overall cost	(309)	-	(9.4)	-	(400)	-	(8.9)	-
c. Overruns	No information		100% in time		None		None	
d. Type of contract	No information		Lumpsum basis		Turnkey	Semi reimburse	Turnkey	Fixed cost reimburse
e. Duration (3)	1977-1981		48 months		1981-end 1984		(4)	
f. Remarks made by the owners;	- overall cost includes w. capital ($42) - underdeveloped site - start-up operation; July 1980 - 2 trains for the acids processing units.		- expect to finish in July 1983 - Reason for delay: slow construction work (by local contractor). - Built on existing developed site.		-phosphoric acid 2 units: equal capacities 2 units; DAP linked to NPK unit of equivalent capacity. - Green field location needed site preparation. - Problems in connection with off-site design.		- developed site - departmental execute on sub-contracts basis. - Late delivery of equipment. - Poor productivity and low standards of constructive work.	

(1) Capacity in tpd.
(2) Cost in $ millions.
(3) Duration in months for contract implementation (the execution period).
(4) Only the date of completion is reported (as March 1980).

equipment did not seem to result in any delays. Furthermore, it appears that no overrun in cost took place probably because departmental execution was assumed via turn-key fixed cost sub-contracts for engineering, procurement and erection activities.

5.2.2 Comparative assessment of plant costs

With no information available concerning the process technology of projects D and Q, it was not possible to make a sound analysis and determine any excessive expenditure. However, a basis for comparing the capital cost of individual plants of these two projects was derived from publications.[70/]

According to the UNIDO Fertilizer Manual,[71/] the cost of major processing units in 1977/78 in an industrialized location is approximately as follows:

Process units	Capacity T/D	Battery limited (costs in $ million)	Total plant
Sulphuric acid	1 300	10.5	15.8
	1 500	11.3	17.0
Phosphoric acid	470	14.5	21.8
	600	16.5	26

Thus for projects in an industrialized country similar to projects D and Q (in a developing country), excluding the downstream units for SPT, DAP, MAP etc., the cost (in million US $) during 1977/78 should have been as follows:

	Battery limits	Total plant cost
Project D, production facility	50	75
Project Q, production facility	44.3	67

Excluding the downstream units, the turn-key cost of acid plants in project D is placed at approximately $142 million (in 1979/80 prices or about

70/ UNIDO Fertilizer Manual (Development and Transfer of Technology Series No. 13) and FAO report to the Eight Session of the Commission on Fertilizers (January/February 1983).

71/ Ibid.

about $104 million in 1978 prices).[72/] This means that at best, the plant cost of project D is almost 40 per cent higher than a similar plant in an industrialized country. But this figure could go up once pre-operation charges (usually incorporated in a turn-key cost estimate in an industrialized region) are added.[73/]

The high cost of site preparation (approximately 10 per cent of the total turn-key plant cost which includes freight charges and taxes) is a major cost item recognized in project D, indicating the severe impact of an undeveloped (green field) location on the overall cost. The other major cost item for the same project is the pre-operation expenditure which points out the problems associated with the preparatory work to startup operations, including provision for initial loading of the plants, training requirements, and replacement or repair services in conjunction with faulty design or manufacturing.

Compared with the cost estimates presented in the FAO report,[74/] the overall cost of project D does not seem too far off. However, with no information on any overrun or type of contract involved, no concrete conclusion can be drawn concerning areas of high cost for either project (e.g. projects D and Q).

5.3 Discussion of results

5.3.1 Cost overrun

The information received in response to the questionnaire and through interviews does not allow a full assessment and comparative analysis of cost. Furthermore, in some cases the response from owners and contractors (or

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72/ This cost includes the cost of the sulphuric acid and phosphoric acid plants as well as the cost of off-sites derived on a proportional basis; it represents the overall cost of major components plus freight charges and insurance, custom duties, taxes and site preparation cost, but not interest or pre-operation/preliminary expenses.

73/ The figure could reach close to 70 per cent.

74/ Analysis and up-dated information included in a study on "Investment and Production Cost of Fertilizers" by W.F. Sheldrick, presented to the Eighth Session of FAO Commission on Fertilizers (January/February 1983).

consultants) regarding the same project varied considerably. Also, there appears to be an attempt by some parties to underplay the overrun when it exists. For instance in the case of project J the owner's response shows a 14-month delay for the completion of the project but no cost overrun. This does not seem to be logical on a cost-plus contract. Also the consultant and the contractor for the same project are blamed by the owner for the delay. In sharp contrast to this, the contractor in his response puts the entire blame for the delay on local suppliers and subcontractors, and thus on the owner who insisted on maximizing indigenization.

Bearing in mind the indicated weaknesses, the collected data show that cost overrun took place in about 80 per cent of the reported projects. For these projects, cost escalation amounted to an average of almost 100 per cent of the originally estimated cost. For the same group of projects the overrun in time of execution averaged about 120 per cent beyond the planned schedule.

For nitrogen fertilizer projects established in industrialized countries, the execution period ranged from 48 to 120 months except in the case of two projects (one was a small expansion job). Compared to a normal implementation time[75/] for projects implemented in a remote undeveloped location, the average time overrun was over 71 per cent for the same scale project.

The average cost of projects in a developing region was about 157 per cent [76/] when compared to the cost of projects constructed in industrialized regions.[77/] If projects which encountered severe delay were compared, their cost was 87 per cent (instead of the average 57 per cent) higher than those in an industrialized region. In other words, if the total project cost in an industrialized region is $150 million ($120 million for

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75/ Refer to Chart 1.

76/ The cost of one of the two projects reported in industrialized countries falls in the same range established earlier, i.e. $ 150 million (1978 prices). See section 3.

77/ The average cost referred to here does not include working capital or out-of-boundary infrastructure cost.

turn-key plant cost), then the total project cost in a developing region should be $236 million, whereas if the project encounters severe delays in execution, its cost would go up to $281 million.

Thus a major factor in cost overrun has been delay in project execution. The magnitude of the effect of each delaying factor on the overall cost could not be quantified although some hints were given in the case of two projects. But it can be stated that the effect of delay on the overall cost is more noticeable when a reimbursable contract was in effect, a case characterizing all projects except one which was implemented on a fixed-cost basis. This project could not be analyzed properly due to a lack of details on the contractual conditions.

The reasons for cost overruns and delays as reported by the owners, some consultants/contractors and a financing institution[78/] involved in the implementation of these projects are summarized in charts 3 and 4. To ascertain the effect of different escalation factors on the overall project cost, the following table is drawn based on data provided for this study (tables 3 and 4).

Cost item	Percentage of overall project cost: Range	Percentage of overall project cost: Weighted average
	(percent)	
(a) Turn-key plant cost		
i. principal cost components		59
software technology	10-24	14
hardware technology	25-39	31
construction	6-19	14

78/ The World Bank commented on four of the projects, e.g. project A, I, M and P. According to the Bank reports, project M is the one that did not encounter any overrun, while two projects encountered 22 and 25 per cent overrun in cost due mainly to poor management. But project A which encountered over 40 per cent overrun (probably 47 per cent according to the current analysis) suffered from poor management, location conditions and financing problems.

ii. cost elements usually ascribed to the turn-key plant cost		26
freight/insurance	3-11	6
taxes/custom duties	2-12	7
site preparation	1-4	3
pre-operational activities79/	4-19	10
(b) Other cost elements		15
out-of-boundary infrastructure	4-6	5
interest	7-20	10

In reviewing the effect of each cost element on the overall cost, the following facts were observed:

- The cost of site preparation in a greenfield location usually exceeds 3 per cent of the total project cost.
- The currency fluctuations which were reported on two projects only constituted 4 per cent and 11 per cent of the overall cost of those two projects respectively.
- The high cost of pre-operational expenses (and contingencies) appears to be associated mostly with a long period of completion and with commissioning activities.
- The longer the period of execution, the higher is the interest cost portion.
- The cost elements usually influenced by location form up to 24 per cent (27 per cent when the interest portion is included) of the total project cost as detailed below:

Freight/insurance	6 per cent
Site preparation	3 per cent
Pre-operational expenses	10 per cent
Out-of-boundary infrastructure	5 per cent
Interest portion for these items	3 per cent

If taxes and custom duty charges (7 per cent) were set aside (not included in the overall project cost), the cost items influenced by location would form about 29 per cent of the total project cost. The ratio of the weighted average cost of the principal cost components (including their portion of the

79/ Including preliminary studies, training programmes, other contingencies etc.

interest but excluding taxes) to the location-influenced elements would be 16:10 (160 per cent).

Recalling the absolute figures extracted earlier in this section, and using the ratios of the above analysis, the following could be concluded:

	Industrialized region	Developing region	
		Normal conditions	Severe delay
Turn-key plant cost	120% - 100%	139% (116%)	166% (138%)
Overall project cost	150%	236%	281%

The difference in the turn-key plant cost between the two regions would be $19 million in normal conditions and $44 million if severe time delays are encountered. This may indicate that on the basis of turn-key plant cost at least a 16-per-cent increase in cost is being encountered due to poor management or contractual modalities, while delay in execution may result in a further increase of 22 per cent (hence making a total overrun of 38 per cent) for projects built in developing countries as compared to projects built in industrialized countries.

This statement could not be generalized since it is possible that a project in an industrialized region also encounters some overruns as it was the case with one of the two reported projects (project N).

5.3.2 Case studies

The cost overrun in fertilizer projects in developing countries has been a subject of concern, not only to owners, but also to financing institutions involved in the establishment of relevant plants. For this reason, research activities have been initiated to study in depth the situation and identify the areas of high cost in order to take appropriate measures to deal with them.

In one study, about 1,600 third-world macro-projects including 110 fertilizer projects implemented in the 1970s have been analyzed[80/] to

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80/ K.J. Murphy: "Third World Macroprojects in the 1970s, Human Realities - Managerial Response", Technology and Society 4, 131-144 (1982).

ascertain the nature of the problems they had to face during the execution period, e.g. their "trouble rate"81/ and cost escalation. The results of that study with respect to different size projects are summarized below:

Size of project (defined in terms of their cost in $ million)	Trouble rate (percent)	Average cost (escalation %)
100 - 249	21	30
250 - 499	28	70
500 - 999	38	106
+ 1000	47	109

Since the current most popular scale fertilizer projects built in developing countries fall in the cost range of $250-499 million, the average cost escalation for these projects is found to be 100-149 per cent and the typical completion delay between one and two years. Furthermore, the bigger and more complex the project, the higher the escalation and problem rates.

In conjunction with this study, a case study on three projects implemented in India was carried out. Time and cost overruns were noted in the case of two projects, while the third one (an expansion of an existing plant) appeared to have no problem of overrun. The reasons cited for overrun in the two projects mentioned above can be summarized as follows:

- Insufficient preparatory work at the conception and formulation stages to allow for more accurate estimates of cost and practical schedule for execution,
- too vague an invitation to tenders,
- poorly designed contract,
- insufficient control by the owner and his consultant,
- late deliveries of both imported and local equipment and material, and
- problems in industrial relations, lack of faith and trust between owner and contractor.

81/ Trouble rate is explained in terms of delays and postponement.

In another case study[82/] involving eight fertilizer projects in India, conclusions revealed that the cost indices of fertilizer plants seem to be consistent, and they fall below the Indian and international indices in six of the eight cases. In that study a similar approach[83/] to the one followed in this study was adopted for the sake of comparing plant costs of diverse projects. The merit of the said study consists in the fact that all the eight projects are located in the same country, and that detail information could be obtained for a closer analysis.

In general, some of the conclusions of that case study have been noted or used in the present document. Among others, the following observations have been retained:

i. Low plant investment was noted when the project is a small expansion job or planned in a developed site location,

ii. For repeated plant jobs, equipment is duplicated at low cost (due mainly to experience gained on the original plant) not only with reference to the Indian price index but also if compared to international price indices.

iii. The advantage of single credit line is obvious, especially for those projects with no tied financial assistance that allows global tendering and procurement from competitive sources.

iv. Infrastructure and off-site costs appear to have an important bearing on the total project costs. In the case of off-sites, it was reported that the high cost was associated with the need for captive power facility and/or in the case of projects based on fuel oil. Safety measures, particularly those associated with power

82/ Study on Fertilizer Plant Cost in India (UNIDO, Sectoral Studies Branch, DIS).

83/ The approach involves the conversion of all plants configurations to a standard-size complex (900 gas-based ammonia/1,500 urea T/D plants), assuming that in each case the project cost should stabilize in two years time from the date of signing the contract.

fluctuations and interruptions which can affect the on-stream factor, necessitated very severely that such facility be installed.

v. A rapid development within the country puts strain on the available infrastructure and hence makes the reliance on the general system of infrastructure within the country not very practical without additional efforts and expenditure to augment it. Thus projects in greenfield locations encountered high cost to develop roads and railway lines including wagons, large ammonia storage facilities etc.

vi. Projects financed by country credits suffered from higher costs because of the conditions that restricted the suppliers, thus limiting for the owner the choice of equipment both for cost and quality. The latter led to further expenses for replacement of faulty manufactured equipment.

vii. Quantifying the impact of indigenization could not be definitive. With the exception of civil engineering work and some manufactured equipment where raw material and components are produced locally, most other functions could not be assessed to determine the impact of their indigenization on the total cost.

viii. The customs and excise duties, sales and other taxes form about 11 to 17 per cent of the basic cost of equipment (and services), a situation that escalates the overall cost of the project by a high fraction.

ix. Delay in completion was noted to range from 10 to 61 months for six of the eight plants (average, almost 24 months) and only one was on schedule. In citing the contributing factors of delays, a few concurrent incidents were observed including:

- lengthy procedure with respect to acquisition of land and for site separation (12 months)
- late delivery of imported equipment (50 months)
- late delivery of indigenous equipment (41 months)
- commissioning problems (24 months).

x. Factors affecting project implementation include State involvement in approving the project parameters (including estimates, foreign exchange resources, equipment supply agreements etc.), the impact of the international oil crisis and the limited experience and/or authority of the project management even when aided by foreign consultants.

xi. Other factors cited for cost overruns include: transportation problems, change in scope of work, untimely completion of supply facility of feedstock or utilities with commissioning, forced indigenization with minimum evaluation of the potentials etc. but it appeared that these factors, usually associated with those mentioned in the earlier paragraph, have less influence in recent projects as optimum solutions are being found with experience.

5.3.3. The point of view of engineering contractors

Although the views of consultants and contractors involved in the execution of the projects analyzed in this exercise were presented in the course of earlier discussion (refer to chart 5) it may be useful to present those views separately particularly since other engineering firms involved in similar projects responded with general remarks based on their experience when they were contacted within the context of this study.

Observations made by engineering contractors concerning the high cost of fertilizer plants in developing countries can be summarized as follows:

i. Contracts designed on a fixed-price basis are usually saddled with large contingencies inserted by the contractor to protect himself. Relevant projects will therefore be more expensive than similar ones implemented in the industrialized regions where the client is capable of supervising an open-cost contract.

ii. In the case of reimbursable types of contracts for projects in certain developing countries, managerial problems have been encountered at times causing delays that brought some escalation.

Cases of this nature were observed when the relevant job was financed by non-profit making organizations (international non-commercial banks/funds etc.) because their bureaucratic procedures had altered the overall schedule. Here any cost saving expected from open-cost contracts were outweighed by escalation associated with lengthy schedule. The same may result when the owner does not have the capacity to monitor such contracts and takes his time in authorizing the implementation of critical elements of the job involved. This can also be quite true when the client's project management is not fully authorized to act fast or with minimum delay.

iii. Quite often, a project in a developing country will be planned in an undeveloped greenfield location. This feature by itself will burden the project with extra cost for the development of infrastructure which may not be particularly related to the "pr per" contract of the plant per se, i.e. harbour and jetty work, roads leading to the plant, railway lines, housing complex, elaborate machine shops etc. Even when the cost of the said infrastructure is not debited to the project in full, and was mainly financed by the State as part of its general development plan, the mere fact that delays associated with its construction result will induce the contractor to increase his prices.

iv. A training programme for the client's staff can add further to overall project cost. But the main problem associated with a training programme will arise when the client, for good reasons, is interested in up-grading the enginering capabilities of his management rather than just prepare his operating staff to take over production activities. In this case, some delays may be expected during the engineering function stage, and the contractor may have to guard against some contingencies.

Chart 3 summarizes the remarks made by engineering firms responding to the questionnaires within the context of this exercise.

Chart 5 Major cost escalating factors in developing countries (consultants/contractors' views)

Contractor/ consultant	Financing	Infra-structure	Delayed decisions	Lack of time consciousness	Owner no/poor proj.manager	Delayed deliveries
A	X	-	X	-	X	-
B	X	X	X	X	X	-
C	-	X	X	X	X	X
D	-	X	X	X	-	-
E	X	X	X	-	X	X
F	X	X	X	X	X	-
G	-	-	-	-	-	-
H	X	X	-	-	-	-
I	X	X	X	-	-	-
K	X	-	X	-	-	-
L	X	X	-	-	-	-
M	-	X	X	X	X	-
N	-	X	X	X	X	-
Total	8	10	10	6	7	2
Percentage	61%	77%	77%	46%	54%	15%

6. MAIN ISSUES ON HIGH CAPITAL COST OF FERTILIZER PROJECTS IN DEVELOPING COUNTRIES

The information obtained through the questionnaires and/or through interviews and discussions conducted within the context of this study leads to the following general conclusions:

- The capital cost of fertilizer projects in developing countries is higher than in industrialized regions.
- While price escalation during the 1970s due to technological changes and inflation had a similar effect on battery limit and off-site cost in both regions, additional cost attributable to location-related cost elements were found for projects in the developing countries. This was particularly noticeable where a domestic engineering industry was not yet developed, and the project being established in a remote area or when the owner's financial capabilities were limited.
- In addition to the cost escalation prospects referred to in the previous paragraph, projects in the developing countries suffered from overruns in cost due mainly to inadequate project planning and formulation and poor management in the execution stage.

6.1 High cost areas related mainly to project formulation and planning procedures

Incomplete or poorly managed functions during this stage will bring about higher than normal investment and production cost at a given period in a given region. The main functions during this stage after a project has been conceived include the following:

6.1.1 Feasibility study

Quite often, especially in developing countries, decisions are taken on the basis of political and social motivations to set up a fertilizer project at a particular location. But usually a pre-feasibility study is conducted to illustrate the viability of the project. To formulate the project it is important that a feasibility study be prepared.

A proper and serious feasibility study is not only essential but vital. The study will serve to determine whether there is really a need for the particular fertilizer project under consideration. The total cost for this stage may not exceed 0.5-1.0 per cent of the estimated project cost. This may seem to be a small amount but the effort required in terms of collection of data, analysis and simulation can be time-consuming.

The main features of the feasibility study involve some critical tasks which identify areas that may bring about capital cost escalation and/or higher production cost.84/

Selection of site

Site preparation could be quite an undertaking should the terrain and soil conditions be such that they require highly expensive site preparation and civil engineering work (foundations, etc.). Furthermore, an undeveloped (green field) location, particularly where a low level of industrialization prevails, could burden the project with extra cost for mobilizing of services and infrastructure needed at a specific time during the construction period and thereafter.

The choice of process technology and capacity

The process technology is usually linked to the desired capacity, subject to the characteristics of available feedstock and the desired product. Although the choice of capacity is usually influenced by the market situation and the economy of scale which in turn is directly related to the process technology, the planners should also take into consideration the level of technological capabilities and conditions imposed by the financing partners that might bring about extra cost. Due consideration must be given to all such conditions at the planning stage.

84/ For detail, refer to UNIDO publication "Manual for the preparation of Industrial Feasibility Studies", Doc. No. ID/206, Sales No. E.78.11.B.5, United Nations Publication.

The interrelated effect of capacity, technology and feedstock on investment and production cost can be noted in Annex II (Figures 2-5).85/ The graphs in these figures should be carefully reviewed if they are to be used in computing absolute figures, keeping in mind that other cost elements are kept constant during construction. Furthermore, there are some limitations with regard to the effect of capacity on cost for certain feedstocks, and this has to be well reviewed.86/

Cost estimation

The most important task (in relation to all issues) to be performed before the implementation of a project is authorized is the cost estimation of the project. The important factors to be considered in order to achieve better results are:

- knowledge of local and world market prices,
- realization of price escalation factors as related to the world and local economic situations,
- capability to predict contingencies within a realistic execution time-table.

The aim of this task is not only to enable the planner to make the economic assessment and evaluation of his project, but also to enable him to define the parameters for the implementation stage.

85/ These graphs were constructed for specific conditions in certain location. For more detail refer to UNIDO Fertilizer Manual (Development and Transfer of Technology Series No. 13), United Nations, New York, 1980.

86/ More information can be found in UNIDO's Fertilizer Industry Series; Monographs No. 1, 2, 3 and 5: (a) Fertilizer production, Technology and Use. (b) Process Technologies for Phosphate Fertilizers (Development of Transfer of Technology Series No. 8, United Nations, New York, 1978). (c) Process Technologies for Nitrogen Fertilizers (Development and Transfer of Technology Series No. 9, United Nations, New York, 1973).

6.1.2 Project formulation

The main issues and features involved in this sub-function include:

Clear definition of the scope of work

For complete assessment of the feasibility of a project, the planner needs to give serious attention to two major issues: (a) financing resources, (b) implementation procedure. To be in a position to insure adequate loans and/or proper schemes in executing the project, a clear definition of the scope of work (identifying management, methodology, principal function, project characteristics and critical activities etc.) has to be done at an early stage to avoid any confusion and to avoid changes at a later stage. In this context, the planner ought to make sure also that all esssential infrastructure which falls beyond the usual plant boundary is defined and arrangements for their undertaking within the project implementation programme or via a separate plan co-ordinated with the government agencies concerned are made at an early stage. Of course the implementation procedure ought to dwell on such important issues as follow-up and monitoring modalities, logistics, organizational responsibilities and type of contract, qualification and particulars of executing personnel and firms, etc.[87/]

Proper timing of the project

When the project is implemented in a country or a region with an intensive development programme, a draw on local (and regional) material, services and skilled manpower, could bring about a competition for these inputs which could result in high cost and time delays. It is therefore imperative that the market situation for these inputs be considered in designing a realistic time table for the project implementation and cost-estimation. World demand situation on contractors and manufacturing firms should also be considered in these estimates.

87/ Refer to UNIDO's publication "Guidelines for Contracting Industrial Projects in Developing Countries", United Nations, Sales No. E.75.II.B.3, New York, 1975.

Well formulated implementation procedure

This involves:

- assigning tasks and responsibilities, identifiying critical functions and activities,
- co-ordinating methodology of all functions that insure speedy and timely completion of all activities,
- monitoring all activities, to insure the required quality and allow quick remedies and changes,
- controlling cost of all functions, and
- type of contract.

These issues would have to be scrutinized throughout the whole process of project implementation. This process may involve certain phases, each of which require special attention and require specific experience, starting with bidding and contract negotiations and ending with commissioning, test-runs and commercial production.

Financing arrangements

The availability of different forms of finance for a fertilizer project and their appropriateness depend on several factors, the most important of which is the owner's capabilities and the location of the plant. The best form of finance is cash which provides the owner with freedom in the selection of equipment, contractors and other services, enabling him to take advantage of the competitiveness of terms offered by different suppliers, assuming of course freely convertible currency. However, there is the problem of having to commit large sums of cash early in the construction period.

The other form is an export credit facility which is usually offered by industrialized countries as a means of financing foreign exchange costs particularly for a country which does not have a developed process engineering industry of its own.

The terms offered by different industrial countries are not identical. The main difference in export credit facilities from different countries would be in the rate of interest and period of credit which depends usually on the foreign borrowers' status or eligibility in respect to resources and level of development. But the common factor is that the eligible costs for export credit are usually the goods and service elements of the project investment to be supplied from the country providing the export credit facility. For this reason, export credits might be obtained at lower-than-the-market rates. Due to this reason which usually imposes further limitations (i.e. choice of contractors and possible interference by credit agencies with desired contractual arrangements) and the requirement of third party guarantees in addition to the time taken in establishing such facilities, export credits may not be as attractive as commercial loans.

In the latter case, other limitations may arise, particularly when loan funds are used to pay eligible suppliers on behalf of the owner-borrower in accordance with specific terms stipulated in the loan agreement; whether such an agreement is drafted in conjunction with a specific type of contract, i.e. lump-sum turn-key, fixed fee-plus-cost reimbursement, etc. Each type of contract has its own particular financing problem which can affect the cost of credit.

Associated with the issue of financing credits from foreign resources, is the problem of future movement of the exchange rate of the currency of the country offering the export credit against local currency which has to be taken into consideration by the borrowing country. It is becoming more apparent than ever that exchange rate movements constitute an important factor in determining the real cost of loan financing, hence affecting indirectly project viability.

Closing the accounts of a project usually lags many months, and often many years, behind the physical completion of the project. There are a number of reasons for this. Some are more or less of routine nature, associated with financial arrangements amd their administration. Invoices and other requests for payment for work done or for material supplied normally take up to three months to process and pay, and that means a three months lag in payment. With some contracts, there may be a cash retention of perhaps up to 10 per cent, to be paid at the end of the guarantee period, normally a year, and that means a further delay in settling the financial accounts. Nowadays, this type of guarantee is being replaced more and more by a "bank guarantee", where the contract is paid up on completion and the bank guarantees to pay the "penalty", in the event that the guarantees are not fulfilled. Such a procedure may save a little on the interest applied.

These are all matters involving payments to contractors. On the other hand, the owner may have been financed by a bank or banks, in which event he may well be repaying his bankers for another five to ten years, depending upon the terms of the loan.

It is the responsibility of the planner to make all financing arrangements with minimum interference and restriction on the modalities of execution, particularly those that limit the choice of engineering consultants and contractors or the sources of equipment and material. The main concern should be the quality of work that ensures speedy and successful execution. Furthermore, the management of financing needs to be organized at an early stage to insure prompt payments. In addition, a source of trouble in insuring prompt payment is quite often inadequate co-ordination and clarity regarding payments when more than one financing institutions is involved. This also has to be taken care of at an early stage.

6.2 High cost areas related to project implementation

Project implementation involves a variety of different but related activities, each one having its own effect on cost if not handled properly or co-ordinated with the others.

6.2.1 Preliminary work

The critical tasks to be undertaken in preparing for the execution of a project and the relevant physical activities comprise certain difficult activities where experience, speed and thorough knowledge and confidence are important. These tasks are the responsibility of the owner and/or his consultant. The most important of these tasks which would have some bearing on any cost variation or on completion deadline include:88/

88/ For more detail refer to UNIDO's publication "The Initiation and Implementation of Industrial Projects in Developing Countries - A systematic approach", United Nations, Sales No. E.75.II.B.2, New York, 1975.

Project team and logistic support

It is advisable for the owner to have his own project team. This may not always be feasible particularly when it is the first project being undertaken by the owner. But, if the owner is a large manufacturing company with substantial technical resources, including management resources, he may find within his organization the nucleus of the proposed team.

Failing to have an in-house project team, it is advisable for the owner to employ an outside reputable consultant to act as his advisor in supervising the project.[89/] It is expected that the consultant identifies himself completely with the owner and the owner's interest and in certain situations acts as the owner's project team.

An important matter that needs to be emphasized in this context is that the owner, once he has chosen his team, should delegate to the team enough authority to dispense with its responsibilities and ensure effective cost control and minimum delay by taking instantaneous decisions about changes in the scope of work or other demanding situations.

Preparation of bidding documents

A vague and poorly defined invitation to bid may, in the long run, prove to be costly for the owner. Some contractors might quote against such an enquiry with a low price but with qualified conditions. The response to a vague invitation to bid can, at best, be also vague. The owner will have no way of comparing such bids since qualifications of numerous provisions and conditions would be extremely difficult if not impossible. Any clarification and adjustment at a later stage will be time consuming, thus causing delays. This is more true if it is the first project ever undertaken by the owner and if he does not have a competent management team or a consultant.

Reputed contractors may shy away from bidding in a vague way but others may be willing to do so. A contractor who intentionally pursues such a

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89/ Refer to UNIDO's Manual on the Use of Consultants in Developing Countries; ID/3/Rev.1; Sales No. 72.II.B.11.

procedure, may get a black mark with a particular owner in a specific country, but he could be getting another "first project" in other places.

Thus there is a need for great care in drafting the bidding documents so that contract conditions and project specifications are related in terms of scope and functions. It is essential that the invitation to bidding represents a clear and specific inquiry, and the bidders given adequate time to prepare clear and specific offers in order to save time during negotiation. Furthermore this will assist in insuring that no other cost items are added at a later date due to oversight or hasty decisions regarding the scope of work.

Selection of bidders

The criteria to be used for pre-qualification of contractors will be drawn from experience of past projects, either by the owner's project team or by his consultant. The most important single factor in this respect is the reputation of the bidder which can only be known through enquiries on the market place.

There are many international contractors specialized in the design and construction of fertilizer projects around the world but several of them are in high demand. Some have particular experience in developing countries. The owner should obtain a list of contractors on the basis of their past performance in some of the recently constructed fertilizer projects in similar regions. The list of pre-qualified bidders should be neither too long nor too short, in order to ensure enough competition on the market place and at the same time a tender evaluation within manageable limits. A total of 3-4 bidders should be optimum if they are selected from a longer list of qualified contractors on the basis of their response to pre-qualification questionnaires and on their capability and willingness to handle the project at the time and location specified.

Tender evaluation

This requires a thorough study and analysis of the various tenders received, not only of the scope of work proposed but also of the exclusions incorporated in the bid.

Even if the bidding document was very precise and bidders were instructed to quote strictly in accordance with the stipulated scope, it is seldom that actual tenders conform to this. The first task, therefore, is to reduce all tenders to the same scope of supplies and services. This may require even quantifying certain supplies and services for which there is no separate price indicated, because in the case of different scopes for various bids, the total price quoted may be meaningless. Bringing all tenders to the same (ideally identical) level is very a important task and can be carried out successfully by reviewing the scope of each tender with the concerned bidder to adjust prices, particularly of excluded items.

Further revision of scope and services after readjusting all prices may be followed with the runner-up of the bidders.

Negotiations and award[90/]

Negotiating a contract is an art or a science the aim of which is to achieve a reasonably economic contract price to both sides with the least ambiguity and pressure in order to avoid future troubles. If the contractor feels that he has accepted an unduly low price because of intense competition, he may try to save at the expense of work quality, i.e. saving on design standards, on safety or overdesign factor, equipment design to barely meet the requirements, etc., all this resulting in equipment failure when the plant is operated slightly above the rated capacity.

Negotiations must be conducted so as to ensure successful project execution, that is to say that the project will be completed in time and within the budget. To be in a position to protect his interest during negotiation, the owner must have been convinced of the merit of the type of contract he likes to have and the scope of work involved, taking into

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90/ Model Contract forms from various sources are included in a UNIDO publication: "Guidelines for contracting for industrial projects in developing countries", E75.II.B.3 and Corr.1, 1975.

consideration the preliminary activities already carried out by him.[91/] Those activities may include such costly items as field investigation which forms the basis for his cost estimates and control during the contract execution. It is noted here that many contractors prefer to carry out their own investigation, thus burdening the project with additional expenses at the outset, particularly if they are to undertake the project on a lump-sum basis at a competitive bidding cost.[92/]

In the case of a contractor bidding for a turn-key lump-sum cost job, he will definitely need to carry out detailed investigations, in detail prior to making his offer. This makes many contractors shy away from such contracts unless they are sure of getting back the expenses encountered, either by incorporating them in the contract cost or by securing compensation in case they lose the bid. In either case the project cost will be increased by additional expenditure.

In the case of fixed cost contracts, the contractor tends to over-price his bid in order to be on the safe side. In other words, excessive assumptions regarding contingencies are made even when enough information is available to make sound estimates.

The more popular type of contract with many engineering/contracting firms is the open-cost contract. A thorough pre-contract investigation may be carried out in order to put a ceiling on the project cost estimate. But the ideal way of handling such a project as far as the contractor is concerned is to base the cost forecast on available information on local conditions plus certain contingencies, provided that the project is clearly defined and there

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91/ Refer to UNIDO's publications: (a) UNIDO Model Form of Cost Reimbursable Contract for the Construction of a Fertilizer Plant, UNIDO/PC.26, December 1981, (b) UNIDO Model Form of turn-key lump sum contract for the construction of a fertilizer plant, UNIDO/PC.25, December 1981, (c) UNIDO Model Form of Agreement for Licensing of Patents and know-how in the petrochemical industry, UNIDO/PC.73, August 1983, (d) Second draft of the UNIDO Model Form of semi-turn-key contract for the construction of fertilizer plant including guidelines and technical assistance, UNIDO/PC.74, August 1983.

92/ Guidelines on the above mentioned forms of contracts are also published by UNIDO, UNIDO/PC.41, June 1983.

is no ceiling imposed on its cost. As the design and development of the project is processed and detailed information is generated, the contingencies for quality, scope and price are re-evaluated and adjusted accordingly. The contractor's concern thereafter is to ensure that all changes are monitored, and their effect on the cost forecasts taken into consideration.

It is usually argued by contractors favouring this type of contract that for each estimated item contingencies are re-evaluated and progressively reduced as the quality of the estimate improves.93/ Such an approach will relieve the contractor of tedious and expensive homework before the contract negotiations begin. But in the meantime it can give the owner some implementation time. Furthermore, it may be a saving in cost for the owner if he has the capacity to monitor and control the cost, particularly if his contractual terms are not so severe and if he has engaged a reputable engineering contractor for the job.

It is to be recalled that, while engineering and procurement cost can be fixed at an early stage, and as relevant activities to these two functions slow down by the time construction activities start (aside from those connected with site preparation and out of boundary infrastructure which may be started earlier), the major part of the open cost will be related to field work, involving mainly manpower and material of construction. Once these two items are controlled, the owner may land with a lower cost than estimated in a fixed cost contract.

93/ For the same project in a developing country two contractors made two different offers; the first was for a turn-key lump-sum cost, the second for a cost-plus job with a ceiling estimate. The magnitude of the fixed cost of the first was almost 20 per cent more than the ceiling of the second estimate. To strengthen his case when the owner insisted on a fixed cost job, the second contractor offered to fix immediately all his software cost, and within one year, once he placed all his orders for major equipments, he would also fix the hardware cost and part of the construction costs, leaving only about 30 per cent of his overall ceiling price open until the second year of the project execution life. It was obvious that the second contractor did not want to take any chance and probably wanted to protect himself with such a low bid to start with.

6.2.2 Execution stage - project management

Project management is an important comprehensive function comprising specific tasks and services. The assignment is to co-ordinate the functions of planning, monitoring of all sections involved in the various project implementation (execution) activities, i.e. estimating, cost control, planning and scheduling, manpower control, etc.

The items affecting the project cost and hence deserving thorough analysis and control during execution by the project management can be categorized as follows:

- manpower expenditure/manpower cost
- bulk material quantities and cost, and
- physical progress achieved.

Deviation from the planned trends in any of the above areas need to be reviewed or reported as soon as they occur, and fast action should be taken to avoid wastage and delays.

To assess the effect of all factors (including variations, changes, etc.) on the degree of completion, the above has to be considered against a time schedule. This implies the design of all parameters of a master schedule to allow the assessment of manpower usage for all significant classes of activities for the project. To do so a manpower loading system and physical progress measurement techniques have to be developed.

For manpower and physical progress measurements, engineering/contracting firms of re-known rely on their own manpower loading and physical progress systems which are considered part of their technological assets and capacity. For instance, in establishing engineering manpower requirement, each firm uses its own established estimating factors and statistical data to forecast the number of engineering hours for each class of work and for associated project service function. Based on that, the engineering schedule is established, allowing manpower loading to be set up for each work class, relating manpower predicted and expanded with the scheduled completion date.

The most important task in relation to the above mentioned parameters is cost control. Cost control is a continuous process to review expenditure and predict future costs against planned cost. The planned cost is usually the sum of estimated cost and related contingencies. Their magnitude is governed by the quality and details used to develop the estimated cost and the assurance that can be ascribed to that estimate in terms of accuracy and completeness.

In many cases when detailed feasibility studies and thorough field investigations have been conducted, the clarity of the scope of work and up-to-date information result in better cost estimates. This is usually the case when the owner is capable of handling the task himself or with the assistance of a reputed engineering consultant. The extra cost involved in this task may save on time and misunderstandings resulting in escalated cost in the future. It could also render the basis for a lump-sum contract with minimum contingencies.

Although the issue of cost control is very important when an open-cost contract is involved, the monitoring of work in progress is an important task for the owner to undertake in any type of contract.

For owners who can handle open-cost contracts, particularly if they prefer departmental execution without the help of consultants, the preparation of a good budget estimate (preliminary cost estimate) is very important. The cost and quantities set forth in this estimate shall serve to budget each function and to review the preparation of the control estimate when the work started. By this time all information required for analysis has been gathered, evaluated and interpreted for more accurate cost prediction. To maintain accurate cost estimate for elements of project cost, comparisons of current predicted job costs with authorized costs must be made as soon as any measurable portion of the design work is completed when specifications and quantities of material are generated. This will allow a clearer view of the cost and schedule for equipment and bulk commitment. Furthermore it will show the trends in direct expenses, growth due to changes in scope and other activities that warrant attention.

Significant variances in cost estimates and conditions should be the subject of immediate action and ·ttention by the owner, particularly if the variances are the result of a change in scope of work.

Changes in scope of work can be drastically reduced if a step-by-step approach is adopted, although mistakes can never be entirely eliminated. Such an approach involves the following sequential steps:

- Completion of the basic project design and definition;
- starting detailed engineering and procurement only after the process flow sheets and line diagrams have all been finalized (as part of the basic design activity);
- starting site activity when detailed design and procurement for the whole project is within six to nine months of completion, unless heavy site preparation and extra developmental infrastructure is needed on the site location.

If this procedure is followed, change may be minimal and the targets for cost and time will almost certainly be met. Unfortunately this approach prolongs the design and construction period very considerably, and that can cost money, but this money is worthwhile spending, assuming that the procurement function is well catered for. The later part refers mainly to timely delivery of equipment.

To maintain delivery time for all important equipment during procurement, the time schedule should be scrutinized with minimum revisions caused by disturbances on the market. Furthermore, inspection of all items should be carried out immediately upon delivery, and when discrepancies in specifications (i.e. coverage, shortages, damages, etc.) are revealed, appropriate fast action with regard to claims against vendors, carriers, or insurance firms should be initiated to affect fast replacement rather than to just define the responsibility for compensation. This will avoid delays during erection, but more so during commissioning.

Early placement of purchase orders with commencement of fabrication as soon as practical is an important feat. However, this has to be synchronized with other related matters such as storage charges, financing conditions in regard to payments, etc. For this reason, early placement of purchase orders with deferred commencement of fabrication may result in a higher purchase price but lower storage charges and financing cost. However, this has to be weighed in order to determine the least costly alternative.

6.3 The role of UNIDO

6.3.1 Workshop on high cost of fertilizer projects

An attempt has been made in this study to identify extraordinary high cost elements in the execution of fertilizer projects in developing countries. Quantification of all cost items, however, was not possible either due to lack of information or because of the abstract nature of the cost elements involved. Yet parameters characterizing areas of high cost were analyzed in detail, which renders further work much easier.

The methodology followed in this study needs to be ascertained or modified for the preparation of a model costing approach against which actual capital costs of fertilizer projects (preferably of similar scope) in various countries could be checked. If the exact scope of work in each case is known, a realistic factor can be applied to bring various projects to the same level for comparison purposes. Cost indexation models of specific plant categories with regard to technology and capacity will form a basis for such comparison.

The index will then need to be corrected for specific local conditions and other intangibles, such as:

- economic climate,
- fiscal policies,
- level of investments,
- financing charges, etc.

To achieve this, it is suggested that UNIDO sponsor a workshop, convening selected groups of different people involved in various functions pertaining to fertilizer project implementation from the industrialized as well as the developing countries. Papers based on experience in recent years as well as relevant studies prepared by UNIDO should provide an appropriate basis for discussion in developing such a model.

6.3.2 Training programme pertaining to the subject of cost control

Cost control is a very important means in averting overruns. It is an essential activity that should start at the formulation stage and continue until the test-runs of the plant have been effected. The main objectives of this activity is to help the project management to keep expenditure within budget, and to insure project completion on time, through:

- monitoring the costs as the project develops,
- evaluating cost trends,
- forecasting final cost,
- providing relevant data at the right time and in an appropriate manner to enable the management to take appropriate fast decisions in respect to changes in the scope of work, with full knowledge as to the cost implications of these changes.

Cost of fertilizer projects ought to be controlled by the owner as well as the engineering contractor since each has an interest in preventing waste. The starting point for pursuing this activity will be when the budget has been set. An important stage where cost control is affected begins with engineering design. During the construction stage, cost control will be mainly to record cost and remedy deviations.

Most of the relevant literature on the subject of cost control is found with engineering contractors and probably some financial institutions. Many project owners in developing countries are not yet fully aware of the subject or of its importance in the follow-up process of project execution. This issue assumes particular significance when reimbursable-cost contracts are involved in implementing a project.

Accordingly, it is proposed that UNIDO sponsor a project with the objective of training a group of technical staff from developing countries on cost control and follow-up activities pertaining to fertilizer projects implementation.

6.3.3 Inflation index applicable to specific regions

As it was noted earlier in this text, inflation indices have been developed and adjusted continuously. Many industrialized countries and very few developing countries have developed their own price indices, and some of these indices were specified for a group of homogeneous, identical or interrelated activities (i.e. manufacturing, oil refining, etc.). Furthermore, some of these indices were used to develop a generalized index on a worldwide basis or on a regional basis but mainly in the industrialized countries.

The adoption of a similar approach to that mentioned above would be very beneficial for developing countries to develop a practical price index of their own tailored for chemical equipment and construction services. The index should be dynamic in relation to location and time.

UNIDO could assist in developing such an approach on a regional or sub-regional bases. To shed a light on the particulars of such an approach, more information and detail may filter through the deliberation of the seminar mentioned in 6.3.1.

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary and conclusions

To meet the objective of this study, a thorough assessment was made of overruns in capital cost of fertilizer projects built in developing and in industrialized countries. Empirical data and information collected from different parties involved in project implementation as well as information available in literature were utilized for this purpose. Modalities and functions of project execution were discussed in detail in order to identify ways and means of averting excessive overruns particularly in areas of significantly high cost. Following is a summary of the findings of this analysis:

1. Cost overruns have occurred in 80 per cent of the projects reported by the developing countries. The average increase in the cost of those projects has been about 100 per cent over the originally estimated cost. The same projects have suffered from delays in execution, and the average execution period seems to have been about 120 per cent over the scheduled time table. In some cases, the planned budget and time schedule have been underestimated. But in some cases the overrun in cost and execution time was very significant in real terms, even for well planned projects.

2. The capital cost of fertilizer projects in the developing countries is higher than that of similar projects in industrialized countries. While price escalation during the 1970s due to technological changes and inflation should have a similar effect on battery limit and off-site cost in both regions, additional cost in respect to location-related cost elements must be added for projects implemented in the developing countries, particularly for projects established in remote areas. However, the cost of location-related elements was found to be exaggerated in the case of some projects.

3. Comparative analysis of the capital cost of fertilizer projects in different regions indicated that although no two projects are ever alike in their scope, for many projects the cost structure pattern was found nearly identical. For these projects, the following average indices for overall

plant and project costs in different regions and with differing levels of delays have been derived:

Region	Plant cost	Project cost	Remarks
(a) Industrialized region	100	125	well developed location
(b) Developing region	116	197	fairly developed location
(c) Developing region	138	233	encountering severe delays

(basis: turn-key plant cost = 100 in a well developed location)

4. The difference in plant cost between (a) and (b) regions (16 per cent) can be attributed to contractual stipulation and/or inefficient management since the cost here represents the stripped cost of software, hardware and construction (turn-key plant cost) which needs not be significantly different from one location to another. Part of the high cost could be attributed to unusually high stocks of spare parts.

5. The difference in the project cost (which include the 16 per cent difference in plant cost) between (a) and (b) regions is higher by 58 per cent (i.e. 197 : 125) over the difference in plant cost. This variation can be attributed mainly to location-related cost elements, namely:

- freight and insurance, including storage and delivery of equipment and materials to the site, which constitute 3 to 11 per cent of the overall project cost,
- site preparation and services needed during the construction period, particularly in a greenfield location which is 1 to 4 per cent of the overall project cost,
- out-of-plant boundary (economic/social) infrastructure particularly in greenfield location which amounts to 4 to 6 per cent of the overall project cost,
- pre-operational activities, including preliminary investigations and feasibility study, training, excessive quantity of spare parts and wasted inputs during initial runs and of contingencies which amount to 4 to 19 per cent of the overall project cost contingencies, etc. and
- taxes and custom duties which constitute 2 to 12 per cent of the overall project cost.

6. Location-influenced cost elements are affected by the level of development of the country, State policies and regulations, geographical/physical characteristics of the site, international freight market situation, etc. Accordingly, part of the overrun connected with the location-related cost elements could be averted with proper planning of relevant functions during different stages of implementation.

7. Excluding taxes and custom duties, the location-influenced cost elements (including their portion of the interest) account for an average of 29 per cent of the overall project cost. In extremely severe cases (remote undeveloped location), this figure is much higher. In the case of delay in project execution, the location influenced cost elements increase the overall project cost by 18 per cent and the plant cost by 10 per cent. This difference can be explained by the fact that the equipment and construction cost which constitute the major part of the total cost is influenced by inflation during delays more than the other cost elements, i.e. site preparation, preliminary study, training, etc.

8. In addition to cost escalation related to the owners' limited financial capabilities, currency fluctuations, normal inflation and location incidents, projects in the developing countries suffered excessive overruns in cost due mainly to inadequate project planning and formulation and poor management in respect of the execution as manifested by the extremely long time schedules and over-priced cost components in some cases.

9. The major result of delay would be: inflation-driven overrun in plant cost, higher financing cost and possible currency fluctuation. The combined effect of currency fluctuation and interest (during the construction period) accounted for 7 to 20 per cent of the total project cost (with a weighted average of 10 per cent).

10. It is to be maintained that a major factor causing delays is poor implementation modalities or inefficient execution management. Other factors include force majeure, industrial relation problems, financing constraints, political instability, heavy (congested) developmental programme within the country or the vicinity of the location, etc. The effect of some of these factors might well be tuned down with proper planning.

11. The major causes for delay as noted by most owners are the late delivery of equipment. This might be attributed to poor management related either to inefficient engineering work or to ineffective co-ordination procedures and late placement of purchase orders. Other shortcomings of poor technical management leading to delays include: changes in scope of work in mid-stream, inadequate cost control and follow-up procedures, lack of experience and lack of authority to take fast action.

12. An important point, worth focussing upon, is the contractual modalities since overrun in plant cost depends not only on the technical and management capacity of the main contractor or the owner but also on the contractor/consultant, costing procedure, type of contract, contractual terms and conditions particularly with respect to performance guarantees, liabilities, indigenization, budgeting, etc. These factors could contribute directly to the overrun in plant and project cost.

13. In almost all cases a semi-reimbursable contract was used for building the reported fertilizer plants and in most cases, the main contractor and/or consultant were from industrialized countries. In a few cases local sub-contractors were engaged for construction and at times equipment was procured locally. But in general indigenization has not been pursued seriously, and its impact could not be accurately substantiated. Furthermore, in most cases, the owner's involvement in project execution was minimal and with frequently reported shortfalls.

14. The foreign exchange portion constituted 23 to 74 per cent of the total cost of projects implemented in developing countries (with an average of 44 per cent). It constituted 30 to 80 per cent of plant cost (with an average of 54 per cent). For plants built in industrialized regions, only one project entailed a foreign exchange portion amounting to 5 per cent of the overall cost.

15. When outside financing was involved (as reported for eight projects in developing countries), the credit was in the form of tied-up loan (except for one project). In most cases this has imposed certain limitations on the choice of contractors, vendors and even the form of contract.

16. Aside from financing and the cases of joint ventures, no other form of co-operation in building fertilizer plants in developing regions was reported between developing and industrialized countries or among the developing countries themselves. It was noted from the performance of some developing countries with respect to their second or repeated job that they had gained good experience and could be in a position to compete in the international market against international firms for the construction of new projects. These countries could assist other developing countries in building their fertilizer projects.

7.2 Recommendations

In discussing the areas of excessive high capital cost of fertilizer projects in developing countries, it has become obvious that overruns can be reduced by improving and upgrading the management capacity of owners. In this respect, different aspects of project planning and implementation have been discussed in detail in order to identify areas of critical importance, such as:

- improving the planning capabilities of project owners in developing countries in order to formulate viable projects with a clearly defined scope of work. A project feasibility study must identify all critical parameters such as the site and process technology, realistic estimate of cost and time schedule, financial arrangements, adequate implementation procedure and close co-ordination of all relevant activities,

- improving project implementation management capacity of the owner in order to enable him to obtain suitable contract(s) for the execution of the project and to ensure proper monitoring and cost control with minimal changes in the scope of work in mid-stream.

To achieve the main objectives of cutting down cost and of avoiding delays during the implementation of fertilizer plants in developing countries in the light of the findings of this study, an action-oriented programme could be suggested as follows:

a. Co-operation between industrialized and developing regions involving such activities as:

- The application of UNIDO's Model Forms of Contracts for the construction of fertilizer plants, since these contracts were negotiated and approved by the various parties involved in the implementation of fertilizer projects;
- affect the finalization and application of the multilateral insurance scheme to provide adequate coverage for consequential losses incurred by fertilizer plants;
- provide or ensure adequate financing to assist developing countries in building their plants with minimum restrictions and conditions in respect to choice of contractors, technology, etc., regardless of the sources of these, credits whether they are on a State-to-State basis, an export credit grant or guarantees covering credit offered by exporters to owners in developing countries.

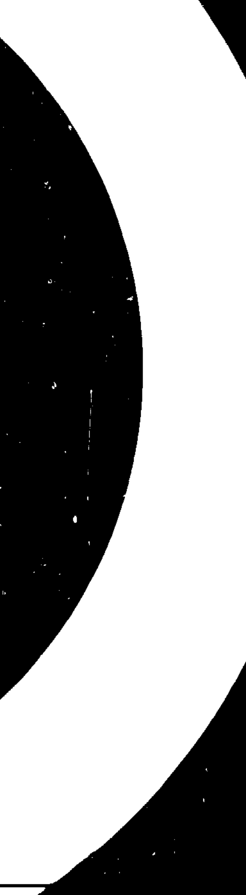
b. Co-operation among developing countries which may involve:

- offering of easy loans or preferential rate discount on state loans to prospective fertilizer plant owners in other developing countries;
- encouraging engineering and contracting firms in developing countries to participate in the construction of fertilizer plants in other developing countries in order to expand their experience and to reduce cost;
- provide technical assistance in the form of experts to help other developing countries in the planning, formulating and implementing of their projects;
- encourage the expansion of capital goods industry in developing countries, particularly those that are already in a relatively advanced stage of development in order to develop their technological capacities and thus lower the cost of future projects, taking into consideration maximum indigenization on a country level as a target and a mean for all developing countries for lowering project costs;
- facilitating the flow of low cost construction labour among the developing countries on regional and sub-regional levels, keeping in mind that indigenization on a country level is an ultimate goal;

- provide training facilities to upgrade the level of engineers and construction technicians of other developing countries, whether via multilateral or bilateral arrangements;
- facilitate the exchange of experience in the construction of fertilizer plants via literature, regional and sub-regional workshops, etc.

c. UNIDO's potential role in catalyzing all relevant activities is important. The need for technical assistance and publications and in particular guidelines for reducing capital cost of fertilizer projects cannot be overemphasized. However, specific topics of a critical nature have been proposed as developmental projects which UNIDO is well placed to perform, including:

- Workshop on high cost of fertilizer projects,
- training programme pertaining to cost control,
- development of inflation index applicable to specific regions to assist developing countries in their cost estimation exercise,
- elaboration of maximum indigenization policies and plans,
- guidelines for project management and capital cost control of fertilizer plants.



For the guidance of our publications programme in order to assist in our publication activities, we would appreciate your completing the questionnaire below and returning it to UNIDO, Division for Industrial Studies, P.O. Box 300, A-1400 Vienna, Austria

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QUESTIONNAIRE

Capital cost control of fertilizer plants in developing countries

	(please check appropriate box) yes	no
(1) Were the data contained in the study useful?	/_7	/_7
(2) Was the analysis sound?	/_7	/_7
(3) Was the information provided new?	/_7	/_7
(4) Did you agree with the conclusion?	/_7	/_7
(5) Did you find the recommendations sound?	/_7	/_7
(6) Were the format and style easy to read?	/_7	/_7
(7) Do you wish to be put on our documents mailing list?	/_7 If yes, please specify subjects of interest	/_7
(8) Do you wish to receive the latest list of documents prepared by the Division for Industrial Studies?	/_7	/_7

(9) Any other comments?

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(2 of 2)

CAPITAL COST CONTROL OF FERTILIZER PLANTS IN DEVELOPING COUNTRIES

ANNEXES

Sectoral Studies Series
No.8, Volume II

SECTORAL STUDIES BRANCH
DIVISION FOR INDUSTRIAL STUDIES

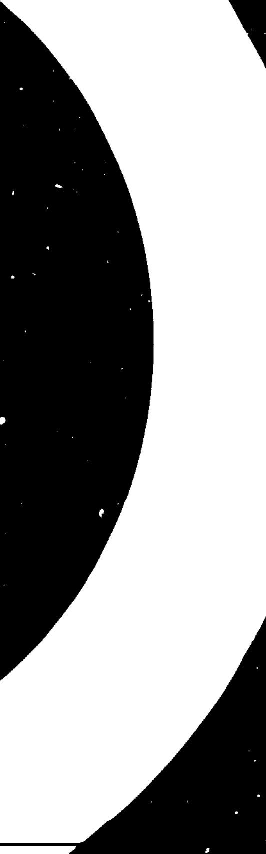
V.83-65577

Main results of the study work on industrial sectors are presented in the Sectoral Studies Series. In addition a series of Sectoral Working Papers is issued.

This document presents major results of work under the element Studies on Fertilizer Industries in UNIDO's programme of Industrial Studies 1982/83.

Preface

This annex contains basic data and information supplementing the analysis of Volume I of the study entitled "Capital Cost Control of Fertilizer Plants in Developing Countries". The annex contains in addition to data and information the questionnaire used as well as some experience from the World Bank with regard to fertilizer projects implemented in developing countries.



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I. QUESTIONNAIRE AND EXTRACTS FROM THE RESPONSES

A questionnaire[1/] was mailed to over 200 selected parties comprising owners, consultants, contractors, associations and government departments who are generally concerned with planning, design, construction of fertilizer projects and manufacture of fertilizers both in the developing and the developed countries.

A total of only 29 responses relating to 25 projects in eleven developing countries and three developed countries were received from various parties, as follows:

-	associations	3
-	consultants	2
-	contractors	6
-	owners	18

Projects reported in these responses are given alphabetical letters to conceal their real identity (name, owner, location etc.) in compliance with the request of respondents, i.e. projects A, B, C etc. A country-wise distribution of the various responses as made by various actors is as follows:

Countries	Projects (as reported by actors involved)
C_1 (developing country)	A* (Ow)
C_2 (developing country)	B* (Ow), C (Ow), D (Ow)
C_3 (developing country)	[illegible] (Ow)
C_4 (developing country)	F (Cr)
C_5 (developed country)	G (Ow) - 6 allied projects
C_6 (developing country)	H (Ow), I (Ow), J (Ow + Cr)
C_7 (developing country	M* (Ow + Cr), also Ct; part project
C_8 (developed country)	N (Ow)
C_9 (developing country)	O* (Ow)
C_{10} (developing country)	P* (Ow)
C_{11} (developing country)	Q (Ow)
C_{12} (developing country)	R (Cr)
C_{13} (developed country)	S (Cr)
C_{14} (developing country)	T ((Ow), U (Ow)

* = Projects covered by the World Bank Feasibility/Appraisal Report
Ow = Owner, C = Contractor Ct = Consultant, C = Country

1/ A blank sample of the questionnaire is following on pages 3-13.

Relevant extracts from the response received are attached hereto. This information follows the same order as the blank questionnaire. Major issues which appeared frequently in the responses were used to crystallise the real reasons for time and cost overruns and served as basis for the proposed guidelines to minimize the capital cost of future fertilizer projects in the developing countries.

The information extracted from the questionnaires is presented in the following order, wherever applicable:

- General information
- Cost structure
- Major problems: as identified by the owner (and in some cases by the consultant or the contractor)
- Lesson learned: as noted by the owner
- Action suggested for future projects: suggestions proposed by the owner team
- Remarks in respect of the project made by a third party, i.e. World Bank, etc.

Questionnaire on CAPITAL COST OF FERTILIZER PROJECTS

(kindly reply in relation to a SPECIFIC recent project)

1. PROJECT: Name

   Owner

   Location

   Country

   Site - Greenfield/Existing - Developed/undeveloped

   Extensive site preparation (yes/no), land filling (yes/no), piling (yes/no)

2. BIDS: Prequalification - Yes/No

   Number of Bids

   Competitive International Bidding - Yes/No

   Tied Aid - Yes/No

   If Yes, state source(s) and respective amount(s) please

3. CONTRACTING:

   Contractor:

   Main process licensors:

   Type of contract: Turnkey/Semi-Turnkey/departmental:

   Payment: fixed price (lumpsum)

   reimbursable

   fixed fee and reimbursable

4. TIME SCHEDULE: Kindly indicate month/year: Scheduled Actual

	Scheduled	Actual
Project conceived		
Feasibility study		
Bids invited/evaluated		
Contract signed		
Completion (mechanical)		
Start up* - First production		
Commercial production		
Capacity utilization (1981), %		

* Any major problem ? Yes/No if yes, what?

5. CAPACITY/COST

A. Battery limits

	Capacity (Nameplate) Metric Tons/day	Cost Million $		
		Local Currency	Foreign Exchange	Total
Ammonia (gas/naphtha/heavy fuel oil/coal/other) - Kindly specify				
Urea				
Ammonium Nitrate/ Calcium Nitrate				
Sulphuric Acid (S/Pyrites /Gases/Others) Kindly specify				
Phosphoric Acid, (Process)				
Phosphatic Fertilizer: SSP				
TSP				
DAP				
Compound Fertilizer: NPK				
TOTAL PROJECT COST:				

Notes: (1) Kindly EXCLUDE off-sites and infrastructural facilities such as roads, railway siding, workshop, township, etc. (see B below)

(2) Kindly indicate, SEPARATELY, capacity and cost (complete) or utilities; also of storage for various products (as follows):

B. Utilities

	CAPACITY	Cost in MILLION $		
		Local Currency	Foreign Exchange	Total
Power station/Steam generator				
Fresh or saline cooling water system				
Power supply/distribution from existing sources				
Substation for supply from external grid				
Total*				
Storage (in terms of number of days production). Please indicate total storage capacity in bulk and bags.				
Ammonia				
Urea				
AN/CAN				
Sulphuric acid				
Phosphoric acid				
TSP				
DAP				
NPK				
Total*				

* If detailed brakdown is not available, please mark the items concerned and indicate the total cost.

6. COST BREAKUP

	Project cost (in m US$)*		
	Local Currency	Foreign Exchange	Total
A. Software and personnel services			
License fees			
Process design (basic/frontened engineering package)			
Detailed engineering			
Construction supervision			
Commissioning			
Training			
B. Hardware			
Plant and equipment for battery limits and off-sites (utilities and storage)			
Spares (for ... years)			
C. Construction			
Civil engineering building and structures			
Mechanical erection, electrical and instrumentation			
Supervision			
D. Financial			
Interest on loans			
Financial charges			
Suppliers credit			
Additional cost due to currency fluctuation			
E. Others			
Land - site preparation, including development			
Catalyst/consumables			
Raw materials			
Freight and insurance			
Duties and taxes			
Preliminary expenses			
TOTAL			

---

* In case of difficulties in specifying amounts, please indicate in percentage of total cost.

7. MAJOR PROBLEMS (Kindly elaborate)

A. With consulting company

(most important): 1

2

3

B. With prime contractor:

(most important): 1

2

3

C. <u>With subcontractors:</u>

(most important) 1

2

3

D. <u>With vendors:</u>

(most important) 1

2

3

8. TIME/COST OVERRUN

	Time, months	Cost, million $
Scheduled		
Actual		
Per cent overrun		

9. MAIN REASONS FOR OVERRUN (kindly elaborate and attach additional sheets) if required)

(most important) 1

2

3

4

5

10. <u>IMPORTANT LESSONS LEARNT FROM THIS PROJECT</u> (and how would you apply them to future projects) Kindly attach additional sheets if required.

(most important) 1

2

3

4

5

11. HOW COULD YOU HAVE REDUCED THE PROJECT COST? Kindly indicate this in SPECIFIC terms. Attach additional sheets if required.

(most important) 1

2

3

4

5

12. IF YOU COULD START ON THE PRESENT PROJECT ALL OVER AGAIN, WHAT WOULD YOU DO DIFFERENTLY? - in specific terms - Please add additional sheets if required.

(most important) 1

2

3

13. REMARKS:

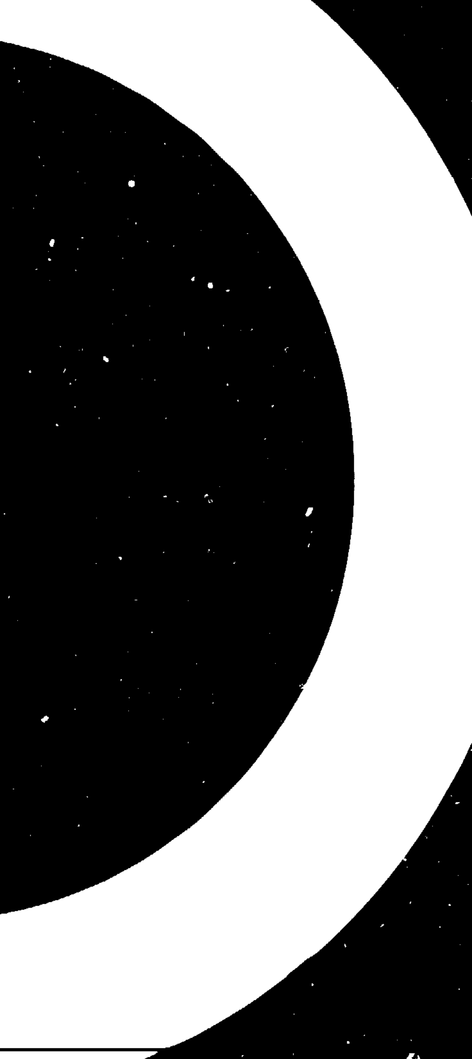
Name:

Address:

Telephone:

Telex:

Residential phone (if you do not mind):



ANNEX I.2 EXTRACTS OF INFORMATION ON PROJECTS

PROJECT A

1. General
   - developing country - reported by owner
   - ammonia (930 T/D) + Urea (1600 T/D) plants
   - greenfield, undeveloped site, land filling, part piling
   - tied aid (from 2 developed countries (-15% of total project cost)
   - contractor (developed country) fixed fee plus reimbursable
   - total project cost: $ 426 million (foreign exchange $252 m) estimate $ 249 m (World Bank Appraisal) with foreign exchange $ 142 m.
   - project completion: December 1981, 80 months, 40% overrun.

2. Cost structure (m$)

- software	62
- hardware	103
- construction	79
- interest	36
- duties and taxes	42
- preliminary expenses	40
- land development	17
- currency fluctuation	17
- freight and insurance	13
- housing colony and railway siding	17
	426

3. Major problems

a. with consultant - one of the financial institutions (developed country)
   - insisted on awarding consultary contract to a firm (from developed country) with no experience in management of large fertilizer plants. This contract had to be terminated and the consultant was changed, thus resulting in unnecessary loss of time and money.
   - poor planning
   - lack of knowledge of exact itemwise requirements
   - lack of follow-up with suppliers

b. with contractor (foreign, from develope developed country)
   - considerable overrun in reimbursable costs (60% in man-months and 330% in vendor representative costs)
   - no experience on projects of this type
   - lack of proper communication with constructors' head-office
   - inexperience on rotary machines, electrical equipment and instrumentation
   - enormous confusion re: scope of supply by vendors.

c. with sub-contractors (local and foreign)
   - too many subcontracts (foreign, developed country)
   - major accidents: chemical cleaning solution going into secondary reformer, ammonia storage tank seriously damaged etc.
   - idle time due to non-availability of requisite materials

d. with vendors (foreign, developed and developing countries) - delay in delivery
 - confusion in scope of supply

4. Lessons learned

- Contractor must have adequate experience
- Owners team must form a part of the contractor's construction team.
- Select a "model plant" for purposes of training and learning
- Electrical and instrument subcontracts must be on a "package" basis
- Price for specialized equipment (e.g. compressor) should include
  a. erection supervision
  b. pre-commissioning
  c. commissioning
  d. vendors service charges
  e. warranty for 18 months after commissioning
- Adequate storage for inspection of materials received
- Procurement from site with back-up from contractors' home office.

5. For future projects

- Engage a minimum number of subcontracts
- Fixed fee and service charges and a contract ceiling price
- Simpler instrumentation

6. World Bank Appraisal Report on this project anticipated major problems and risks involved giving the following reasons:

- The proposed complex plant considered as formidable undertaking in the country's current state of economic development
- Further equipment price escalation in a strong seller market
- Delays in equipment deliveries from fully booked suppliers.

The report also warned of costly delays in project management.

PROJECT B

1. General
   - developing country, reported by owner
   - ammonia (900 T/D) and urea (1100 T/D)
   - greenfield, undeveloped site, extensive site preparation, land filling/piling
   - total project cost: $ 283 million (foreign exchange $ 82.4) international financial loan: from developed country)
   - departmental execution: purchasing and construction by owner
   - license engineering through direct negotiations. No competitive bidding
   - mechanical completion July 1982. Commercial production January 1983

2. Cost structure (m$)

a.

- battery limits	175
- utilities	42
- storage and handling	27
- others	39
	283

b. cost elements

- software	36
- hardware	102
- construction	36
- interest	25
- land development	10
- freight and insurance	8
- price escalation	29
- contingency	17
- working capital	15
- others	5
	283

3. Major problems
   - No previous experience on plants of this size
   - Fabrication and project errors of some machines
   - Quality control not so rigid during construction
   - Construction during the "boom" of a major petrochemical complex in the country
   - Engineering/purchasing during the oil crisis
   - Problems during start-up due to:
     . deflective instrumentation and machinery
     . failure of one auxiliary boiler and dirt in the steam generation system

4. World Bank Appraisal Report envisaged project cost of $ 283 million and commercial production Jan. 1, 1981. The project seems two years behind schedule but without any cost overrun. The scheduled 4 years to commercial production was stated to be longer than estimated for similar bank-financed projects elsewhere. However, it was thought of as realistic , considering:

   a. low level of industrialisation in the proposed plant location area
   b. somewhat complicated co-ordination procedure between the two concerned national companies and the engineering companies.

PROJECT C

1. General
   - developing country, reported by owner
   - ammonia (1200 T/D) and urea (1500 T/D) - also sulphur recovery unit (58 T/D) and methanol unit (24 T/D)
   - existing developed site adjacent to a petroleum refinery which furnishes the necessary feedstock (= high sulphur residual petroleum fraction)
   - packaged units from individual suppliers
   - total project cost $ 532 m (foreign exchange = $ 159 m)
   - completion: Feb. 1983. 100% overrun in time and cost. Original estimate 40 months and $ 272 m.
   - major reason for overrun: Pre-operational problems

2. Cost structure (m$) - 5 months before completion

- software	38
- hardware	171
- construction	59
- supervision and pre-operation	81
- interest and repayment during construction	103
- railroad	4
- land development	6
- taxes and fees	9
- others	12
	483

3. Major problems
   - critical equipment was first time deliveries from local suppliers.
   - Late purchase of items (mainly electrical and piping) not originally provided for in the scope of work
   - Problems during commissioning:

a. Ammonia plant
   - refrigeration unit (from developed country) underdesigned
   - liquid nitrogen wash plant (from developed country) grossly underdesigned
   - shift converter - bad distribution of gas in the catalyst bed
   - HCN stripper - does not meet specifications (25 PPM of HCN in the column effluent)
   - air separation plant (from developed country) spray cooler outlet air temperature over 12°C (against design of 8°C)
   - atomizer guns for gasifiers - life time too short - 200 hours instead of 1200 - 2000 hours
   - instrument air compressor (from developed country) - underdesign and excessive vibration
   - ammonia storage area refrigeration compressor - underdesigned
   - air compressor turbine (from developed country) high vibrations, also does not operate over wide range of speeds
   - nitrogen compressor (from developed country) failure of a twisted blade

- high pressure feedstock pump specified for 150°C (actual: 190°C)
- flare system overdesigned and stock height and function not according to normal established standards
- deionized water system and steam system - water and steam consumption higher than expected

b. Urea plant

- CO_2 compressor turbine (from developed country) - steam leeks through bolt holes
- high pressure ammonia pumps (from developed country) - experimental design, mechanical failures of valve spring, connecting rod pin and brushing
- carbonate pump - low efficiency
- ammonia pumps (from developed country) - damping gets damaged very quickly and the bladder not as per specification
- urea weighing machine (from developed country) - not suitable for hygroscopic material, urea adheres to the wall
- CO_2 compression (from developed country) - gas flow instability in the 2nd casing due to a "rotating still" - also underdesigned.

c. Others

- steam balance - very tight
- elective supply - not completely trustworthy

4. To reduce project cost and operating cost the following were recommended:

- improvements in fuel economy, e.g. use of steam from urea plant during start up to pre-heat boiler feed water
- sampling system to analyse oxygen in the gas auxiliary boiler to reduce excess air required for efficient fuel burning
- recuperation of waste oil
- use of additives carbon oil to reduce deposition of heavy metal high temperature
- utilization of waste fuel gas (from refinery) in auxiliary boiler
- use of heavier feedstock available refinery with appropriate change in plant
- reacceleration of motion devices plunger pump of gasification.

5. For future plants

- better layout
- two auxiliary boilers instead of one
- four gasifiers instead of three
- thrustworthy power supply
- additional compressor (oxygen or nitrogen) preferably motor devices
- improved affluent treatment system
- storage capacity: Feedstock to suit refinery operations, and for ammonia to suit market conditions

6. World Bank Staff Project Report (April 1976): Project cost was estimated at $ 272 million, a basis of prices as of end 1975, including provisions for contingency and price escalation. Price escalation was too low since engineering had already progressed and most equipment already ordered on fixed price basis.

PROJECT D

1. General
- developing country - reported by owner
- phosphate fertilizers

Sulphuric acid	2 x 1300 T/D	Contractor A (DC)
Phosphoric acid	2 x 470 T/D	Contractor B (DC)
Triple superphosphate	1 x 1040 T/D	Contractor C (DC)
Monoammonium phosphate	1 x 1000 T/D	Contractor C (DC)

- undeveloped site, extensive site preparation
- no information on time and cost overrun. Start up July 1980.

2. Cost structure (m$)

- software		48
- hardware		79
- construction		68
- land at site improvements		23
- pre-operating expenses		23
- freight, insurance and taxes		7
- interest during construction		19
- installed cost		267
- working capital		42
	Total	309

Phasing of expenditure (m$)

1977	34
1978	88
1979	122
1980	54
1981	15
	309

Costs plant-wise (m$)

- sulphuric acid	43
- phosphoric acid	71
- TSP	36
- MAP	32
- Offsites + utilities	44
	225

3. Major problems: No information furnished.

PROJECT E

1. General
   - developing country - reported by owner
   - ammonia 540 T/D, urea 940 T/D
   - existing developed site preparation and land filling
   - tied aid - one (from developing country) of the four financing sources. About $ 10 million.
   - Contractor (developed country) - fixed fee for design, engineering, procurement, training, erection and start-up
   - project cost $ 181 m (foreign exchange $ 115 m), 20% overrun
   - completion Aug. 1980 - 67 months - 70% overrun
   - commercial production Sept. 1981

2. Cost structure (m$)

- software	33	(includes reimbursables to contractor)
- hardware	72	
- construction	10	
- site preparation	5	
- pre-operating expenses	27	
- freight, insurance and duty	20	
- interest during constr.	12	
- others	2	
	181	

3. Major problems

   a. with consultant (developed country)
      - project manager: performance unsatisfactory and was replaced
      - consultant could have helped owner set up his project organisation

   b. with prime contractor (developed country)
      - delay in organizing project team of head office
      - construction progress unsatisfactory
      - poor performance of expatriate supervisors
      - communication gap between contractors' site office and head office

   c. with sub-contractor
      - poor performance (local and foreign - developed country)
      - poor supervision (local and foreign - developed country)

   d. with vendors
      - cost of rectifying object in their equipment had to be borne by the owner
      - cost of vendor servicemen - excessive technicians and their overtime rate and holiday pay
      - long delays in supply of structural steel and
      - poor quality control at vendors' works.

4. Main reasons for overrun
   - delayed deliveries
   - delay in construction
   - equipment failure.

5. Lessons learned

- Essential to have an expert team for negotiating an equitable contract. Present contract proved most unsatisfactory for the owner
- Contractor liability too mild or none at all (e.g. for excessive use of feed and fuel, to the extent of $ 10 million, during the prolonged start-up period.
- Owner must set up his project team at the earliest stage of project execution.

How could the project cost have been reduced?

- Minimizing delay in completion of the project
- Short commissioning period
- Financing from one source. In present case, owner had to deal with contractors in four different countries and this made the co-ordination job rather difficult.
- Use of proven equipment. Trial of an approved burner one of the critical furnaces caused very heavy waste of feed/fuel during commissioning and delayed the project considerably.

6. For further projects

- higher penalty (for contractor) for delayed completion
- ceiling on charges for contractors' personnel
- contractorial limit on feed/fuel consumption during start-up
- greater control and better inspection of local materials
- continuous audit at the contractors' site office
- greater control over selection of contractors' local staff.

PROJECT F

1. General
   - developing country - reported by contractor (Developed Country)
   - phosphoric acid 220 T/D P_2O_5
   - existing developed site
   - tied aid (developed country)
   - contract on lump sum basis, departmental execution
   - completion (expected) July 1983, 24 months behind schedule (48 months).

2. Cost structure
   - contractor's fee, including past supply $ 9.4 million
   - all other work done by owner, no cost figures furnished.

3. Major problem
   - no information furnished except for the statement:"will not have full extent until project is complete".

4. Main reason for delay
   - slow construction and erection by clients local contractors.

5. Lessons learned

   "will not be able to evaluate extent until project is completed".

PROJECT G

1. General
- developed country - reported by owner. 6 different projects all in West Europe
- departmental executive
- sites - Vienna, as indicated below

2. Relevant data for the 6 projects

	PLANT	COMPLETION	CAPITAL COST m$	COST OVER-RUN	REMARKS
G1	Fertilizer	1972	8.7	13%	At existing developed site, no extensive site preparation
	Nitrite Acid	1972	2.8		
	Phosphoric Acid-expansion	1972	2.9		
	Utilities	1972	2.5		
		Total	16.9	13%	
G2	Sulphuric Acid, Phosphoric Acid and MAP	1969	20.7	- 5%	Greenfield, undeveloped site
G3	Sulphuric Acid	1981	15.0	4%	At existing developed site
G4	Sulphuric Acid	1974	10.6	7%	At existing developed site
G5	Sulphuric Acid	1970	3.1	11%	At existing developed site
G6	Nitric Acid	1981	11.3	- 4%	At existing developed site Cost under-run inspite of 30% time over-run (22 months instead of 17 months)

3. All projects completed on or near scheduled time with nil or nominal cost over-run.

PROJECT H

1. General
- developing country - reported by owner
- expansion (Ammonia by 415 T/D and Urea by 660 T/D) at an existing developed site. Plants similar to existing
- departmental execution, process licensors from developed country, hardware re-imbursable, detailed engineering and procurement through local offices of engineering companies (from developed country)
- no tied aid, no competitive bidding. Negotiated contracts
- mechanical completion, June 1981 in 24 months from contract signing. Completed on time but with 10% cost overrun. Project cost: $ 96m, with a foreign exchange element of $ 29m.

2. Cost structure (m$)

a.

ammonia plant	47
urea plant	34
utilities	15
	96

b. Cost elements

software	10
hardware	53
construction	10
interest and financial charges	11
duties and taxes	11
catalyst/consumables	1
	96

3. Major problems

a. with consulting companies (local; for detailed engineering and local procurement)
- lack of appreciation of cost control
- tendency of overdesign
- poor expediting with vendors

b. with prime contractor
- (none engaged)

c. with sub-contractors
- civil - lack of mechanisation. Material shortages (cement, steel) also price premium in open market (compared to controlled price)
- piping - too much dependence on manual welding
- equipment erection - lack of adequate lifting equipment, shortage of good quality skilled tradesmen.

d. with vendors (mainly local)
- raw material availability
- late ordering of raw material and import components
- lack of appreciation of contractual obligations
- industrial disputes (freight, developed country also)
- owner having to assert with solution to technical problems.

4. Main reasons for cost overrun.

- 3.8% due statutory price increase in steel, cement and diesel oil, etc.
- 3.7% due currency rate fluctuations
- 1.5% due mobilizing additional manpower resources for expediting, site supervision and commissioning.

5. Important lessons learnt

- ensure timely availability of project funds
- avoid changes
- vigorous and skilful expediting necessary
- obtain commitments from consultants, contractors and vendors
- competent project management team with delegation of authority is imperative
- helping sub-contractors with their problems is advised.

6. To reduce project cost

- maximize fixed cost contracts
- prompt payment for delivered work
- reduce wastage and losses/pilferage
- improve management information system
- prompt action particularly in respect of industrial disputes etc.

7. For future projects

- in-house computer exclusively for project execution is an asset
- better planning of shipment/transport, particularly for imported materials
- streamlining of documentation
- adequate attention to commissioning management.

PROJECT I

1. General
   - developing country - reported by owner
   - ammonia 900 T/D + urea 1500 T/D
   - greenfield, undeveloped site requiring extensive site preparation, land filling and piping
   - tied aid
   - semi-turnkey execution. Consultants (developed country)
   - project cost $ 228m (foreign exchange $ 111m), 22% overrun.

2. Cost structure ($m)

a.

- ammonia	63	
- urea	29	
- utilities	43	
- storage	4	(most likely:
	139	excluding construction, interest, etc.)

b. cost elements

- software	23	
- hardware	115	
- construction	31	
- interest, etc.	33	
- others	38	
	240	
- less	12	credit for pre-operational production, inventory and construction supplies
	228	

3. Major problems

a. with consulting company (developed country) - wrong indent of refractory materials. Mistake not detected at time of inspection.

b. with vendors
   - delayed deliveries of major items (imported from developed country), particularly compressors, large-sized towers, piping and bulk materials
   - delayed deliveries from local vendors due industrial disputes, and power cuts. Steam generation plant delivered 12 months late.

4. Main reasons for overrun
   - change of feedstock from furnace oil to naphtha
   - port strike and later heavy congestion at port
   - heavy power cut during construction/commissioning due severe draught conditions in the project area.

5. Lessons learnt
   - project management ought to be able to anticipate and consequently deal with unforeseen situation.

PROJECT J

PART 1 - reported by the owner

1. General
   - developing country
   - ammonia 1350 T/D + urea 1600 T/D
   - greenfield, undeveloped site
   - departmental execution, 3 contractors from developed country and 2 from developing country. Fixed price for engineering and reimbursible for services
   - completion December 1981 (68 months instead of 54), cost over-run
   - project cost Rs. 4450 million. No over-run (?). Tied aid.

2. Cost structure (Rs. million)

- software	544
- hardware	1168
- power station	317
- construction	249
- interest, financial charge and currency fluctuation	1079
- duties, taxes, etc.	436
Total	3793
Other expenditure	657
Overall project cost	4450

3. Major problems

   a. with consulting company
      - co-ordination with different agencies
      - too many inspection agencies.

   b. with prime contractor
      - lack of experience
      - too many revisions
      - delays in details of piping.

   c. with sub-contractors
      - insufficient mobilization (expediting process)
      - manpower shortage
      - no proper material accounting.

   d. with vendors
      - delays in delivery
      - equipments not conforming to standards
      - tendency for extra claim even for minor changes
      - wrong certification of material from foreign vendors(developed country).

4. Main reasons for over-run

- delay in engineering; mainly piping and instrumentation by engineering contractor. Also modifications/revisions at site
- delay in importing steel plates due to strike in Europe
- delay in local deliveries (compressor, pump, vessels, and heat exchangers)
- delay in importing fabricated piping
- port strike.

5. Lessons learnt : The following should be achieved

- clearer and well-defined contracts
- realistic project time schedule
- more responsibility to local consultants.

6 For future projects

- move Head Office to project site at an early
- no change in top management (even Board of Directors) in mid-stream
- select only one contractor for overall project co-ordination
- better expediting with foreign suppliers
- more and smaller erection sub-contracts at site.

PART 2 - reported by one of the three contractors from (developed country)

1. General
- no tied aid
- contract signed March 1979. Project completion October 1981
- Fixed fee ($ 14.7m) and reimbursable ($ 69 hardware).

2. Major problems

a. with client
- no authority in respect of local supplies/services
- insufficient local engineering personnel in prime contractor's home/office
- extremely complicated and cumbersome import procedures.

b. with sub-contractors (site)
- delay in detailed engineering
- shortage of skilled manpower.

c. with vendors of imported materials
- unreliable quality assurance/inspection leading to replacement of imported materials at a late stage of the project execution period.

d. with local vendors
- strikes and industrial disputes
- bought-out items did not match requirements in many cases
- time consuming co-ordination of battery limit connexions/ conditions.

3. Main reasons for overrun
- late supply of imported and local materials and equipment
- shortage of skilled manpower for erection
- delay in import licenses.

4. Important lessons learnt
- assign competent main contractor(s) at the earliest stage possible
- early placement of orders for long delivery local equipment
- minimum number of local vendors/workshops to streamline material procurement and quality assurance
- there should be no preference for public sector suppliers.

5. To reduce project cost
- uniform design specifications/requirements for the entire plant
- competitive and early tendering for local equipment to enable timely action for import license in case of unrealistic high price and/or long delivery
- erection contract (local) should have an escalation clause
- more mechanical sub-contracts (5 instead of 3) to reduce labour problems
- simplify and speed-up procedures for import license.

6. For future projects
- adequate authority for main contractor for effective co-ordination
- competent group of clients' engineers in contractors' office during the entire engineering phase
- project team of prime contractor should be present locally during detailed engineering phase.

PROJECT K

1. General
- developing country - reported by owner
- ammonia 600 T/D, urea 1000 T/D, naphtha-based
- greenfield, undeveloped site, extensive site preparation, land filling and piling
- departmental execution - process licenses and engineering/ procurement/construction supervision by a foreign (developed country) firm, on fixed fee by reimbursable basis
- contract signed October 1967, commercial production November 1976. 5 years later than scheduled
- overrun in time 180%, in cost 163%
- project cost, approximately $ 923 million.

2. Cost structure (m Rs)

a. Plant costs

- ammonia	247
- urea	147
- utilities	63
- other project expenditure	466
	923

b. Project cost elements

- software	221
- hardware (incl. spares)	283
- construction	139
- interest, financing charge and currency fluctuation incident site	157
- land, site preparation and development	22
- catalyst/consumables	14
- freight-insurance	14
- duties and taxes	38
- others	35
Total	923 (foreign exchange m. 233 Rs.)

3. Major problems

a. with consulting company (who also procured the foreign portion of the hardware from a developed country)

- limited experience with ammonia plant using centrifugal compressor
- unproven equipment, poor workmanship, failure, e.g.

  1. pumps, H.P. boiler feed water pump
     boiler circulation pump
     H.P. carbonate charge pump

  2. teflon seated ball valves in hot naphtha vapor line had to be replaced with globe valves

  c. purge gas from the synthesis loop was never used (as intended) as reformer fuel

- inadequate steam balance design
- very tight design with no margin.

b. with sub-contractors

- the sub-contractor for erection of flue gas boiler abandoned the job at a very late stage
- labour unrest.

c. with vendors

- delayed deliveries, both local and imported materials by as long as 27 - 48 months.

4. Main reasons for overrun

- delay in land acquisition
- shortage of steel for fabrication of equipment
- some major items procured locally for the first time were delivered considerably late
- labour problems
- major problems during start-up/commissioning:

  (a) critical equipment failure (see previous section)
  (b) seal and tube leakages of reformer gas boiler
  (c) defective speed indicator of synthesis gas turbine
  (d) power - irregular supply.

5. Lessons learnt

- the consultant selected should have had prior experience in similar/identical plants
- no tied credits, least of all for critical equipment and machinery
- avoid multiplicity of agencies for design, procurement, etc.
- make liberal provision for utilities (safety margin in design)
- captive power plant must be included.

6. To reduce project cost

- judicious selection of consultant and of critical equipment
- pre-qualified vendors
- ensure good industrial relations
- project scope clearly defined in detail
- realistic estimate with provision for escalation - local and global
- competent project management team
- clearly defined responsibility of consultant/contractor and owner.

7. For the next project

- choose a standard size plant
- use proven equipment and machinery
- realistic estimate on basis of in-house data and data from reliable sources.

PROJECT L

1. General
- developing country - reported by contractor
- ammonia 900 T/D, urea 1550 T/D (Fuel-oil based ammonia plant)
- greenfield, undeveloped site requiring extensive site preparation, land filling and piling
- turnkey contract (developed country), fixed fee for services and reimbursable for hardware
- contract signed mid 1974, mchanical completion mid 1978, commercial production end 1979.

2. Cost structure (m$)

- software	22	foreign exchange element = $ 73m
- hardware	145	
- construction	20	
	187	

(Incomplete data. It is not certain whether this represents the plant cost or the overall cost, although logically it could represent the turnkey plant cost).

3. Major problems

a. with vendors
- delayed deliveries due to labour problems
- defective equipment:

(1) synthesis gas compressor (from developed country), ammonia - vibration
(2) air separation unit (from developed country), cold box, explosion.

4. Main reasons for overrun
- 6 months due to air separation unit accident
- 6 months due to delay in equipment supply - labour problems at the works
- 12 months due to short supply of coal and fuel oil (feedstock).

5. Lessons learnt (by the contractor)
- must collaborate with a local engineering company.

6. Future projects
- either to undertake the project execution on turnkey vasis.

PROJECT M

PART 1 - reported by the owner

1. General
- developing country - reported by owner
- ammonia 1000 T/D, urea 1725 T/D, (gas-based ammonia plant)
- greenfield, undeveloped site requiring extensive site preparation, land filling and piling
- turnkey contractors (developed country) on basis of fixed fee and reimbursable
- contracts signed end 1975, mechanical completion end 1978, commercial production mid 1979. Completed on time
- project cost $ 208 million - within budget
- built-in advantage: present project is a duplicate of a previous one at the same site.

2. Cost structure (m$)

- ammonia	126
- urea	46
- utilities	11
- storage	25
	208 (foreign exchange $ 153 m)

3. Major problems

a. with prime contractor
- contractor's warehouse control system was not effective
- excessive (lost/stolen/unaccounted for) materials
- surplus materials at end of the project execution were not properly identified.

4. Lessons learnt
- performance test guarantees for utilities/auxiliary must be clearly spelled out
- owner must oversee the materials control system, also ensure the use of construction equipment rented by the hour on a reimbursable basis.

PART 2 - reported by the contractor - for urea plant:

(Only additional or conflicting information is included here).

- project completed in 33 months instead of the scheduled 36 at a cost of $ 29.14 m (scheduled: $28.96) - represents the fixed fee and the cost of partly imported hardware.
- same vendors, as the previous project (of which the present is a duplicate at the same site), proved to be of great advantage.

To reduce project cost, it is advised that the following be effected:

- world-wide bidding for big items
- purchase small items from the country of origin of the engineering company

PART 3 - reported by Technical Advisor from developed country

1. General - conflicting information

- the work involved replacement of the prilling system of an existing urea plant with a poor granulation system
- existing, developed site but with extensive site preparation, land filling and piling. Completed June 1981 (in 36 months), 12 months behind schedule (100% overrun)
- project encountered 50% overrun in cost.

2. Major problems

a. with contractor (=owner)

- inadequate inspection of major equipment prior to shipment
- inadequate experience of project manager and his team (the job was their first project).

b. with vendors

- delayed delivery
- failure in meeting equipment specifications.

3. Main reasons for overrun

- development/demonstration type project
- change in project manager during project execution.

4. Lessons learnt

- better to use an experienced (outside) engineering contractor or consultant
- qualified project manager is imperative.

5. For future project

- better equipment specifications and bid evaluations.

PROJECT N

1. General
   - developed country - reported by owner
   - ammonia 1350 T/D, urea 1000 T/D
   - greenfield, undeveloped site with extensive site preparation, land filling and piling
   - contractor (developed country) on basis fixed fee and reimbursable
   - mechanical completion, early 1979 in 51 months instead of scheduled 36 months (42% overrun)
   - project cost: $ 288 million (15 per cent foreign exchange)

2. Cost structure (m$)

   a. Individual plants cost

- ammonia	186
- urea	72
- utilities	12
- storage	18
	288

   b. Cost elements

- software	32
- hardware (incl. spares)	74
- construction	105
- interest, currency fluctuation	47
- land development	9
- prelim. expenses	5
- raw materials (incl. catalyst)	7
- freight and insurance	9
	288

3. Major problems

   a. with prime contractors

   - lack of project co-ordination at all phases from basic design to commissioning
   - underestimation of qualities in civil, electrical, instrumentation, insulation and painting

   b. with subcontractors

   - insufficient manning

   c. with vendors

   - numerous design and manufacturing errors particularly with rotating equipment, e.g. coupling assemblies and mechanical seals had to be fitted corrected and (most serious) support of a steam turbine which lacked rigidity gave rise to bearing and coupling failures which had to be corrected by brazing in the field.

4. Major reasons for overrun

- delay in procurement and delays in civil design
- industrial relations problems
- weather (adverse) conditions

5. Lessons learned

- proper staffing by client and by main contractor
- owners team in contractors' office should be strengthened
- more emphasis on contractors' industrial relations right from the start and owner to maintain effective control thereof.

6. To reduce project cost

- Prime contractor must produce at the outset a detailed integrated schedule of all activities
- Monitoring of the above by the owners project team for early detection of slippage is imperative.
- Minimize number of options for product handling/despatch.

7. For future projects

- Contractor must provide the track record of his Project Manager Designate and Construction Manager Designate periodically.
- Owner's project team must include an experienced engineer for monitoring progress against the schedule
- Briefing the contractors' project team including the industrial relations staff on the industrial relations situation with particular reference to communication systems is essential.

PROJECT O

1. General
- Developing country - reported by owner
- Ammonia (1000 T/D), urea (1500 T/D)
- Greenfield developed site, but requiring extensive site preparation, land filling and piling
- Tied aid
- Contractor (developed country), lump sum fixed price contract, departmental execution envisaged
- Project completed in 72 months instead of scheduled 24 months
- Project cost m$ 181 with 200 per cent overrun
- Commercial production in May 1982.

2. Cost structure (m$)

- software	6
- hardware	58
- construction	125
- other charges	12
	201

3. Major problems

a. with consulting firms
- delay in receipt of technical information
- delayed engineering and that of a local firm needed corrections

b. with contractor
- slow progress, average 4 per cent per month instead of scheduled 7 per cent
- contract not well defined and therefore programme suffered

c. with subcontractors
- steel structure delayed by one year due to lack of capacity
- ammonia sphere delayed by local subcontractor due to inexperience
- clarifloculator below specifications - leak in the concrete foundation.

d. with vendors
- delayed receipt of technical information
- increased prices due to devaluation
- delayed supplies due to late payments by owner
- long procedures for imported equipment

4. Main reasons for overrun
- change in government
- change in internal organization of the owner's company
- modifications/repairs of equipment due to change of location
- increased engineering work load (for adjustment/corrections)
- delayed deliveries from suppliers
- rapid turnover of personnel in the local engineering firms
- lack of supervision by the owner at the beginning of the contract
- shortage of qualified manpower due to major constructions in the country.

- Shortage of cement
- Lack of effective construction programme.

5. Lessons learned

- The scope must be clearly defined at the outset
- Early ordering of long-delivery items (e.g., control instruments)
- Proper storage facilities available before hand
- Minimizing changes once engineering and other work starts
- Better quality control
- Quicker checking of suppliers drawings specifications
- Clearly defined scope in case of overlapping suppliers
- Close control on delivery and cost of hardware
- Minimize personnel turnover
- Better communications and human relations between owner and contractor.

6. To reduce project cost

- Mobilize appropriate human resources
- Strict supervision of contractors
- Fixed price for hardware
- Close and frequent review of foreign contractors' man/hour rates
- Establish early and adequate storage system for supplies received at site.

7. For future projects

- Strict control on suppliers, local and foreign
- Frequent cross-checking in various areas throughout project construction
- Quick approval of execution instructions
- Instructions must be clear and precise
- Strict inspection of critical equipment and instruments
- Execute strictly in accordance with plans
- Exact definition of engineering scope and supply services
- Storage area not to interfere with work area
- Streamline receiving and despatching system
- Cross check detail engineering drawings before start of construction
- Use unit price as far as possible
- Different contractors for civil work and for technical erection
- List of items missing to be drawn and acted upon
- Clear knowledge of funds available at various times
- Firm commitment and better human relations owner/contractors.

PROJECT P

1. General
- developing country - reported by owner
- ammonia (1000 T/D), urea 1725 T/D
- greenfield undeveloped site with extensive site preparation and piling, but not land filling
- tied aid from two developing countries and also suppliers credit from a third developing country
- contract signed 1977, mechanical completion end 1981. Total period, 48 months (33 per cent overrun)
- Semi-turn-key execution with fixed fee plus reimbursable contract
- Project cost $ 296 (25 per cent overrun) foreign exchange, $ 178 m.

2. Cost structure (m$)

a. Plants cost

- ammonia	59
- urea	31
- utilities	41
- storage	13
	144 (incomplete)

b. Cost elements

- software	37
- hardware	108
- construction	51
- financial	33
- freight + insur.	19
- catalyst/consum.	12
- duties and taxes	9
- land development	7
- other	20 (it could be working capital and/or contingencies)
	296

3. Major problems

a. with prime contractor
- insufficient planning at all stages
- insufficient preparation at home office
- too much work (design and procedures) at site
- site staff not authorized to modify design and specification of home office

b. with subcontractors
- local civil contractors had cash flow problems.

c. with vendors
- cement shortage
- delayed deliveries for foreign equipments by 2-10 months

4. Main reasons for overrun

	$ million
- transport (unrealistic estimate by the general contractor	11
- interest	12
- unprecedented escalation	12
- construction	9
- taxes	5
- administration, pre-establishments	5
- technical assistance	4
- railway siding (not originally provided for)	2
	60

5. Lessons learned

- Engineering design must start immediately on contract signing.
- Funds and payment procedures must be ready at contract validity time.
- Prior investigation of local conditions (power, water, transport, vendors, contractors, etc.)
- Owner to be involved in cost control from the very beginning.

6. To reduce project cost

- Advance engineering and procurement
- More use of local supplies
- Employ more of local foremen and supervisors.

7. For future projects

- Pay more attention to

  a. engineering, procurement and commissioning schedule
  b. process design of utilities

- Owner's personnel must take active part in

  a. supervision
  b. quality control
  c. pre-commissioning.

8. World Bank appraisal report

- Project cost estimate $ 260m (foreign exchange $ 173 m). On stream scheduled) mid-1980.
- Project sponsors: local party plus one of the largest fertilizer producers in a developed country
- The latter were to provide an experienced project manager.

PROJECT Q

1. General
- developing country - reported by owner
- sulphuric acid (pyrites-based) 1500 T/D, phosphoric acid 2 x 600 T/D, diammonia phosphate and NPK compound fertilizers 2 x 65 T/D
- Greenfield site with extensive site preparation
- Turn-key contractors (from developed country) fixed fee and reimbursable basis
- Contracts signed end 1981, mechanical completion end 1984 (expected)
- Project cost (estimated) $ 400 million (foreign exchange $ 280 million). No overrun so far.

2. Cost structure (m$)

- sulphuric acid	157
- phosphoric acid	69
- DAP and NPK	49
- Utilities	34
- storage	89
	400

- software	7.5%
- hardware	55.2%
- construction	37.3%
	100.0

3. Lessons learned

- more optimized off sites design
- less stringent environmental restrictions
- more realistic specifications of final product quality

PROJECT R

1. General
   - developing country - reported by contractor (developed country)
   - sulphuric acid plant (300 T/D) based on sulphur
   - developed site without much site preparation necessary
   - contract on turn-key basis, fixed lump sum price
   - total project cost $ 8.9 m (foreign exchange $ 5.3 m)
   - commercial production March 1980.

2. Cost structure (m$)

- software	1.65
- hardware	3.45
- construction	3.24
- interest and currency fluctuation	0.11
- catalyst/consumables	0.10
- freight and insurance	0.35
Total	8.90

3. Major problems
   - no consultant
   - no prime contractor

   a. with subcontractor (from developed country)
      - lack of skilled tradesman
      - poor productivity, probably due to long working hours (12 hours per day with one day off every 2 weeks)
      - safety standard not up to the mark.

   b. with vendors
      - late delivery of an item from developed country

4. Main reasons for overrun
   - late delivery of an imported item

5. Lessons learned
   - A local partner (active agent) is a must
   - In the absence of help by the owner, the contractor had to rely on local tax consultants
   - Clear and specific stipulation in the contract regarding local taxes should be known
   - No clear-cut boycott stipulation was received
   - Practically no local sources of supply
   - Difficult to service mechanical guarantees without continued presence
   - Arbitration/litigation almost impossible because of local laws.

6. To reduce project cost

   Prior knowledge of local working conditions

7. For future projects

   Must have a local agent of sufficient stature.

PROJECT S

1. General
   - developed country - reported by the contractor (developed country
   - ammonia (1360 T/D), urea (1090 T/D), ammonium nitrate (1000 T/D) (gas-based ammonia plant)
   - existing developed site with no extensive site preparation, but some piling required
   - contract on turn-key basis, payment reimbursable
   - commercial production end 1978, overrun of 1 1/2 months over the scheduled 40 months completion. Cost 9 per cent below scheduled.

2. Cost structure (m$)

   a. Individual plant cost

- ammonia	63
- urea	29
- ammonium nitrate	15
- utilities + storage	63
	170

   b. Plants cost components

- software	28
- hardware	48
- construction	94
	170

3. Major problems

   none mentioned

4. Main reasons for overrun

   - three months slow-down by the owner due to shortage of feedstock

5. Lessons learned to reduce production cost

   none

6. For future projects

   none

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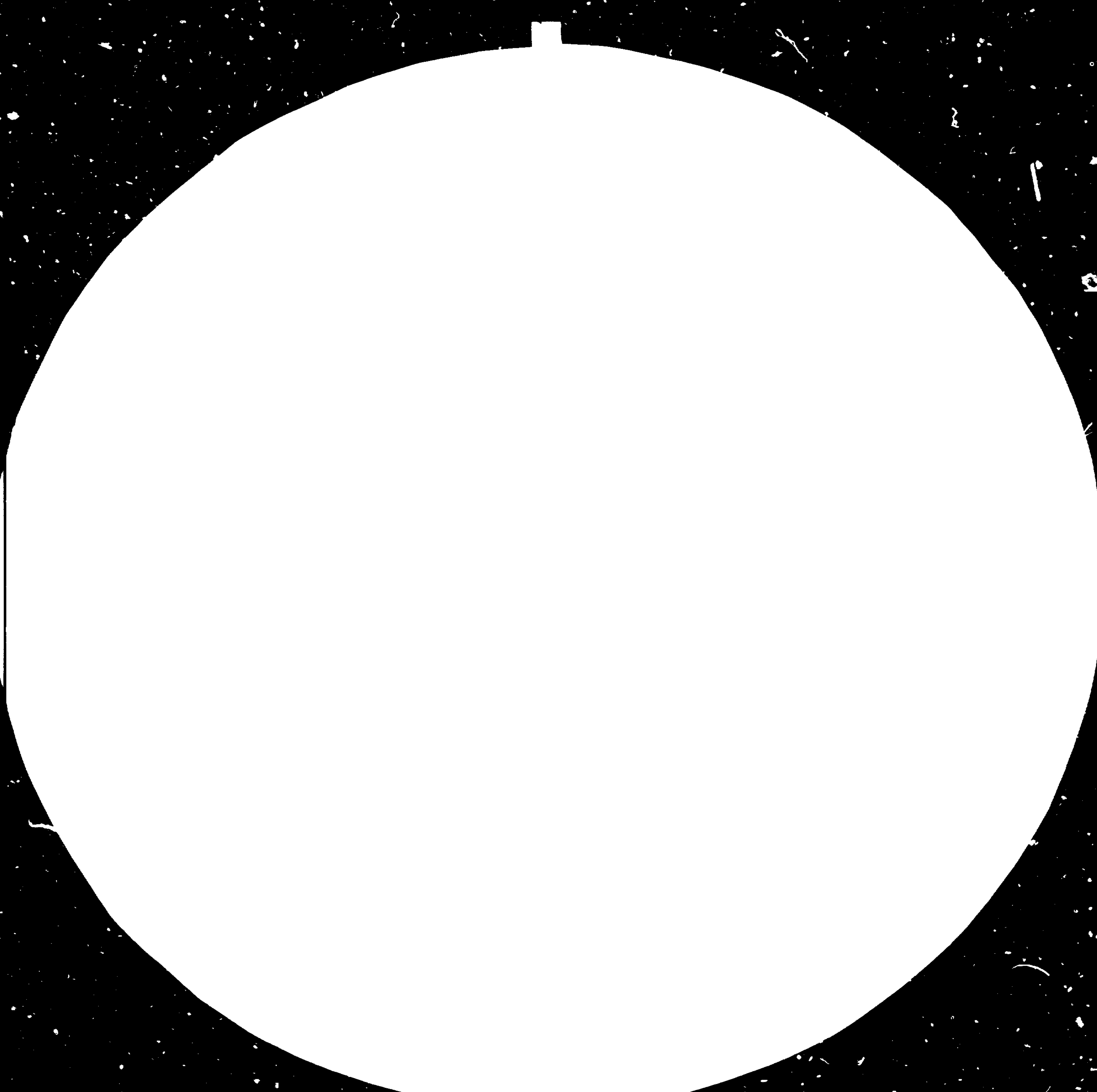
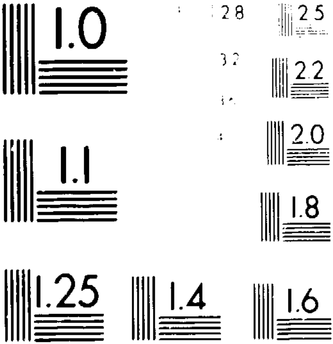




MICROCOPY RESOLUTION TEST CHART

PROJECT T

1. General

- developing country - reported by owner
- ammonia (600 T/D), urea (750 T/D), phosphoric acid (250 T/D, 100 per cent P_2O_5), TSA (1400 T/D), DAP (380 T/D), gas-based
- existing developed site but with some site preparation and piling
- turn-key contract with 3 contractors (all from developed countries)
- commercial production 1979 in 120 months instead of the 36 scheduled previously
- project cost 106 million dollars (283 percent cost overrun)

2. Cost structure

- ammonia	14.4
- urea	7.0
- phosphoric acid	5.4
- TSP + DAP	3.8
- Utilities	6.6
- Others	69.0
Total	106.2

3. Major problems

a. with consultant

- lack of definition for the entire project

b. with prime contractors

- incomplete programme
- inadequate inspection
- specifications not clear-cut

c. with subcontractors

- same as above

d. with vendors

- substandard equipment
- inadequate materials

4. Main reasons for overrun

- lack of clear definition
- constant changes
- lack of decision making
- lack of central supervision
- type of contract
- subcontractor unable to implement proposed programme

5. Lessons learned

- clear definition and specific developing plan
- clear definition of programme
- realistic plan for work and its implementation
- more control necessary at all stages

5. <u>To reduce project cost</u> (see previous section)

6. <u>For future project</u> (use the experience gained on this project)

PROJECT U

1. General
   - developing country - reported by owner
   - ammonia storage facility and some other facilities
   - existing developed site requiring site preparation, land filling and piling
   - contractor (developed country) fixed price contract, semi-turn-key basis
   - project completed in 54 months instead of the scheduled 24.
   - project cost 38 million dollars (31 per cent cost overrun)

2. Cost structure (m$)

- ammonia storage	8.9
- others	28.9
Total	37.8

3. Major problems

   a. with consultant
      - technical specifications not completely defined
      - delay in bid evaluation
      - delay in delivery of major equipment

   b. with prime contractor
      - none

   c. with sub-contractor
      - none

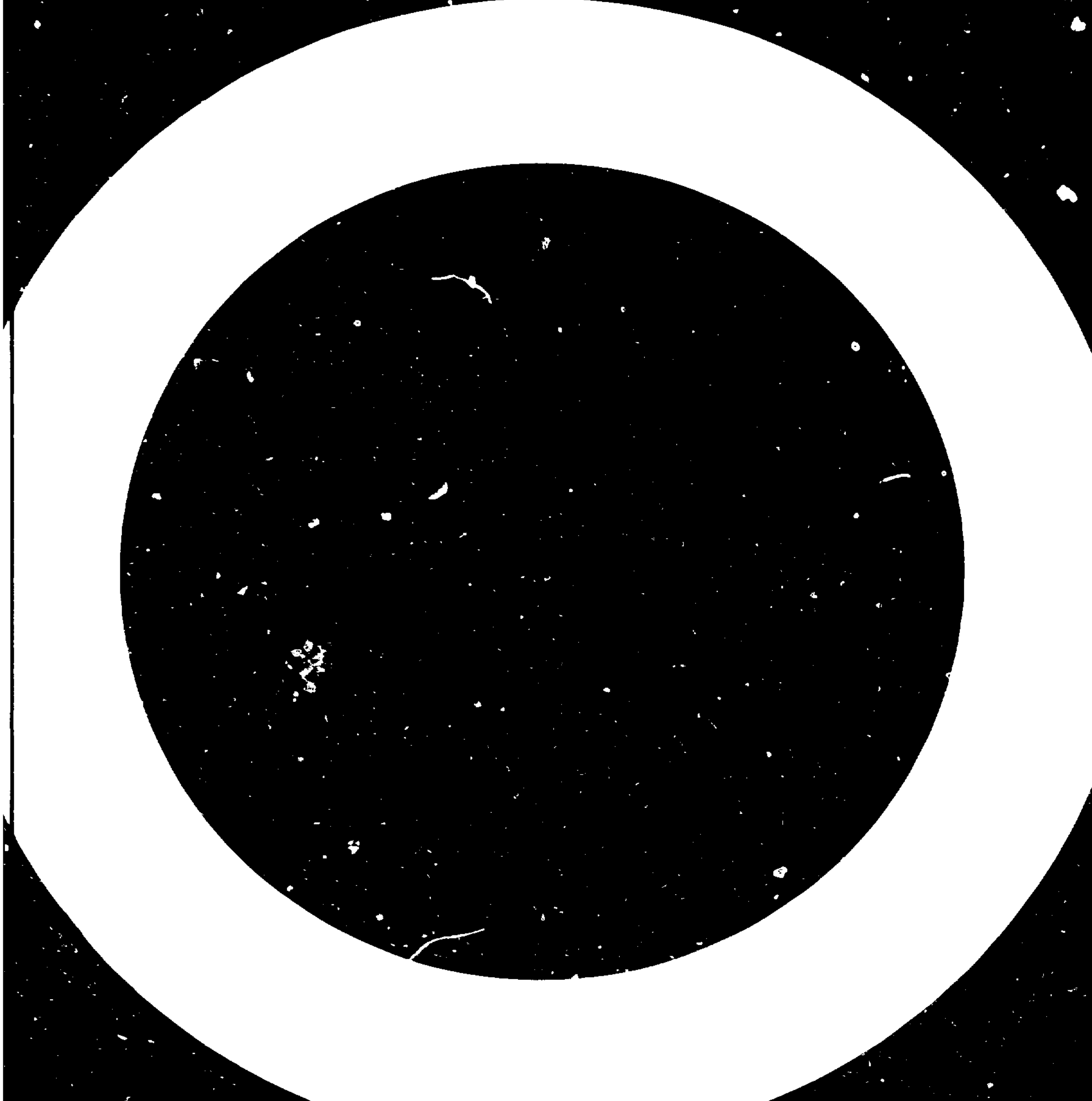
   d. with vendors
      - delayed delivery.

4. Main reasons for overrun
   - delay in engineering details
   - delayed material delivery
   - changes

5. Lessons learned
   - better project control and project management
   - clear definition of basic engineering

6. To reduce project cost
   - better control at all stages
   - clear and well defined technical specifications

7. For future projects
   - clear concept of the project
   - entrust construction and engineering to a specialized country.



ANNEX I. 3 SPOT VISITS
LATIN AMERICA

The reports of the spot visits to three Latin American countries, Brazil, Mexico and Venezuela, are included herein. The visits were helpful in getting a first hand "feel" of problems relating to execution of fertilizer projects in these countries and also to understand the structure of the industry. The highlights of the visits are summarized below.

Brazil

The general policy is to maximize local purchases of services and equipment. As an example for the Laranjeras plant, the local participation constituted 35 per cent for the first unit and 75 per cent for the duplicated second unit. In the second unit nearly 75 per cent of the entire hardware, including all vessels, heat exchangers, reactors were procured locally.

The price of local hardware is usually competitive except for highly sophisticated items like ammonia converter which were made in the country for the first time. For example, the cost of locally produced converters was almost three times that of imported ones. This is, perhaps, the initial price one has to pay for indigenization. Local hardware is also competitive in the international market except, of course, for highly sophisticated items as the ammonia converter mentioned above.

The second fertilizer project at Laranjeras was completed in 5 1/2 years perhaps one year later than desirable. Overall, however, it can be said that the project authorities were able to exercise good cost control as a result of proper co-ordination during erection of the plant.

The foreign contractor (from developed country) submits a list of local vendors and this has to be vetoed and approved by the owner company or his local engineering wing. The procurement and co-ordination is also overseen by the owner.

Some of the lessons learned for the future are:

- greater flexibility in steam generation
- better inspection during local fabrication
- possibility of a Brazilian firm as the main contractor.

Venezuela

The entire fertilizer industry is government-owned and the product is distributed at subsidized rates. The older plants were executed on turn-key basis and the newer one on semi-turn-key basis or departmentally.

Delayed deliveries from local suppliers have been one of the reasons for long completion periods and cost overrun. For one of the projects executed, the final overall cost was $ 283 million as compared with the initial estimate of $ 142 million. This borders the cost of one of the earlier projects when the principles of sound project management and in particular the value of "time control" was not fully recognized.

The entire civil engineering construction, electrical work and mechanical erection is done by local contractors. Detailed engineering is also done locally either by national firms alone or with foreign collaboration.

Delays of fertilizer projects execution have mainly been affected because of

- lack of clear and specific project definition
- lack of quick decision
- over-centralization of supervision
- delayed delivery of local hardware particularly due to technical and quality control problems.

Chemical production, and presumably fertilizers as well, are now tied to the Andean Pact under which different productions are assigned to different countries within the pact. The projects proposed include joint ventures with multinational companies. They are also planning to have joint venture fertilizer projects in third countries, i.e. Colombia.

Mexico

The fertilizer industry is now entirely nationalized since all the private fertilizer units were taken over by the government during the period 1962-1967.

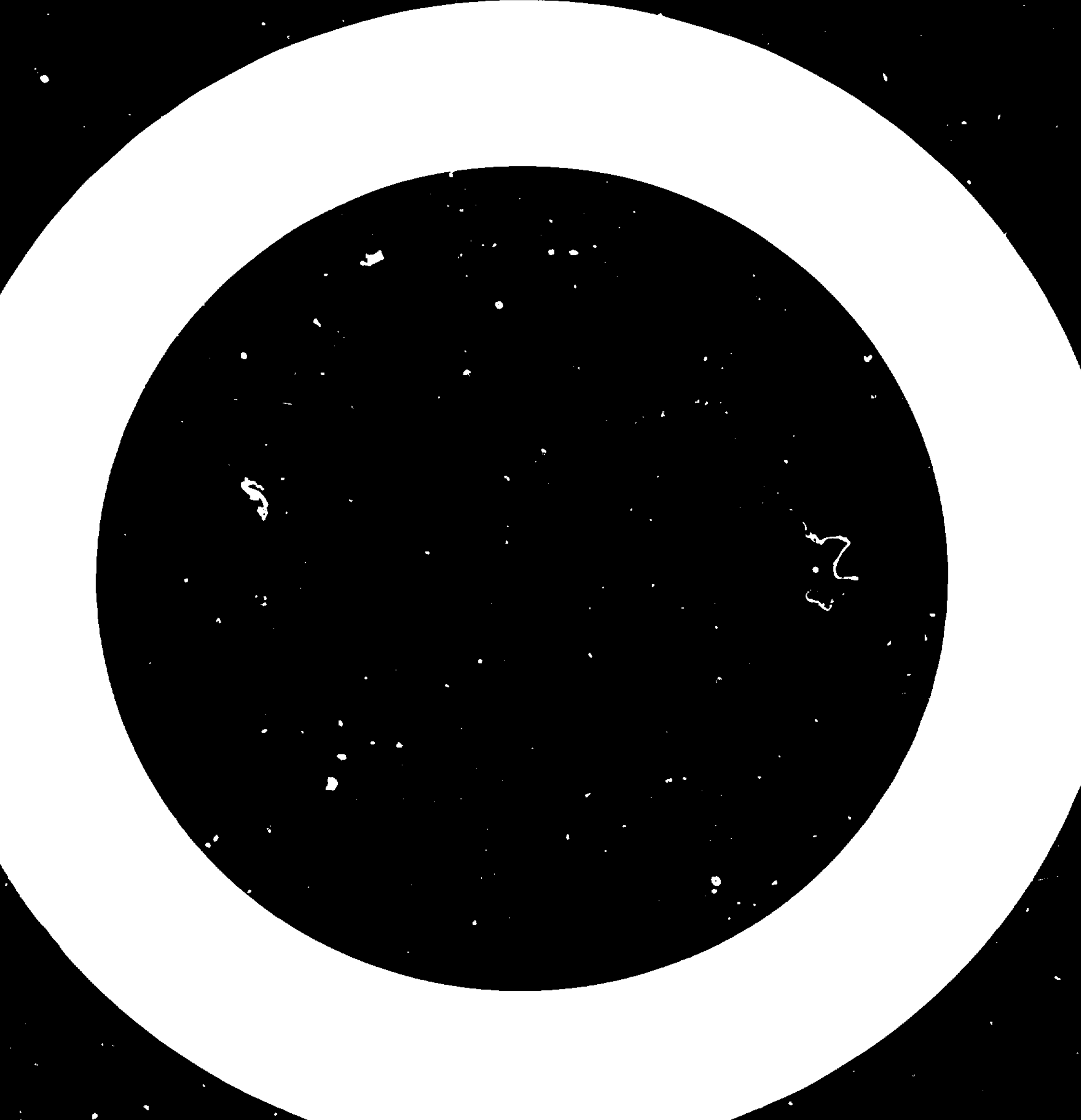
The feedstock to the fertilizer industry is made available at international prices so that it can compete on actual terms.

Two of the major problems in implementing a recent project have been due to mechanical failures, i.e. in case of the turbine, the blades were not up to the specifications and ultimately they had to be changed by the supplier, and in the case of the urea reactor, the valves are found to be corroded. Both of these items were supplied by a vendor in a developed country.

Fertilizers are a priority industry in the country and plant location is connected with providing infra-structure as part of social development of particular areas. This of course could have jacked the overall cost of the project.

Pre-planning has been one of the major problems in delayed execution of projects. This not only leads to delays (direct), but indirectly causes subsequent changes that are necessary. This is now sought to be corrected for future projects.

A central office is now responsible for the elaboration and supervision of feasiblity studies, detailed engineering design, procurement, co-ordination of construction as well as provision of technical assistance to operating plants.



ANNEX I.4 ABSTRACTS FROM INTERVIEWS WITH CONTRACTORS/CONSULTANTS

Some contractors were visited, by prior arrangement, between December 1981/January 1982. In many cases, the contractors asked for more time to consult amongst their colleagues locally as well as in other countries. To by-pass the implications, they were requested at the end of each meeting to furnish a brief outline of their views on the subject matter with particular emphasis on ways to minimize capital cost of future fertilizer projects in developing countries. Almost all the contractors kindly responded to the request. The highlights from minutes of the meetings and from the "briefs" received subsequently are included in this section. As far as possible, the wordings of consultants/contractors have been retained, though in a considerably shorter format. The overall impressions of those visits are:

a. All parties were most co-operative, but some more than others. It was clear that in each case they had already done some spade work beforehand not only among colleagues at the same location, but also by inviting (by telex/letter) relevant information from their head office (i.e. USA) and appropriate subsidiaries elsewhere. Meetings were generally at fairly senior level (vice-president).

b. It was emphasized by most that the present issue is a complex one and that no simple universal answer and/or solution exists. Each case must be studied in depth to get at the heart of the problem. A superficial look at this issue could easily lead to absurd conclusions and wrong solutions. This could only make matters worse.

c. Contractors generally and obviously blame the project authorities (and the concerned governments) for the "run-away" costs. Informally some of the contractors interviewed agreed that some developing countries may have, at times, been overcharged. Few added that it was, however, their own doing (developing countries'). One went so far to say that contractors were also, at times, suffered from bad deals and at least one of them went bankrupt as a result of a single contract.

d. Total project cost is meaningless unless the entire scope is completely spelled out. No two projects are ever the same. Unless comparison is made for similar projects, the whole exercise (of comparison, analysis and solution) may be one of futility. Hence the need for thorough homework.

e. The parties met anxiously await UNIDO's findings on this vital subject and in particular the Guidelines thereof for ultimately, they will be involved in translating these into practice to the mutual benefit of all the parties involved in planning and executing fertilizer projects.

CONTRACTOR A

1. Knowledgeable clients take advantage of the competition on the market place. Every six months they obtain an up-date (through a questionnaire) on the major contractors and entrust work to those contractors who are short of work. Developing countries could do likewise but may need an outside consultant to act as their "arm" in the absence of an in-house project engineering team.

2. Extent of increase in project cost due to various factors:

- 5 - 10 per cent Project finance
- 10 - 20 per cent Freight, insurance, transport
- 20 per cent Contingency for guarantees and liabilities.

3. Suggestions to owners for reducing cost of future projects:

- reimbursable - type contract (avoids overproviding risks)
- go easy on liabilities - contractors stake in terms of share and profit is small in relation to project cost
- exploit market place competition as 1. above
- use management contractor or consultant to supplement own project team, if necessary.

CONTRACTOR B

1. The cost of hardware for process plants is not much different whether the plant is in Timbuktu or the U.S. Gulf Coast. It is other considerations that largely influence the project cost.

2. Other considerations include
   - financing (source and conditions) is the crux for final cost
   - lack of infrastructure and human resources
   - procedures and bureaucracy: bidding/customs, etc.
   - delays due to formalities, construction mobilization, etc.

3. In some countries the socio-economic cost considerations generally overshadow the cost of bare process plants. The desired location may have no rail facilities, no power and very little water because of their desire to provide employment for people in the area. In addition, port facilities, many miles away, have to be built to accommodate export shipments of fertilizer.

4. A contractor needs to know, apart from the product desired:

   a. Is the project to be a world-scale facility to export most of the fertilizer or is it to be a smaller facility to serve only the needs of one country? In the former case, the adequacy of existing land shipping facilities to deliver raw materials to the plant and to deliver products to a port and port facilities must also be analyzed.

   b. What raw materials are locally available and what must be imported? (This will determine what fertilizers should be produced)

   c. Has the site been selected or should investigations be conducted of a number of sites?

   d. Information on energy and non-energy operating costs vs. capital costs trade-off for guidance of front-end engineering effort. Optimization considerations differ for each developing country.

   e. Whether the project is to consist only of a grass roots production facility or whether an infra-structure is to be included.

   f. Review bidding practices tied to financing, process licensing, and guarantees. As alternative, consider process selections studies, licensing and front-end engineering package prior to bid solicitations. Front-end engineering would include site specific matters, offsites, transportation considerations, etc. so as to limit bidder's risk.

g. If a client, or financing institutions, insist on overall performance guarantees for a total grass roots project, then the contractor's risk is substantially increased and hence the project cost. Therefore, we believe that a client should not insist on overall performance guarantees.

h. To contain/reduce project cost:
   - Adequate homework, beforehand, is a must.
   - Front-end engineering is desirable prior to bidding.

CONTRACTOR C

1. Infra-structure including transportation can add substantially to the cost.

2. Most contractors can achieve project targets up to FOB shipment. Major labour problems in vendors can, of course, result in delays to critical equipment. This happened in the 1974 crisis in the United Kingdom, during the "three-day working week" period.

3. To achieve a reliable construction estimate, a minimum of sixty per cent of the detailed engineering should be completed, in order to give accurate quantities - concrete, steel, piping, buildings, electrics, etc. also a detailed investigation should be made of the conditions in the country where the plant is to be located - port installations, government regulations, custom/tariff payments, transportation, labour, workshops, productivity, etc.

4. These pre-requisites very often are not completed, due to developing countries' desire to conserve foreign currency They request a turn-key bid without a prior engineering contract. By so doing, they obtain better credit terms and also do not risk venture capital on feasibility studies. However, this is probably why many projects fail.

5. The contract is weighed against the contractor who has taken an excessive risk in bidding. Sometimes he makes unexpected profits, but usually the client selects the lowest bidder, and this results in a loss situation. The contractor will, under these circumstances, seek to reduce his costs to a minimum. This could be through reduction of expatriate supervisors, choice of lowest cost sub-contractors, delays in committing staff to construction until complete delivery of materials and contractural disputes with the client.

6. To minimize project costs
   - feasibility study with estimate of ± 15 to 20 per cent
   - detailed engineering and material enquiry stage with estimate of ± 5%
   - preparation of bid documents for selected equipment or process units, with construction being separate
   - implementation stage - complete detailed engineering, supply and construction
   - the client should assign staff to work with the management consultant or contractor as part of the project team controlling each phase. The client should apply his local knowledge and muscle to assist the project.
   - Many of the cost overruns arise from initially poor preparation and inadequate estimates.

CONSULTANT D

1. In most cases, high cost can be quantified and explained. Main causes: scope, clients' ignorance. Contractor is seldom to be blamed.

2. Additional costs over and above Western Europe in some Gulf Arab States due to such items as freight, insurance, air-coolers, site labour, essential and optional expatriate supervision, other design factors range from 36 per cent to 50 per cent.

3. High selling costs for a serious consultancy assignment. In one country consultants were called for discussions but on arrival found that one person concerned was not available (called for another assignment) and would not be back but for one week. Later the client (knowing of the consultants' annoyance) decided to visit London with a team of negotiators. Again the consultants will have to spend a few days without any assurance of the job. Ultimately someone has to pay for such "sales effort".

CONTRACTOR E

1. Scope factors contributing to additional costs in developing countries:

    a. Climate, geology/topography, elevation above sea level
    b. Availability/reliability of water, power, transportation
    c. Regulations: environmental and safety
    d. Plant labour customs/practices: canteens, medical facilities, change houses, permanent housing
    e. Availability of maintenance equipment and materials: shops, warehouse
    f. Local standards and construction practices, i.e. concrete structure vs. steel

2. Additional cost on account of hardware:

    a. Imported items: export packing, freight, import duties, source of financing
    b. Local items: often more costly (protected market) or of lesser quality, longer/uncertain deliveries
    c. Terms: Onerous contracts in terms of warranties or guarantees - delays in payments to suppliers/contractors

3. Additional cost on account of construction:

    a. Labour: efficiency, construction practices, labour camps, worker transportation
    b. Supervision: qualified local contractors but expatriates supervision
    c. Construction tools and equipment: Partly imported.

4. Additional cost due to contractor's home office in regard to:

    a. Process packaging: expatriates if engineering done locally, Language/system of measurement
    b. Detailed engineering (local): unfamiliar codes and regulations, efficiency, expatriate supervision, language/system of measurement
    c. Purchasing: divided responsibility, purchasing/engineering at different locations
    d. Project management: divided responsibility, language, communications, travel

5. To reduce capital costs: pursue and/or have:

    a. untied credits
    b. standardise plant capacities

c. standardise plant process and design - simple to suit local conditions

d. standardise plant equipment supply and spares

e. relax onerous contract conditions and project procedures

f. strong project management team (owner/consultant)

g. single responsibility for engineering and purchasing

h. consultant to represent owner (in early stages of development)

i. site chosen with minimum civil costs, infrastructure, requirement etc.

CONTRACTOR F

1. Engineering

   a. Plant design fully specified and agreed before contract award

   b. Site soil study available beforehand

   c. Process design should be agreed before engineering commences and no process changes mid-stream

   d. Plot plan should allow adequate space for storage and fabrication shops. This is particularly important when the site is a hydraulically filled, reclaimed area in a low lying district with no possibility of enlargement without major cost involvement.

2. Procurement

   a. Procurement procedure should be prepared and agreed before hand. World Bank procedures require considerably more manpower than normal commercial projects.

   b. Critical materials and proprietary equipment: these should be specified and agreed to in the contract with a list of nominated suppliers.

   c. Pre-qualification procedures: The vendors' list should be prepared at the earliest post-contract award date,based on the contractor's experience of international procurement. The lenders could review the list to ensure that all countries participating in the funding are included.

   d. Approvals: to save time, lenders' representative with the necessary level of approval authority be located in the contractor's offices.

3. Shipping and transport

   a. Shipping to, and transporting inside third world countries should be very carefully studied and firm agreements reached with forwarding agents, shippers and in-land transport companies as soon as possible.

   b. Some ports are prone to labour disputes, power cuts and inadequate off-loading facilities. Congestion surcharges are normal.

   c. Contractors should have permanent shipping co-ordinators in the main ports in the clients' country where the plant is to be built.

   d. Payment for shipping should be through a revolving fund to reduce delays incurred with letters of credit.

4. Accounting and disbursement procedures

   a. Lenders' disbursement procedures are unnecessarily complex and cumbersome, leading to late payments.

b. These delays have chain reaction: orders are not firmed up until advance payment, shipments are delayed.

c. It is recommended that the use of payment by a revolving fund is established at the beginning of a project.

d. Need of experienced expatriate accountants to ensure obtaining funds in good time.

5. Construction

a. Construction philosophy must be agreed upon as soon as possible after award of contract. The split between local and foreign subcontractors should be defined clearly.

b. The subcontractors should include materials such as cement, aggregate, sand and reinforcing steel.

c. Equipment being supplied piece meal (e.g. heaters, waste heat recovery systems, cooling towers) should be ordered on a supply and erect basis.

d. Training in the mechanical trades; welding; pipe fitting, etc. Instruments and electronic work is generally best left to expatriate subcontractors with expatriate staff.

e. Employing expatriate working foremen who could show the local staff how to do the work as well as how to direct their labour.

f. Temporary facilities must be provided/arranged by the contractor to ensure there are no restraints to the employment of expatriate and national labour.

6. Client relations

a. The client must clearly define his organisation as due of his advisors and their levels of authority and responsibility.

b. Adequate means of communication such as telex and telephone

c. Owners' representatives in the home office of contractors should have the authority to approve immediately orders and payments.

7. Lender liaison

a. The lead lending agency should appoint their own project manager capable of acting as mediator for disputes.

b. At the earliest time, meetings should be held between the lender, the client and the main contractor to define where equipment and material can be purchased and will be purchased under the lender's rules. More flexibility should be given as to where equipment can be purchased, for instance, tying of construction equipment to the A.I.D. loan was costly and time consuming, as in many cases electric motors etc. on proprietary construction equipment manufactures in the USA was incompatible with the supplies at the site, and better and cheaper equipment could have been obtained in a number of cases from European sources which were not covered by that particular fund.

c. Insistence on local purchases should also be less rigid.

8. Overall

a. simple and clearly defined contracts and procurement procedures
b. no unnecessary stringent specification for products to be covered guaranteed by the contractor
c. plants should be small (in capacity) and simple.
d. simple instrumentations. Avoid electronic and complex computer systems
e. Impress (on the client) the need for quick decisions.
f. Expatriate staff should be fully briefed.
g. Pay-offs, if encountered, are an added cost element.

CONTRACTOR G

1. The major cost elements and their respective contribution to the total project cost of a fertilizer plant (or for that matter any process plant) are:

software	20 per cent
hardware	40 per cent
construction	40 per cent

2. For a typical developing country (with no engineering and fabrication facility) the first two items will remain the same (except for freight and transport elements) at all locations (developing or developed) and the main difference will arise in case of construction. The difference will vary from case to case and each case will have to be examined in depth in order to allow for quantification.

CONSULTANT/CONTRACTOR H

1. The high cost (20-35 per cent) is mainly due to the lack of infrastructure, increased scope of work and interference by the financing institutions.

2. Credit tied to one country as source of supply can lead to a 20 per cent price increase. Desirable to have a credit package permitting competitive bids from several countries. An untied credit package may involve several organisations and its servicing may be time consuming (leading to higher costs) due to bureaucratic procedures (advertising, pre-qualification). Some bidders even refrain from quoting, this leading to an uncompetitive situation. Higher equity proportion (to credit) would be conducive to impose greater discipline.

3. Five to seven years lead time can be due to the financing pattern, low capability level, restricted infrastructure and lack of disoipline.

4. It takes two to four years to reach 100 per cent capacity utilisation from start-up.

5. Best training is on the job. It is desirable to have an experienced operating company for the first few years of operations during which time locals can be trained on the job.

CONTRACTOR I

1. Factors which can be quantified:

   a. tropicalisation: to cover the additional cost of equipment to cater for:
      - operation in extreme climates
      - earthquake resistant if required, and
      - export packing

   b. Shipping, port fees, CIF charges and in-land transport to site
   c. Civils: could be similar to that in the developed countries but must be investigated before hand.
   d. Construction: location is important. It may be close to a main urban area (e.g. Newcastle in the United Kingdom, Lagos in Nigeria) or in a totally remote site, e.g. Nigg Bay in the United Kingdom. The difference between the two is the cost of establishment of a temporary site township and all the necessary domestic facilities for the construction crew.
   e. Commissioning: additional travel and subsistence expenses of supervising engineers
   f. Engineering: The necessity of site visits and the inevitably extended project time scale having an effect upon the efficient use of man/hours.
   g. Exclusions: These below the line costs of financing, bonding, duties, etc. vary greatly, but represent a significant percentage in the cost of a third world project.
   h. Adequate/liberal spare parts - much more than for a site from where standard items can be procured quickly.

2. Factors which cannot be quantified:

   a. The invitation to bid (ITB) may well contain rigid definitions of engineering standards.
   b. In case of an additional plant at an established site, matching of standards for valves, electric motors, switch-gear, cables and instruments, piping and vessels can be a major problem.
   c. A long validity date of the tender and protracted negotiations have a major bearing on the contract price.
   d. Infrastructure, including transport, cranage etc. can be <u>partly</u> qualified
   e. The client's staff may be well educated in the form of university

degrees but have probably not had exposure to industry and, for example, do not know the difference between one type of steam trap and another, nor when a butterfly valve (low cost) may be used instead of a conventional control valve (high cost).

f. Any engineering change or change of specifications can be costly, particularly if such a change is imposed by the client late in the engineering phase. A "simple" change of motor specification nine months into the engineering phase could alter a great deal of detailed engineering drawings and cost a great deal of money.

g. The client may take a considerable project responsibility himself, while he may not be capable of doing so. Take over of even little contracting at a late stage can be quite expensive.

To summarize, additional costs for third world projects are due to:

- remote location
- the effect of an uneducated client.

In total, these two factors could add 50 per cent to the project total erected cost.

3. To reduce capital cost of future projects, the following should be considered:

- prequalifications of bidders
- reasonable (to both parties) contract
- pay the contractor well - it pays off in the long run;
- reimbursable for hardware and even for construction - avoids over provision of risk/contingency by the contractor
- quick and high capacity utilisation
- a competent consultant to act as client's arm.

CONTRACTOR J

1. The three major cost components of capital projects (in developing and perhaps also in developed countries) have been escalating thus:

- engineering and supervision, 6 per cent/year
- hardware 6 to 8 per cent/year
- construction, 20 to 30 per cent/year.

2. Economy of scale is lower at higher capacity and could even be negative at very high capacity. Also the operating/raw material costs have been escalating much faster than capital cost, so much so, that the former constitute a major portion (well over 50 per cent) of the production cost. For these reasons there is a very strong (technical and commercial) case for medium size (rather than world scale) plants for developing countries where the infrastructure (e.g. transport) is inadequate and/or inexpensive.

CONTRACTOR K

1. Plants can be built either on complete turn-key basis (entire responsibility resting with the contractor) or on a departmental basis, wherein the client/owner becomes the project manager and subcontracts (for services and/or hardware) most of the work/supplies to a number of contractors/suppliers.

2. Turn-key can prove cheaper (in the long run) since one draws upon the "know-how" of the contractor. In case of departmental execution (for sake of learning/training) one has to pay the "entrance fee" for the "learning curve". The developed countries have done so in the last part of the 19th century whereas the developing countries are doing so now. This explains the extra cost of fertilizer projects in the developing countries.

3. In many cases the owner appoints a single project manager and relies on the various local subcontractors interfacing with each other without much planned control of labour or materials. This extends the construction period far beyond the normal and increases the overall investment cost.

4. There seems to be a trend back to turn-key type contracts but with restrictions on the use of foreign labour and of maximising local manufacturing and fabricating facilities. These can be more expensive.

5. There is a compensating factor of the advantageous financing and aid facilities that plant owners in developing countries receive from the governments of developed countries.

6. The total project cost could be reduced by spending a little more initially at project definition stage by employing an international consultant/contractor who could also act as the client's project manager. This is until such time that the client can develop his own project team.

CONTRACTOR L

1. General considerations

a. The cost depends on plant location and on the degree of industrialization of plant site. Plants built on site where already infrastructure is available, good quality equipment and materials purchased locally and specialized and competitive erection companies found in nearest areas, investment costs are not too different from Europe.

b. In third world countries, where most of hardware has to be imported or where local labour was scarce or poorly specialized and where even all accommodation facilities had to be provided, investment costs are higher than expected. This in spite of the fact that the hourly labour costs, which represent more than 30 per cent of total investment, are lower. Other factors for higher cost: expatriate supervisors, higher shipping costs, and custom duties on imported equipment and materials. However, skilled labour in some of the developing countries (e.g. India, Pakistan, Philippines and South Korea) is not only cheap but also highly productive provided there is close supervision.

2. Quantitative: Major cost elements of fertilizer projects:

- software 20 per cent
- hardware 50 per cent
- construction 30 per cent

First two items are the same (except for freight and insurance), irrespective of the location. The main difference is in case of construction. The components, their contribution and cost ratio, developing/developed country (roughly):

- 2,0 materials
- 0,5 labour - local
- 0,8 " - others
- 2,0 " - expatriate
- 2,0 supervision, expatriate, including accommodation etc.

Such factors, if established for each location, may provide the key in the present assignment.

3. Cost estimates

Assuming 100 as the cost of equipment and materials ex-works (and this figure does not depend on the location of the plant), the final project cost for three typical locations is worked out as:

	Europe	Pakistan	Libya
	%	%	%
Equipment and materials	100	100	100
Transport, custom duties	6	17	14
Civil works	10	25	30 1/
Erection	48	55 2/	113 1/ 3/
Supervision	6	8	10 1/
Engineering	19	21	21
	189	226	297
Cost factor	1	1,19	1,57

The major increases over European costs appear on civil works, erection and supervision. The big increases in Libyan costs may be caused by the particular location in a desert area which required full accommodation facilities.

4. To reduce project cost, use direct hiring (for civil and erection) with own erection equipment (purchased/hired on a selective basis, since some of the equipment is required during operation/maintenance) rather than the usual method of subcontracting. But this requires a strong and experienced project team.

1/ Including camp accommodation

2/ On direct hiring basis

3/ On subcontracting basis.

CONTRACTOR M

1. The rapid escalation in the cost of fertilizer projects in the developing countries is not caused for sure by a stronger profit orientation of plant suppliers in industrialized countries as it might be suspected by some investors in the developing world.

2. It is predominantly due to substantial time and cost overruns experienced by the contractors within their usually fixed price contracts. New contracts will always reflect past experience and the contractor must take into account, also pricewise, of the particularities of the customer's country.

3. Main reasons for time and cost overruns:

   a. In many cases, data furnished by the client with regard to soil conditions, quality and safety of local supplies, standard of housing for expatriate personnel, time required for procedures of the local administration etc., did not prove reliable. This necessitated:

      - spending more time and money to establish exact data
      - taking over services, e.g. camp management, transportation, etc.
      - more man-hours for project management, local supervision, etc.

4. The clients' top management is usually very competent, but the middle management has a lower degree of professional expertise and working experience leading to:

   - reluctance to innovative technical features
   - safety-first thinking with regard to contractual interpretations, etc.

5. The existence of a client's consultant is generally welcome, however:

   - scope of activities and responsibilities must be clearly defined.
   - Consultant must be accepted by the working level of the client.

6. Substantial infrastructural development means more time and cost.

7. Increased local supplies/services mean longer delivery periods, more inspection personnel, provision for own experts to remedy defective performances of local suppliers, etc.

7. Excessive bureaucracy which is a well known problem

8. The burden of high capital costs becomes still heavier if the plant cannot be operated at its planned capacity.

(PROCESS PLANT) ASSOCIATION N

Major factors for high cost of fertilizer projects in developing countries are:

- lack of infrastructure
- need for expatriate supervision and skilled labour
- delayed completion due to bureaucratic procedures, vague contracts, split-up responsibility
- lack of qualified subcontractors
- bureaucratic procedures.

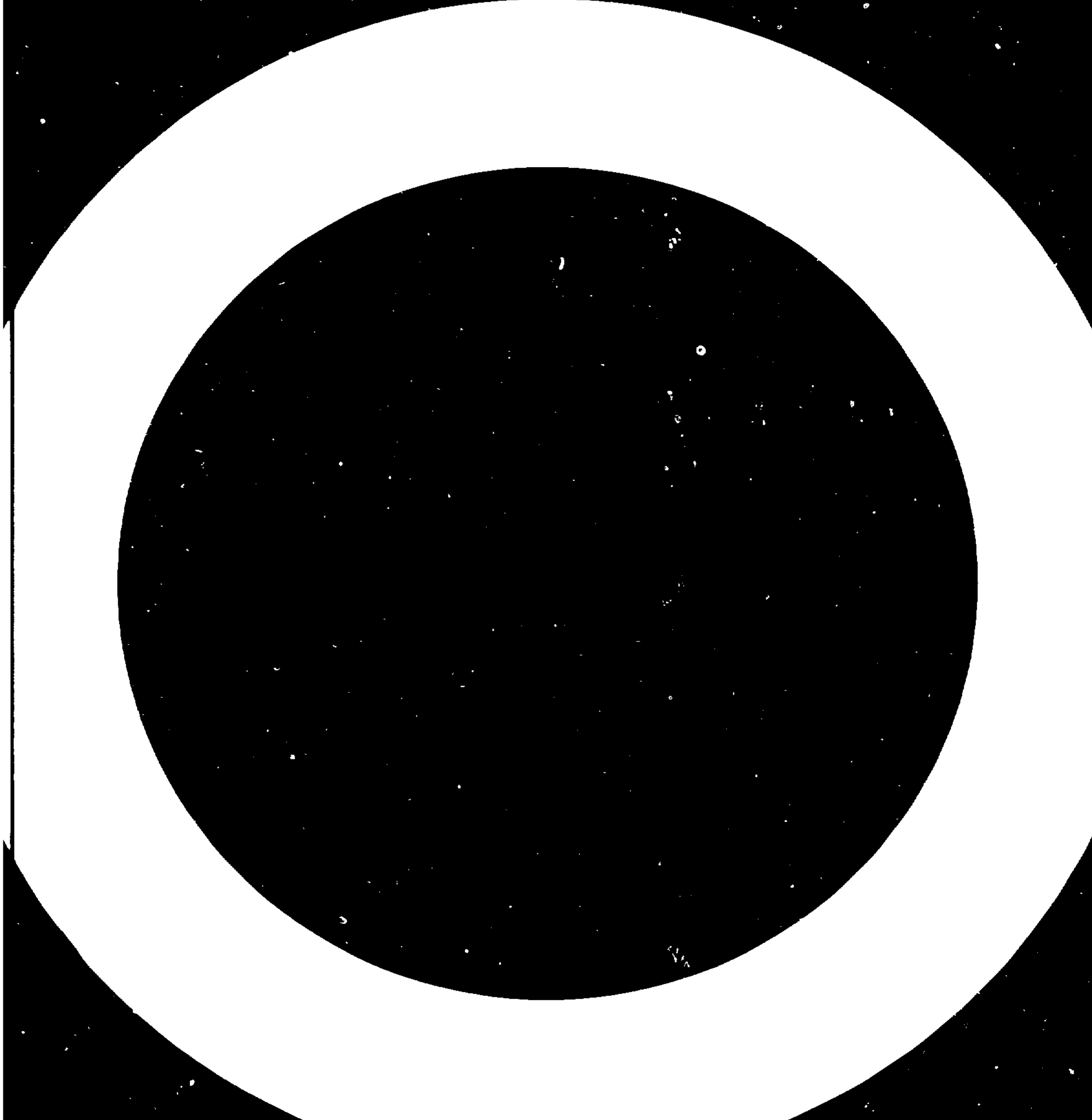


Table A.1

Capital Cost Structure Elements

COST ELEMENTS OF FERTILIZER PROJECTS		TURN-KEY PLANT COST: Battery Limits	TURN-KEY PLANT COST: Off-site Facility	OTHER PLANT COST ELEMENTS	ADDITIONAL COST ELEMENTS CHARGED TO THE PROJECT
MAIN COST ELEMENTS OF THE PROJECT / PLANT COST COMPONENTS		-Principle process equipments. -Secondary equipments and auxiliary materials. -Civil engineering and errection work. -Freight and taxes.	-Utilities units and distribution system -Storage and material transfer facility. -Control and maintenance facility. -Civil engineering and errection work. -Freight and taxes.	-Preliminary and preoperation activities (feasibility study, site development, training of operators, preparation and material for start-up operations etc.) -Interest -Insurance.	-Contingencies (for delays, price escalation, currency fluctuation, change in scope of work, extra inventory of spares. -Out-of-plant boundary infrastructure -Management -Engineering/Marketing training.
PRINCIPAL COST COMPONENTS	SOFTWARE TECHNOLOGY	-Front end engineering (including licenced patents) -Detail engineering. -Technical management for execution: procurement, inspections, monitoring and cost control, construction supervision and contract coordination		-Feasibility study -Training programme for operators.	-Technical management -Training programme for engineering and marketing. -Detail engineering and management for out-of-plant infrastructure.
PRINCIPAL COST COMPONENTS	HARDWARE TECHNOLOGY	-Plants and equipments (processing units and auxiliaries including steel structures, fittings etc.). -Piping, electrical and control equipments etc. -Spare parts		-Material and spare parts for first charge (loading) of the plant during commissioning (start-up operations).	-Out-of-plant boundary (fence) infrastructure equipment and material. -extra inventory of spare parts.
PRINCIPAL COST COMPONENTS	CONSTRUCTION	Labour, construction and material equipments for -Civil engineering work. -Mechanical engineering (errection) work. -Piping work. -Electrical, instruments, insulation installation and connections.		-Site preparation	-Civil engineering work in connection with out-of-plant boundary infrastructure.
OTHER COST ITEMS		COST ITEMS USUALLY ASCRIBED TO PRINCIPAL COST COMPONENTS: Transportation and freight charges (including insurance), taxes, custom duties, interest.		-Balance of interest -Insurance	-Contingencies

Table A.2 Comparison of erected costs of plants USA cost = 1.0

As of Jan. 1	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Belgium	0.58	0.68	0.65	0.73	0.94	1.07	1.00	1 01	1.10	1.18	1.36	1.21
Denmark	0.64	0.73	0.71	0.76	0.97	1.06	1.01	0.98	0.98	1.10	1.13	1.05
France	0.57	0.61	0.61	0.68	0.83	0.85	0.93	0.89	0.87	0.96	1.02	1.04
Germany	0.62	0.71	0.77	0.81	1.08	1.02	0.98	0.99	1.02	1.12	1.26	1.13
Italy	0.58	0.63	0.63	0.66	0.78	0.86	0.88	0.81	0.82	0.91	1.01	1.01
Netherlands	0.60	0.66	0.72	0.75	0.97	1.04	1.05	1.05	1.12	1.13	1.22	1.14
United Kingdom	0.58	0.62	0.66	0.69	0.72	0.77	0.81	0.70	0.72	0.80	0.94	1.08
Australia	0.62	0.62	0.66	0.67	0.87	0.92	0.89	0.94	0.85	0.87	0.84	0.90
Canada	0.83	0.87	0.86	0.82	0.90	0.92	0.95	1.05	0.98	0.87	0.90	0.90
Japan	0.38	0.40	0.39	0.45	0.54	0.58	0.55	0.59	0.65	0.82	0.79	0.77
Norway	0.72	0.79	0.83	0.87	1.09	1.16	1.16	1.28	1.25	1.29	1.31	1.32
Sweden	0.86	0.87	0.90	0.95	1.17	1.24	1.18	1.24	1.13	1.19	1.26	1.29
U.S.A.	←					1.0						→

Source: Engineering Costs and production economics, 6 (1982), 273.

Table A.3 Location cost index - Various countries

(USA = 100)

Country	Type of plant	Year	Index
Algeria	P	1970	111
Australia	G	1970	120, 105
Belgium	P	1970	100
	G	1970	94
Brazil	G	1970	110
France	P	1970	100
	G	1969	94, 86, 91
	G	1970	91, 98
India	P	1970	123
	G	1970	135
Iran	P	1970	116
Italy	P	1970	95
	G	1969	89, 86
	G	1970	86
Japan	G	1969	82, 83, 95
Netherlands	G	1970	92
Peru	G	1970	104
Saudi Arabia	G	1976	140
Spain	G	1970	100
Sweden	G	1970	100
Taiwan	S	1961-5	100
	C	1961-5	100
Turkey	P	1970	115
United Kingdom	P	1970	95
	G	1969	90, 91
	G	1970	91, 103
West Germany	P	1970	100
	G	1969	88
	G	1970	88, 95
ECM	P	1965	95
Underdeveloped countries	P	1965	123
Underdeveloped countries (with financing)	P	1965	145
Developing country	FR	?	123 - 160

Source: The Cost Engineer, 19 (4, 5, 6) 1981

C = complex; G = general; P = petrochemical, S = simple, FR = fertilizer plants and refinery

Table A.4 Location factors
(Basis USA = 1,00/year)

Australia		1.3
Austria		1.0
Belgium		1.0
Canada		1.15
Central Africa		2.0
Central America		1.0
China	(imported element)	1.1
	(indigenous element)	0.55
Denmark		1.0
Ireland		0.8
Finland		1.2
France		0.95
Germany		1.0
Greece		0.9
Holland		1.0
India	(imported element)	1.8
	(indigenous element)	0.65
Italy		0.9
Japan		0.9
Malaysia		0.8
Middle East		1.1
Newfoundland		1.2
New Zealand		1.3
North Africa	(imported element)	1.1
	(indigenous element)	0.75
Norway		1.1
Portugal		0.75
South Africa		1.15
South America	(North)	1.35
South America	(South)	2.25
Spain	(imported element)	1.2
	(indigenous element)	0.75
Sweden		1.1
Switzerland		1.1
Turkey		1.0
United Kingdom		0.9
United States of America		1.0
Yugoslavia		0.9

Source: Process Economics International, Vol. I, No. 3, Spring 1980.

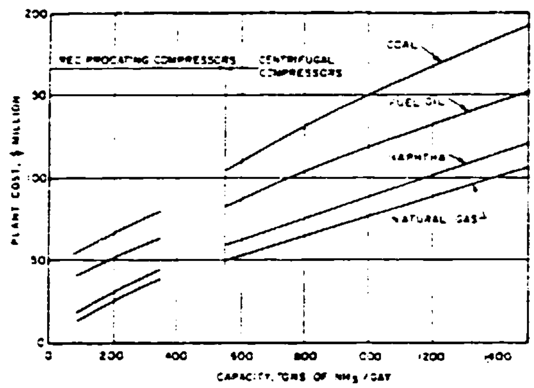
Notes: 1. A factor should be increased by 10% for each 1,000 miles, or part of 1,000 miles that the new plant location is distant from a major manufacturing or import centre or both.

2. When materials or labour, or both, are obtained from more than a single source, the appropriate factors should be prorated accordingly.

ANNEX II OTHER RELEVANT DATA AND INFORMATION

B. Figures

Figure 1 Estimated turn-key plant cost for ammonia plants as affected by capacity and feedstock



Basis: Industrial location in developed country. Turnkey costs = battery limits cost plus 50%.
Notes: The most reliable data are for natural gas-based and naphtha-based plant with capacities of 550, 900-1,140, and 1,360 tpd. Data for smaller plants and other feedstocks are more speculative because few such plants have been built.

Figure 2 Effect of type of feedstock and plant capacity on production cost of ammonia

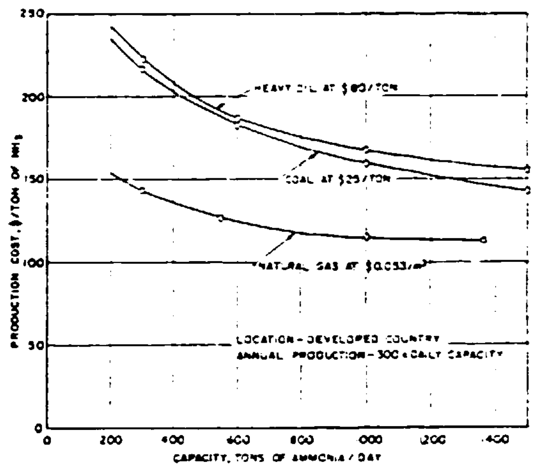


Figure 3 Estimated investment cost of urea plants as related to capacity

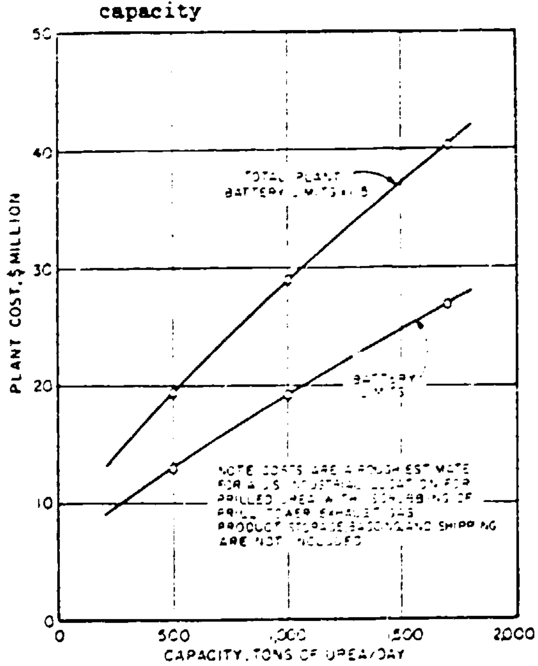
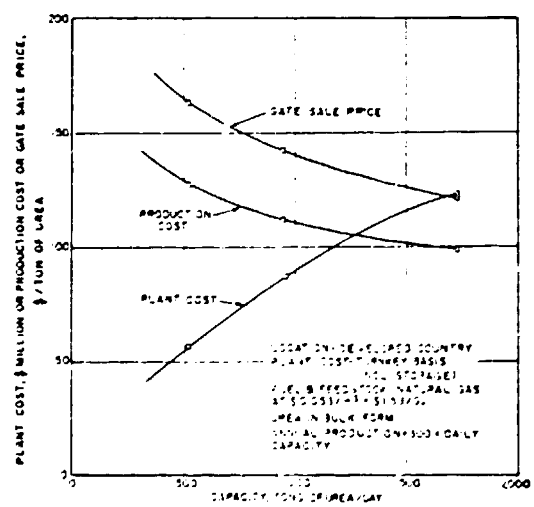


Figure 4 Plant cost, production cost, and gate sale price for urea produced in an ammonia urea complex as affected by capacity



Source: UNIDO Fertilizer Manual "Development and Transfer of Technology," Series No. 13.

Figure 5 Capital cost of sulphur-burning Sulphuric Acid Plants, Double Contact, U.S. or European Location

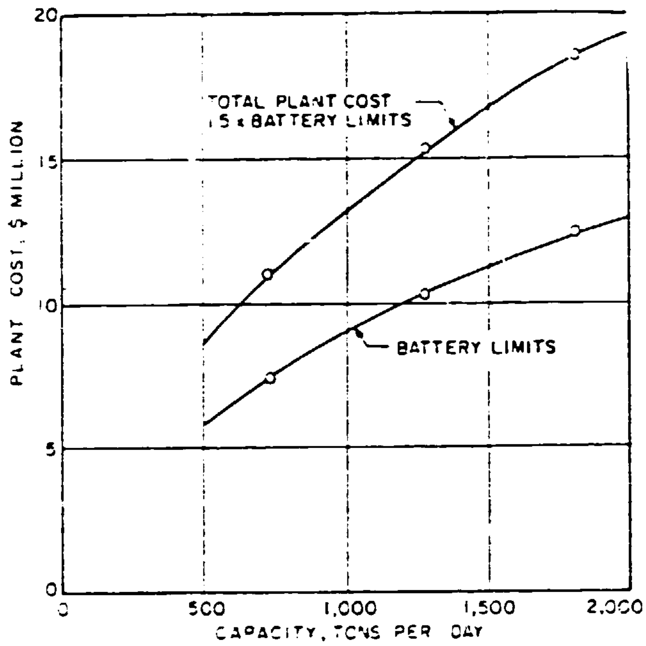
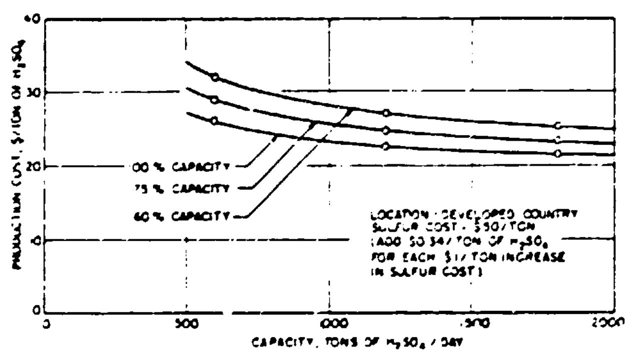
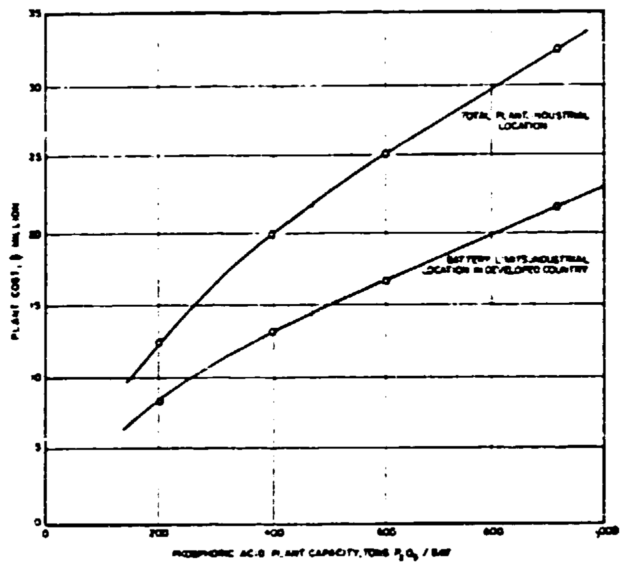


Figure 6 Estimated Production Cost of Sulphuric Acid as Affected by Plant Capacity and Capacity Utilization



Source: UNIDO Fertilizer Manual "Development and Transfer of Technology", Series No. 13.

<u>Figure 7</u> **Estimated Cost of Wet-Process Phosphoric Acid Plants**



<u>Source</u>: UNIDO Fertilizer Manual "Development and Transfer of Technology" Series No. 13.

ANNEX III. WORLD BANK EXPERIENCE WITH REGARD TO FERTILIZER PROJECTS IMPLEMENTED IN DEVELOPING COUNTRIES

The World Bank has been actively involved in financing numerous fertilizer projects in the developing countries. It is estimated that nearly 1/4 of all new projects in developing countries have included finance from the World Bank.

1. Overview

The following table gives an overview of the number of projects where the World Bank has been involved.

Table A.5 Role of World Bank - Investment in fertilizer projects

	Loan m$	Number of projects	Number of countries	As of August 1980 Completed	Completion due	Completion later
- 1973	300	19	17	-	-	-
1974-1977	1000	-	-	-	-	-
1978	200	4	-	-	-	-
Aug. 1980 (cumulative)		27	11	13	6	8

Before sanctioning finance for a particular project, the World Bank prepares a thorough feasibility appraisal of the same. At the end of the project performance, an audit report is also prepared to highlight the major problems, if any, encountered during execution. Such a report, of course, includes not only the total completion time but also the actual cost in comparison with the estimated cost in the appraisal report. The summary of 22 such fertilizer projects is given in table A.6.

2. Major cause for overrun

Table A.6 below also indicates the major causes of delay/overrun of the major projects in different countries. A separate analysis of the World Bank assisted projects, completed during the period 1970-1980, shows the following major causes of delay in project completion (see table A.7).

Table A.6 Summary of projects sponsored by World Bank

	Date of completion	Months to completion		Project cost, m$		Major causes for delay
		Apprais. report	Actual estimate	Apprais. report	Actual estimate	
Bangladesh						
Project 1	Oct. 80	34	59*			Soil/compaction + project management
Brazil						
Project 1	Aug. 80	34	52*			Materials not to specifications
Project 2	Dec. 80	39	59*			Late delivery of equipment
Egypt						
Project 1	Jun. 80	37	64*			Late delivery, civil works
India						
Project 1	Jan. 70	37	34	68	65	- - -
Project 2	May 73	36	41	70	71	- - -
Project 3	July 76	33	55	41	56	Materials shortage and management
Project 4	July 77	35	53	95	138	Late delivery, damage
Project 5	Mar. 78	32	48	57	83	Late delivery
Project 6	Dec. 78	41	58	166	187	Late delivery, local equipments
Project 7	Jan. 80	45	61	181	168	Change in feedstock
Project 8	Dec. 75	-	-	15	21	- - -
Indonesia						
Project 1	Sept. 74	30	34	67	77	Late appointment - technical advisor
Project 2	Dec. 76	32	31	166	165	- - -
Project 3	Aug. 77	30	26	157	130	- - -
Mexico						
Project 1	Oct. 80	32	56*	-	-	Civil works, currency devaluation
Morocco						
Project 1	Oct. 76	36	40	136	148	Civil works
Pakistan						
Project 1	Sept. 79	28	52	85	171	Late delivery, floods political unrest
Project 2	Feb. 72	-	-	71	77	- - -
Romania						
Project 1	Sept. 80	38	59*			Late delivery, change of scope
Turkey						
Project 1	March 77	36	44	107	137	Change in project management and project team

* Mechanical completion from date of effective control

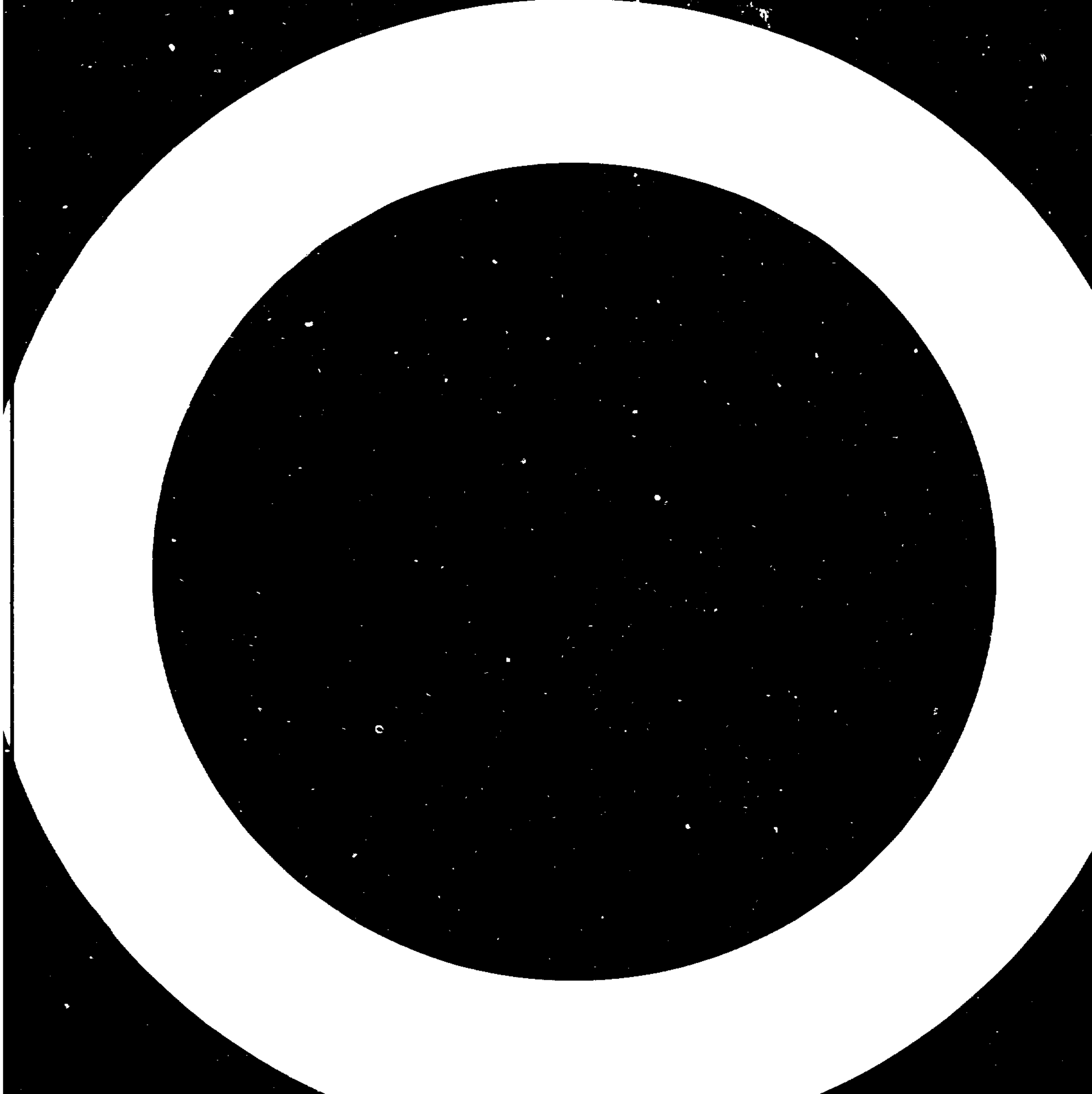
Table A.7 Major factors contributing to Delay

Factor	Percentage
Late delivery of equipment	19
Management constraints	11
Unforeseen circumstances	11
Late appointment of engineers	9
Scope changes	8
Erection/Civil work delays	8
Late completion of basic design	8
Shortage of skilled personnel	7
Shortage of bulk materials	50
Delays in finalizing procurement	5
Others	9
	100

Overall, nearly three-fourths of the projects were delayed because of late mechanical completion and one-fourth because of problems encountered during commissioning and stabilization.

3. Remedies

In order to prevent cost overrun for future fertilizer projects, one must take into account the lessons learned from the past projects.



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