

BUREAU OF INDIAN STANDARDS
DRAFT FOR COMMENTS ONLY

(Not to be reproduced without the permission of BIS or used as Standard)

Draft Indian Standard

Guide to Terotechnology
Part 2 Introduction to Techniques and Applications
(First Revision)

ICS No. 03.100.01

**Management and Productivity Sectional
Committee, MSD 04**

**Last Date for receipt of Comments
July 2024**

NATIONAL FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Management and Productivity Sectional Committee had been approved by the Management and Systems Division Council.

In any organization, it is necessary to identify and then choose between the investment options open to it and to make decisions on how best to invest the capital available. Once a decision has been made to make an investment in some form of physical asset or project, then the application of terotechnology should assist in the object of getting the best value for money from that investment and thus justify it.

Terotechnology is a multi-disciplinary study or research or industrial practices combining the core branches of management, finance, design and engineering, operation and maintenance, life assessment and disposal applied to physical assets in pursuit of desired economic life cycle. It is concerned with the specification and design for reliability and maintainability of physical assets such as plant machinery (rotary and static), instruments and control equipment, buildings etc. The application of terotechnology concept takes into account the economic methods /processes of supply chain including transit, asset installation and commissioning, operation and maintenance, modification and replacement. Business decisions on asset's acceptance or rejection at any stage of life cycle are influenced by information on design, commissioning, performance and costs throughout the life cycle of a project.

Terotechnology applies equally to both assets and products because the product of one organization often becomes the asset of another. Even if the product is a consumer item, the needed reliable design and performance (as perceived by customers) will get a boost by the adoption of terotechnology and thus improving market security for the producer.

Terotechnology was developed in the context of larger organizations, with the objective of making them more efficient and competitive. Throughout this standard the applicability to a larger organization is used as a basis as this with represent the more complex situations. However, the objective of maximizing value for money spent and the principles involved in achieving this, are equally applicable to small organizations. Small organizations face problems as much as those faced by the larger; more complex organizations. Their problems may be simpler but the principles of problem solving remain the same.

The small organization can, therefore, benefit from this guidance by selecting those parts of the decision-making process that can help them.

The key ingredients of success in the application of terotechnology are enthusiasm and cooperation throughout a well-structured organization with impetus maintained by enthusiastic senior managers. Discipline too, is important to efficient application and managers need to specify the degree of analysis which backs different levels of decision-making in various phases of assets the organization is operating. In order to arrive at the right key performance indicators of the business processes, it is essential that adequate and quality data are available within the enterprise to support the required confidence level limits that are possible to attain after adoption of Terotechnology.

Regardless of the success (or failure) achieved in the management of an asset, the experience can provide valuable feedback which is fundamental requirement of terotechnology. This feedback is gathered by monitoring decisions, actions, consequences and the lifetime performance of the asset and can be used to improve confidence in new decisions.

The cyclic nature of terotechnology demands that decisions about asset management are reviewed in the light of increasing experience and knowledge. Throughout an asset's life, the relevant data need to be collected and analysed in order to guide current and future decisions.

This structured and analytical approach amalgamated with latest philosophies of plant management especially acquisition management, operation and maintenance management, latest scientific disposal management based on Life Assessment etc results in better decision-making throughout the organization, thereby providing opportunities to improve profitability, efficiency, cost-effectiveness, sustainability and overall organizational reputation. Proven strategies are given here in brief in the various places in the text considering their appropriateness in life cycle phases.

This standard sets out in detail all the activities that should be carried out to ensure that the organization, which uses terotechnology, could compete successfully and at the same time, achieve consumer satisfaction.

This standard is largely based on BS 3843 (Part 2): 1992, 'Guide to terotechnology: Part 2 Introduction to the techniques and applications.

INDIAN STANDARD

GUIDE TO TEROTECHNOLOGY
PART 2 INTRODUCTION TO TECHNIQUES AND APPLICATIONS**1. SCOPE**

This standard (Part 2) provides introductory guidance to managers on the techniques used in applying terotechnology (The techniques themselves are described in Part 3 of this standard). It outlines the techniques and describes how, generally, they are incorporated into decision-making processes. It also illustrates how individual, departmental interests and considerations interact with others, and emphasizes the importance of communication throughout the enterprise.

2. REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

<i>IS No.</i>	<i>Title</i>
9990: 1998	Glossary of terms in terotechnology (first revision)
15363	Guide to terotechnology:
(Part 1) : 2003	Introduction to terotechnology
(Part 3) : 2004	Guide to available techniques.

3. DEFINITIONS

For the purpose of this standard the definitions given in IS 9990 shall apply, together with the following:

3.1. Board - Superior management level of the organization, ultimately responsible for deciding upon and authorizing any new project, specifying the objectives and policies to be followed in assessing options.

3.2. Organization - In the context of terotechnology, this means the totality of the enterprise which is to undertake a proposed new or additional project.

NOTE: This may be a large industrial company, a public service or in the extreme an individual

3.3. Spare - A replica or equipment component purchased to replace the original component supplied a part of the asset.

NOTE - Replacement is normally expected to be required due to failure in its widest sense

4. PRINCIPLES OF TEROTECHNOLOGY

4.1. Investment in capital plant, buildings and equipment is fraught with uncertainties and risks which make the assessment of lifetime economics difficult. Terotechnology provides techniques within a structured approach which help an organization both to evaluate an investment and having invested, to protect and service it economically throughout its working life, Terotechnology's first and paramount

prerequisite is communication. Because its techniques are interactive it is vital that departmental interests do not become isolated. Instead, there needs to be continuing dialogue between all the functional departments in the organization and line managers need to understand the weight of every argument, for it is their responsibility to decide on the level of risk that is acceptable to the organization.

4.2. Clearly the most financially desirable venture is worthless if based on unachievable technology and equally the cleverest invention is useless, if it is beyond the financial reach of the market. As a general rule, however, ventures are rarely as clear cut and careful, comprehensive analysis are required in evaluating all the factors that contribute to decision-making. When investing in a domestic appliance, for example, a wise buyer seeks the best buy to meet his or her particular needs. In reaching a decision the factors such as cost, capacity, appearance, potential time-saving, running and servicing costs, maintenance and insurance are examined. At times, decisions are often conditioned by advice from other users of similar products or services. Performance reviews throughout the product or service life (particularly at the end) reveal whether the forecasts made at the time of purchase have been realized or not. This review provides valuable input to decision-making, firstly whether or not to replace the product or service, and secondly, to revamp the process of selection itself.

4.3. This selection process marks the beginning of a new life cycle.

4.4. These thought processes represent the application of terotechnology in the simplest, and probably most effective form. The principal activities are best summarized as follows:

- a) Initial investment appraisal using the 'best data currently available.
- b) Investment in the acquisition of the asset. **(See 6.3)**

Then, when the asset has been acquired and its useful life progresses, the user develops:

- a) Operational experience
- b) A maintenance history.

Finally, experience during these four activities is used in:

- a) Improvements needed to the asset or in its use.
- b) Decisions on disposal and replacement.

While understanding and executing the various activities in assets' life cycle, an important philosophy to be borne in mind always is the Performance Excellence of the Assets. It is emphasized in summary in Figure - 2.

4.5. Mass production cannot meet the individual's specific needs. Instead, a wise manufacturer will include market research as a key element in applying terotechnology in respect of his products. Based on the results of such exercises, he will ensure that desirable features are developed and undesirable ones dropped or designed out.

(Dissatisfied customers are more likely to air their views and prompt, positive reaction by designers to the most common complaints should render the product more competitive and marketable. Negative attitudes to customer input, have the opposite effect and many suppliers adopting a take it or leave it sales policy have found that customers have taken the latter choice. Often such suppliers have failed to survive).

4.6. An organization contemplating a multi-million-rupee capital project, perhaps to build a factory to produce domestic appliances, applies identical principles in its decision-making. However, because the financial risks are very much greater, a structured, formal approach to lifetime costs and decision-making is required. Unfortunately, far too frequently, economic appraisals and cost-benefit analysis are carried out merely to support an acquisition-decision already made. **Thereafter the asset is often managed by instinct and in ignorance of the industrial efficiency and cost-effectiveness. Terotechnology offers a structured approach and the standard here introduces the primary techniques that are currently available.**

4.7. Part 1 of this standard describes the consequential benefits and costs of introducing terotechnology. Benefits to be gained by an organization through introducing terotechnology are listed in 5 of IS 15363 (Part 1).

This standard describes how those benefits can be achieved and emphasizes the need for regular and structured communication between different functions. Tables used to illustrate this structure and to list the thought-processes and techniques that support decision-making. All of the tables in this Part have a similar layout and they summarize those matters, which can influence the major decision phases of the asset life cycle.

These phases are: concept and investment decision, acquisition, useful life (comprising operation and maintenance as the principal activities) and disposal. The four columns of the Tables list the followings:

- a) Primary analysis, listing the particular factors that need to be analysed as contributions to each major decision.
- b) Consideration, providing an aide memoire of the matters that typically impinge on the factors of the primary analysis
- c) Techniques and procedures, outlining the methods by which the considerations can be measured objectively (and where necessary optimized) in reaching judgments on the primary analysis factors.
- d) Interacting interests, indicating those departments or activities within the organization which might input information to, or gain benefit from, the aspects of terotechnology listed in (a), (b) and (c).

5. GENERAL CONSIDERATION

5.1. Organizational Strategies

5.1.1. An organization may wish to embark on a new project for a number of reasons. These include the followings:

- a) Expand the organization's share of a market for a given product or service.
- b) Fill a gap perceived in the market, that is a new or updated product or service.
- c) Meet customers' requests.
- d) Conform to a statutory requirement.
- e) Support other activities being undertaken by the organization.
- f) Replace another project coming to an end.

5.1.2. In cases 5.1.1 (a) to 5.1.1 (e) the circumstances will directly determine the product or service and in most cases, the output as well. Options will exist with respect to the assets with which to carry out the specified objectives. There will also be an interaction between the detailed design of the product (for manufacturing enterprises) and the assets needed to execute this design. This increases the number of potential options that will have to be considered.

5.1.3. In the last case 5.1.1 (f), the board may direct an objective that may not be specific in terms of the product but may be simply in terms of turnover or profit. This will increase the number of options open to the manager of the new project

5.1.4. In all cases the organization is likely to be faced with a number of options, one of which might be not to proceed with a new project at all. By employing terotechnology techniques, a best choice of options can be selected and decisions in respect of the assets made throughout the life cycle in the interest of achieving the most economic life cycle costs.

5.1.5. It is clear that, in pursuit of the terotechnology objective, the cost and benefit implications of all aspects of the asset's life need to be considered. Where costs and benefits are distributed in time throughout the life cycle, analytical techniques such as discounted cash flow are used to sensibly compare incomes and/or notional expenditures at different dates. However, in addition other aspects which may not have a notional cost and/or benefit implication need to be taken into account; in some of these a notional cost implication might be appropriately used. In other cases, alternative approaches may have to be taken. The principal areas to be considered are outlined in 5.2 to 5.7.

5.1.6. Techniques based upon the principles of discounted cash flow are also used in comparing the costs and benefits arising from different forecast scenarios which identify the factors that maximize the benefits to the enterprise. Of equal importance are factors which could negate these benefits and these key areas of risk need to be identified (especially health-risk in value-adding production line assets that are responsible for reliable products) and the risk minimized wherever possible. These are discussed in 'operation and maintenance aspects' paras. In essence, an attempt should be made to identify those uncertainty factors which have the greatest influence on the likely return (sensitivity analysis) and, if necessary, to concentrate resources on investigating and keeping in place the requisite mitigation strategies to arrest those factors in detail. This is particularly relevant to the most common sources of risk which arise from uncertainty in the data used in the economic assessments, used in the asset health assessment and plant reliability and manufacturing process reliability.

5.1.7. There should be a corporate input to decisions to invest in capital projects so that the impact of existing policies on forecast scenarios (and possibly the converse) can be properly examined. The organization needs to ensure that the investment does not affect the nature and objectives of the business in an uncontrolled way because this could result in uncontrolled risk.

5.1.8. Inevitably any new project will result in change which can affect both the organization and those outside it, such change may involve factors which are subject to external constraints and these have to be considered and their influence included in the investment appraisal.

5.2. Community

5.2.1. The social and environmental acceptability of changes are increasingly prominent considerations for organizations contemplating new investment or developing existing facilities. These aspects can impact with equal severity whether the proposal is to extend a dwelling house or to build a major

production facility. People awareness of such developments quite properly increases with improved living standards and wider educational aspirations. As knowledge grows, so increasingly more stringent international, national and local controls are applied to protect the environment. In addition to these legal constraints, developers also need to consider individual local acceptability as well as the specialist views of pressure groups. What may be regarded as a prosperity-generating asset by one section of the community can equally be considered a dangerous, toxic monstrosity by another.

5.2.2. Because of these differences of view, there is a risk of future growing public unacceptability which might limit the operation of the asset. For example, increased legislative requirements in regard to, say, effluents, noise and even demolition and disposal processes could significantly affect lifetime cost equations.

5.2.3. In planning changes the owner and/or user needs to assess the risk to the investment or the organization's overall image and the associated effect on profitability.

5.3. Nature of the Business

5.3.1. Developers should also consider the risk that investment proposals pose for the organization's existing business. Here, concern centres on whether or not the proposed investment is concomitant with, or fundamentally different from, the organization's traditional business. For example, a proposed new project may produce goods or services repugnant to existing customers on political or ethical grounds or which may be seen to compete with products of customers who purchase the traditional products or services of the organization. This could be reflected in market resistance to the existing products and the consequent reduction in profitability having to be made good by income from the new investment. The corporate study might conclude that this effect would be so severe that the proposed investment would adversely affect the organization and thereby select other suitable alternative(s).

5.4. Commitments/Involvement

The third area of risk is that of corporate confidence in the ability to maintain the quality of existing and new products with increased diversity and that commitment to and involvement of customers old and new will be unaffected. Further, the commitment/involvement of employees has to be considered because they, too, will have opinions about environmental and ethical aspects which may so affect their reactions to internal changes that low morale would reflect in poor quality. Proper consultation with employees at every stage is desirable if their support for change is to be forthcoming.

5.5. Markets

On the more tangible aspects of the business, the investment appraisal needs to examine the market for the asset's products. There has to be high confidence that a significant and continuing market exists and that foreseeable output booms and slumps can be accommodated without undue risks to production costs, delivery schedules, stockholding costs, product quality or asset viability. It is also important to recognize that products themselves, particularly in the high technology field, can rapidly become outdated. This imposes the need to examine the adaptability of production facilities, the market life of products and the impact on the asset of the introduction of new products, possibly by competitions. Future opportunities should be critically assured for product innovation and design development keeping pace with digitalization, rationalization, improved quality, unit cost and price reductions.

5.6. Production

Input by production specialists to the corporate analysis includes the effect of the investment (particularly where asset refurbishment is concerned) on unit costs that will be achieved as the result of increased output from more efficient equipment, providing there is a market. Though this cheaper product allows the marketing section increased input to terotechnology by way of wider analysis in opportunities, it presents alternatives and new risks, and therefore calls for an increased order to maximize profit (or minimize loss) whether through changed volume of sales or altered selling prices, or reduced production, selling or administrative costs. The longer the term of the investment, the greater will be the uncertainty and risk attaching to these key data elements. The greater the perceived risk, the greater the depth of investigation that should be undertaken. The need to examine various combinations of 'what if?' questions give rise to the need for sensitivity analysis to guide decisions adequately. Production specialists would also assess, for example, the efficiency with which the operation of the asset could be managed, seeking to minimize money tied up in queuing and work in progress and the ways in which new processes will be integrated into established areas. These aspects also influence the cost equations.

5.7. Resources

5.7.1. The organization needs to examine financial and human resources. In material terms it has to be able to finance the investment and decide on sources of capital. Where external finance is sought, lenders or shareholders will wish to understand the risk they are accepting and all the foregoing corporate considerations should be included in the formal investment proposal. With increases in technology and technology assisted value-adding production line assets (producing products) that demand specialised operation and maintenance skills, the human resources development and management become very significant in organization. Due consideration should, therefore be given to the value and availability of the personnel equipped with such skills in the organization.

Decisions on acquisition, installation, operation and maintenance of the assets are generally a matter of the organization's policy and related to its size and experience in that activity rather than just implementation of terotechnology. Operation and Maintenance and in fact, entire life cycle management be preferably resourced in-house. However, depending on the size, complexity of assets, nature of business etc., few specialized activities may be out-sourced economically. Many new initiatives to optimise productivity, quality and cost, demand external professional services from related consulting organization/ specialists, and OEMs providing services both hardware and software.

6. MANAGEMENT AND TECHNIQUES THROUGH THE PROJECT LIFE CYCLE**6.1. General, Economic Appraisals**

6.1.1. Throughout the life cycle of a project, opportunities for alternative ways forward will arise almost constantly and management will be faced with decisions between such alternatives. Unless there is an overriding consideration, such as, a statutory constraint, the decisions made should always be, such as, to achieve the best economic solution. An economic solution needs to be viewed in terms of the full residual life of the project and, where relevant, the objectives set for it. The result of Residual Life Assessment (RLA). Asset Life Assessment (ALA) discussed in Disposal phase should be part of economic decision-making while looking for any new alternatives or even assessing current operation. These may, of course, differ from those originally set when the project was initiated due to developments in the organization and rise of new thought-processes of remaining life assessment that helps assess operational risk during aging process. Each time a decision has to be made, a new appraisal should be

carried out into the differences expected throughout the residual life of the project, in terms of costs and benefits. In the earliest phases of the project, these appraisals may have to be made in absolute terms as well as in terms of differences between alternative options to ensure that the project remains viable in terms of the set objectives. Similarly, at later stages during aging, during the useful life of the asset, an appraisal in absolute terms may be appropriate to ensure that continuation of the project remains viable.

6.1.2. In the case of both comparative appraisals and absolute appraisals, where the comparison is against financial objectives laid down for the project, similar techniques are employed.

6.1.3. The important aspect of any project whose life extends over a period of time, there is a need to compare the cash flows at different points in its life time. Various methods like Discounted Cash Flow (DCF)/ Net Present Value (NPV), Internal Rate of Returns (IRR) etc. may be used to arrive at worth of the current investment after the desired period of operation of the enterprise.

6.1.4. Another source of difficulty in comparing cash flows at different future points in time arises from changing price levels, both general and specific. However, in many cases relative values, when viewed over the lifetime of a project, may be assumed to be reasonably constant. In practical terms the selling prices of products can be expected to remain in roughly the same ratio to the prices of labour and materials, all changing proportionately -to the changes in value of the currency. Owing to the impossibility of predicting future inflation, it is normal to assume a constancy of value in economic assessments, that is to assume no inflation at all will take place and the relative cash values of materials and services as well as selling cycle of the project. Assessments made on this basis are normally termed as being on a constant price basis, for example, all values in terms of January 20XX prices.

6.1.5. Where, however, a particular service, Labour need or material is expected to change in price in real terms, that is its price is expected to rise faster or slower than the general price level, this should be taken into account. In such circumstances, when using constant prices, one should nevertheless calculate the variations in terms of the expected rates of relative change in real value and not in terms of price. A similar consideration may have to be made regarding the rate of interest to be used in discounting future cash flows. if comparative assessments are carried out in constant price terms the rate of interest to be used in discounting future cash flows should also reflect changes in value rather than prices. When comparative assessments are carried out in constant price terms the rate to be used in discounting future cash flows should not necessarily be taken as the current rate of interest which contains an element to compensate for the current inflation rate.

6.1.6. The above considerations are common to all economic appraisals and assessments. In consideration of the total costs and benefits of a project over its life, especially those arising before commitment to the project is made, several approaches may be used in presenting, in a summarized form, the overall results of the appraisal.

6.1.7. While the underlying principle of discounting is the same, sometimes the circumstances of a project make one of its variants preferable to another.

6.1.8. Table 1 lists the various methods of making economic appraisals, which may be required in any phase of the life cycle, and shows the variants of the discounted cash flow approach.

6.2. Concept/Investment Decision Phase

6.2.1. As discussed in 5,1, an organization's incentive to initiate a new project may arise from any one of a number of reasons. According to the circumstances the product of the project may or may not be

known from the start. If the product is not so specified, a number of possible product options may be offered for consideration and, in most cases, there will be further option on product output.

Table 1 General Economic Appraisals
(Clause 6.1.9)

SI No (1)	Primary Analysis (2)	Consideration (3)	Techniques (4)	Notes (5)
i.	Forecasts of capital expenditure	Need to identify transactions in terms of time and value	As given in Tables 2 to 6	
ii.	Economic appraisals	Comparison of optional courses of action or judgement of viability against objectives	1) Discount cash flow a) Net Present value b)) Internal rate of return c) Annuity 2) Rate of return 3) Payback 4) Cost-benefit analysis	1 2 3 4 5 6 7

NOTES

- All forms of DCF take into account the time value of money, but different forms are more appropriate for particular situations.
- This, the commonest form of DCF, is suitable where constant rates of interest apply throughout the life of the project.
- This variant of DCF takes account of varying rates of interest applicable throughout the life of the project.
- This variant is only relevant when there is need to finance a project on an even basis throughout its life and is normally only appropriate to government (especially local government) projects. Strictly it is based on calculations of net present value or internal rate of return (*see Notes 2 and 3*).
- This takes no account of the time value of money, nor of the interest benefit of depreciation.
- While this approach recognizes the time value of money, it fails to recognize adequately the situation in the more distant future.
- This is used in cases where the costs or benefits cannot easily be quantified in monetary terms.

6.2.2. Alternative production methods and the assets needed for these widen the choice still further. Before the possible production methods and the assets to achieve these can be considered the product design should be developed to an advanced stage. This should be carried out with the tero-technological needs of the customer in mind.

6.2.3. The establishment of these choices into a series of proposed projects, each with a given output of product, produced by a given method from defined assets, is the first step in the conceptual process. In all circumstances the number of such options will have to be reduced to manageable proportions. Some may be eliminated because of serious deficiencies in terms of the factors discussed in 5. Thereafter, the number should be reduced to those offering the best economic prospects by conducting and repeating investment appraisals on each remaining option, using progressively refined inputs and eliminating those which fail to meet the organization's specified objectives or are less attractive from a life cycle cost benefit point of view. On the final short-list of options an investment appraisal should be carried out in

as much detail as possible and using the best input data available. The exercises should also identify areas of risk and the implications that these may have on the costs and benefits of the proposed projects. These studies should be pursued until an optimum choice is clearly established and the probable full consequences for the organization can be appreciated. At this point the final decisions can be made on the option to be chosen and whether to proceed with this final investment decision or not

6.2.4. The items to be considered in the investment appraisal and the techniques that might be employed are given in Table 2.

6.2.5. This does not mean that terotechnology is inappropriate to such projects. On the contrary, its application is simply a matter of defining the benefit in different terms. Rates of treating patients, processing documents or passing examinations for example may be perfectly valid parameters on which decisions can be founded.

6.3. Acquisition Phase

6.3.1. In the acquisition phase of a capital asset, many contractual routes are open to the user organization, particularly in case of physical electro-mechanical plants. For example, an organization may wish to consider hiring or leasing rather than buying. Tero technology can be applied to this decision as to all others in order to determine, say, the net effective cost of hiring compared with buying the asset or some of its components. It often transpires that hiring or leasing is more costly than buying but the elements of risk accruing to the hirer may be very considerably reduced in comparison with buying. Leasing may also reduce the peak financial borrowing required for the project and this may be of significant value to the organization.

6.3.2. At the acquisition stage, the organization seeks to turn investment plans and decisions into reality in the form of buildings and plant, completed to time and cost schedules, ready to begin productive operation.

6.3.3. The plant reliability and latest maintenance thought-processes when integrated with the acquisition criteria, the decision-making becomes realistic and economical. This has been detailed in the following paras. Some of the vital tasks are equally applicable and part of Operation and Maintenance phase, which will be addressed in appropriate places and suitability of concept reflected therein. lists relevant considerations, shows the appropriate techniques and lists the various functional specialities which interact at each stage of analysis. It shows how the management of the acquisition process involves the overall planning, control and coordination of a project aimed at achieving the concept objective by completion on time, within the defined cost parameters of the investment appraisal/decision and to defined quality standards.

6.4. The Acquisition Activities are:

- a) Plan and programme all the resources and activities required to complete the project.
- b) Commit everyone involved to the project's objectives particularly those relating to programme and cost.
- c) Design the plant, structure, or buildings comprising the asset.
- d) Make appropriate arrangements for the supply, delivery and setting to work of the asset.
- e) Construct and/or install the asset.
- f) Commission and run-in the asset.
- g) Monitor, control progress and take remedial action where appropriate to achieve the programme.
- h) Finance the project and ensure that costs are contained within the planned budget.

6.5. The Acquisition Criteria:

The merger and acquisition exercise so far more on corporate diversification, or investment and cost economic centric and normally focused with higher priority around financial parameters including the operating costs, review of the current contracts involving suppliers and Original Equipment Manufacturers (OEM), administrative processes/ issues like Human Resources (HR) and personnel, management characteristics and ownership model, statutory and government regulations etc. But recently higher emphasis is given to Safety and Reliability aspects of assets of manufacturing plants. Since, it is quite obvious, no financial benefits would be realized through value-adding production line if asset health is in question.

Therefore, before integrating an old plant with an existing set-up or a completely new acquisition, it is of paramount importance to consider and assess plant asset's Reliability-related issues more precisely so that the new plant after transition can integrate and operate smoothly, economically and all the business systems including Enterprise Resources Planning (ERP)/ Computerized Maintenance Management System (CMMS) can be subsequently easily revised/ updated. Few important acquisition criteria concerning mainly physical assets are to be the subject of acquisition procedure. These are:

- a) **Management of Life Cycle Costing:** LCC is industry's buzzword in this era for all investment decisions due to its completeness and practical relevance to the whole concept of asset management, as it provides a fair idea on Total Cost of Ownership (TCO) reflecting the LCC results in Net Present Value (NPV) of the machinery (this has already been detailed in Concept phase)
- b) **Design and Technical Documentation**
The plant and assets P&ID, Technical specifications, documentations related to operation and maintenance, upgrades, modifications and expansions done previously.
- c) **Maintenance Strategies**
When acquiring old plants or setting up new plant, the maintenance strategies adopted or to be adopted are to be ascertained, as the right strategies facilitate in the reliable equipment and availability of production line. It fosters the seriousness of the organization in the adoption of Tero-technology concept in running the business. The level of implementation of Precision and Predictive techniques, the maturity level of implementation of reliability focused initiatives such as Reliability Cantered Maintenance (RCM), Risk Based Inspection (RBI) etc following National and International Standards.
- d) **CMMS and Asset Management Enabler**
The measurement and control of asset's performance and business performance Key Performance Indictors (KPIs) depends on data manoeuvrability within ERP package. In acquiring old plant, the level of CMMS implementation, data quality, management of internal customer relationship and logistics, interfacing ability of IT enablers are important to consider. This point of acquisition parameter may be extended to Condition Based Maintenance System (CBMS) which provide a picture on plant's machinery management.
- e) **Warehouse Management System**
During any plant acquisition, the old plant's spare management system indicate lot on the health of its physical assets. An eeffective warehouse system assures plant's capability on how best maintenance, repairs, spare stock-out issues are tracked and tackled, preservation norms of high value spare, management of vendors etc.
- f) **Repair and Reclamation**
The asset restoration strategy and inspection strategies have direct relation to overhead costs, Mean Time to Repair (MTTR), spare quality checks etc. It indicates plant's response and promptness to breakdown repairs, reduction in maintenance hours and overheads.

The specialized service providers and spare parts suppliers are major stakeholders and their involvement throughout the life cycle is most important in any company. It is wise to check their workshop, their facilities, the list of services available, agreement norms, insurance liability issues etc.

g) Adherence to National and International Standards

Adherence to National/ International Standards (IS.....) for asset management and compliance to Best Practices that sustain Safety and Reliability.

h) Risk Management System

In any project financing or any acquisition task, the risk documents are most valuable inputs in decision-making. The documents reflect how best assets are maintained and operated. The risk management system, risk financing norms and regulations adopted, such as banker's involvement, obligations to lenders, local legal and insurance norms, availability of scientific studies like Hazard and Operability study (HAZOP), Hazard Analysis (HAZAN), Probabilistic Safety Assessment (PSA) are representative indicators.

i) Root Cause Analysis and Bad Actors

A comprehensive and quantitative approach to Bad Actors management (with Reliability analysis, Failure analysis, Growth analysis, Cost of Unreliability analysis) is a boon to plant's sustained performance. The same way, the quality of Root Cause Analysis (RCA) indicates inter-disciplinary team's experience in in-depth quality analysis of perennial problems and lays foundation of lessons learned. The points to note here is to assess enterprise's seriousness in responding to the breakdowns and the mitigation of unreliability and risk.

j) Emergency Response Management System

The speed of Response following any unfortunate breakdown/ incident/ accident is better indicator of plant's responsiveness and utilization of resources.

k) Supply Chain

The reliability of each chain (also relationship between chains) is worth-considering and the impact of each 'unreliable chain' on the plant's reliability, considering supply, process and distribution activities. A good system of Supply Chain Management (SCM) in the company is an excellent presenter to in-house effective process flow between functions while processing raw materials to finished goods, to external OEMs and suppliers. It leads to better Spare Management, organization's reputation and corporate communications.

l) Utilities Management

The energy need, the water and air supply are critical while deciding to integrate the acquired old plant with the new set-up. The availability of captive power plant within complex, power purchase agreement through national grid, type and availability of fuel, water availability, treatment facilities, HVAC, storage facility etc are to be considered while assessing plant for acquisition.

6.5.1. Whether these functions are performed directly by the buyer or consultants on his behalf, the considerations, techniques and interactions listed in Table 3 are equally applicable. The scale of the project and its attendant risks naturally given the depth of analysis of each aspect, but even quite modest projects benefit from the disciplined approach outlined in Table 3.

6.5.2. Though acquisition decisions may be delegated throughout the management organization, they cannot be made until the corporate decisions to invest has been reached and promulgated, providing

clear financial and engineering / technical objectives together with the ethical, social and environmental parameters which have to be accommodated.

6.5.3. These decisions are influenced by the analyses and considerations listed in Table 3. The degree to which they are applied requires discretion and depends upon the gravity of the decision. For example, the purchase of an additional typewriter would require only minimal analysis whereas a new factory project or acquiring old plant would attract the most rigorous examination at the highest level. Table 3 shows that an early decision is required on whether the asset is to be hired or bought and despite the objective view provided by a cost-benefit analysis, other considerations might be more powerful. For example, cash availability could be the prime determinant, in which case hiring might be the only course open to the enterprise. Here, the input by the finance department is a key element and prompt communication of its advice reduces abortive effort elsewhere in the organization.

6.5.4. Analysis of lifetime benefits and costs calls for methods that reduce the variable money values occurring throughout an asset’s life to a common monetary level in order to facilitate proper comparisons. This is achieved by the methods described in 6.1. Because many of the inputs are themselves estimates, they have to be tested using statistical techniques and by comparison with past recorded experience of similar assets. Techniques like regression analysis together with sensitivity and probability tests are necessary to establish levels of confidence conducive to sound management decision making and the reduction of risk in the acquisition to acceptable levels.

6.5.5. These analyses of costs and benefits continue into the early stages of specification and design of the purchased asset including future asset’s performance critical parameters are considered in acquisition and because they aid the selection of alternative designs, maintenance and operation strategies and the layouts that can equally well to achieve the technical objectives. Before considering the detailed requirements for the asset, the design of the product needs to be developed in sufficient depth so that the total requirements for the asset in terms of output, quality and possible operation and maintenance methods can be identified.

Table 2 The Concept/Investment Decision Phase

SI.no (1)	Primary Analysis (2)	(Clause 6.2.4) Consideration (3)	Techniques (4)	Interacting Interests (5)
i.	Objectives set by board	Product Output turnover or profit Project life Organizations purpose and policy Resources available	Volume rate, Turnover, EBITDA	Organization’s business plan
ii.	Identification of options	Products and output Product designs and production methods Outline of assets required	Market research	Marketing
iii.	Identification of common bases of judgement	Basic scenario assumptions Scenario variations and ranges Price level changes Interest and discount rates Taxation/grants,	See Table 1	Planning Finance

		accounting methods Items not measurable in cash terms Method of presentation of selection/recommendation		Legal and/or statutory obligation
iv.	Select shortlist of viable options	Roughly estimate life cycle costs and returns of options in (ii) Select short-list of best projects for further study	See Tables 3 to 6	
v.	Detailed study and evaluation of short-listed options	Refine product designs Life of project Cost of finance Time to come on stream Probable capital cost Project design appraisal	Product design See Table 3 Project design appraisal	Design Sales programme Contracts Finance Operations, Maintenance Marketing Procurement Cost engineering
		Product proceeds Cash flow expectations Forecasts of outputs from Tables 3 to 6 Implications for other activities of the organization Report on each option		
vi.	Factors to be included: 1) Risk and uncertainty	Effects of scenario variations within ranges identified in (iii) Uncertainties in data Range and distribution of uncertainties	Probability analysis Risk analysis, Risk Financing, Spare stock-out costs	Cost engineering, Reliability
	2) Effects on budgets	Annual expenditures Annual revenues Effects on other activities Contingent costs for uncertainties Interest during construction Use of facilities		Contracts, Finance Quality surveyor Project staff, maintenance Board
vii.	Selection of best option	Comparison with objectives Cash flow predictions Report of appraisals and recommendations Approval to proceed		

Table 3 The Acquisition
(Clauses 6.3.3,6.3.4 and 6.3.6)

SI.no (1)	Primary Analysis (2)	Consideration (3)	Techniques (4)	Interacting Interests (5)
i.	Choice of hire, lease or use of existing internal sources or merger with old manufacturing plant	<p>Cash availability, Uncertainty and risk, Obsolescence of Component and System, Reliability of resources</p> <p>Suitability of available components – spare management, repair & reclamation strategies,</p> <p>Effect on taxation/grants, etc Responsibility for maintenance costs Compare costs of alternatives</p>	<p>Cost-Benefit Analysis. Remaining Life assessment & Depreciation Costing</p> <p>Inventory Assessment. EOQ, ALA</p> <p>See Table 1</p>	<p>Finance, Engineering & Centralised Reliability function</p> <p>Design, Operations & Maintenance, Reliability, Finance, Contracts,</p> <p>Design, quality, Reliability</p>
ii.	Prepare specification of asset requirements:	Complete product / services design	Product / Services design audit	Design, sales, quality assurance, reliability function
	1) Technical requirements	<p>Consider alternative asset/ component types to achieve product /services design objectives.</p> <p>Output capacity, quality, maintenance and operational requirements Highlight safety & risk</p> <p>Identify requirements regarding-compatibility in production line, between profit-units, redundant assets, supporting auxiliaries, utilities.</p>	<p>Asset selection, types, power, application, costing (Engineering phase)</p> <p>Performance Analysis Risk Analysis (Probability x Occurrence)</p> <p>Asset Reliability and Risk Assessment</p>	<p>Engineering, Project, Operation, Maintenance</p> <p>Marketing Safety, operations</p> <p>Operations, Maintenance, Reliability</p>

	Replication / New assets- Number, sizes, locations of production streams Economic configurations, Optimization of alternatives and orientations	Drawings Queueing theory, Value analysis	Operations, Work study Work study, Inspectorate
	Statutory requirements, Standards (Company and national) Spares provisions Time to come on stream	Allowance for statutory inspections Control of waste/ energy/ pollution	Inspectorates/ Govt authorities as mandated by Standards
	Reliability or maintainability demonstrations	Reliability/ maintainability analysis	Operations maintenance, Reliability
	Asset life	Plant history files, ALA/RUL studies	Operation, Maintenance, Reliability Engineering & Design
	Special materials to be used or prohibited, Supply sources	Vendor assessments, Ratings, Organizational strategy	Procurement, Maintenance, Operation, Contracts, legal
	Efficiency aspects Suitability for special grades of operations/ maintenance personnel	Performance analysis Ergonomics	Design, Operations Maintenance, Personnel, Operations
	Environmental requirements to be met Communications	Environmental planning as per govt norms, Flow chart	National and/ or local government
2) Contractual requirements	Form of contract for asset Penalties for non-fulfilment of contract conditions and	NDA, MOU, Contract Agreements	Purchase, Supply Chain, Contracts Project staff

		programme Guarantees		
		Payment schedule and cost variations		
iii.	Assess tenders or offers to supply asset:			
	1) Technical/contract	Review against factors identified in (ii)	See (ii) Design appraisal	See (ii)
	2) Additional factors	Estimate likely capacity decline with time Review constructability		
		Review supply programme	Construction analysis Modelling	Project staff
		Likely asset availability Life expectancy of various likely operating regimes Effects on public accountability and relationships, Areas of uncertainty Status of proposed designs	Inventory Control, EOQ	Operations, Maintenance, Stores, Purchase
iv.	Select supplier	Review assessment under (iii) Review expected life cycle costs and incomes against those authorized at end of investment decision phase Identify best offer and report If needed, seek approval of selection Place order or contract	Vendor development tools, Previous supplier rating, Transit/ Packaging methodology	All departments. Purchase, Supply Chain
v.	Design and manufacture asset	Design submission procedure Design freeze, Design and development programme	Drawings, Specifications/ Asset Data Sheets, Assets P&ID	Project management, Engineering and maintenance
		Quality Assurance, Work tests	Quality programme	Quality Assurance

			Quality assurance methods Test procedures	
		Progress and stage payments	Budgets	Finance, Project management
vi.	Erect/build and install	Procurement/construction programme Interface management and access Terminal points Effects on existing operations Quality assurance and stage inspections Surveillance Safety of people and plant	Network analysis Bar charts Progress assessment Quality programme Safety Consultation Structural safety limits Allowance for statutory inspections	Project management Quality Assurance Safety, Reliability, Operation, Maintenance Inspectorates
		Handling and storage	Technical manuals, Preservation procedure	Stores, Maintenance
		Time and cost	Expected cost to completion	Supplier, Purchase, maintenance
		Security	Physical assets, Data, Cyber	Supplier, Management, IT
vii.	Commissioning	Commissioning programme Design limits, fits, tolerances Documentation	Network analysis Quality programme Drawings, technical manuals, commissioning	Supplier Quality assurance, Project management, Operations, Reliability

	procedures, SMP & SOPs, OEM guidelines, related standards	
Train operations and maintenance staff	Training schedule, Need identification, Assessment tools, Structured Job Description (JDs)	Personnel/HRD, All Technical & Non-technical Department, External agencies /training providers (list)
Pre-commissioning checks during installation, adherence to use of latest instruments in checks Test and run up plant, etc Load/output tests to ensure contractual conditions met Extended production run Time to come on stream	SMPs & SOPs. OEM guidelines, related standards Acceptance testing Performance guarantees	Supplier, Operations, Maintenance, Project Operations, Maintenance Design, Contracts Operations Maintenance Design, Contracts
Re-test economic equations before setting initial sales price of product.	Contracts See Tables 1 and 2	Finance, sales, cost engineering

6.5.6. In the asset design stage, the value engineering technique can be applied to problems ranging in magnitude from plant layout to rationalization of the smallest components, whilst a scale model of the asset (where appropriate) aids the design's development. In addition, network analysis, of manufacturing, delivery and construction programmed may be necessary.

6.5.7. The second major input to design and specification of the asset is the feedback of data relating to actual performance of similar assets, coupled with lifetime estimated data used in the earlier cost and benefit statements. Mathematical modelling can be used to optimize different aspects of operational life, such as, reliability, availability and maintainability. Differing possible operating regimes can also be tested using these models. Again, operational research techniques, such as regression analysis and probability analysis provide the means of comparing alternative courses of action.

6.5.8. The acquisition's social and environmental aspects often demand outside liaison with Governmental and other public bodies, and consequently systems need to be established to seek the necessary consents and to make financial and design provisions to meet all legal requirements relating

to both the local community and to national statutes. This could include the need to cover against product liability claims.

6.5.9. Aspects of acquisition process have two main facets, procurement and financial control. Procurement strategy is concerned with the selection of the tenderers, the conditions of contract and purchase, the price required by the tenderers and the eventual selection of a supplier. Guidance on technical matters from designers and reliability dept (as elaborated in para X.X.X.), and on financial aspects from the finance department are required in order to contract for exact needs. Financial control involves the development of cash flow programmed to align with the procurement processes of manufacture, construction, installation and commissioning and will need to consider the consequential interest on money tied up in these processes during procurement. Again, for consistency, the discounted cash flow and other techniques are used and escalation and inflation are handled as separate elements in the budget for the acquisition phase of the project.

6.5.10. At the hardware stage of the acquisition, beginning with manufacture, the major elements of capital expenditure begin. The project management is generally pre-occupied with two main factors: time and cost.

6.5.11. Timely completion of the acquisition satisfying all criteria is vital for two reasons.

- a) No income can be generated by the asset until it is installed and commissioned.
- b) Many elements of capital cost can be time dependent and therefore delayed acquisition means increased capital cost as well as delayed income generation.

6.5.12. Consequently, great care is necessary on the part of the organization, agents, suppliers and installers to ensure that realistic, optimized programme are prepared, agreed and followed. The techniques most commonly used for all but the simplest programming are network analyses, of which critical path analysis (CPM) and programme evaluation review technique (PERT) are perhaps the most widely used. However, the choice of techniques depends on the particular application, organizational preferences, whether analysis is manual or computerized and the capacity of particular computer software packages amongst many other considerations. Simple programme which contains no significant interdependencies and have few parallel activities can be directly drawn in bar chart form. As shown in Table 3, network analysis can be used to programme all aspects of the acquisition and provide overall and departmental objectives. Used in connection with computing systems, the techniques can be applied hierarchically to provide a computer aided management system for each level in the organization acquiring the asset. Such systems analyse the networks to produce working documents, such as, bar charts, resource requirements and schedules which all assist in both targets setting and the control of acquisition time and reliable assets.

6.5.13. The need for cost control is self-evident; if it is not enforced the very basis of the asset's lifetime cost effectiveness can be put at risk. Cost control, like time control, required a programme of cash flows which derives primarily from, but might also influence the logic of, the time control programme itself. Normally the cumulative expenditure programme (or budget) for a capital acquisition is presented in the form of a money versus time curve (known as an 'S' curve). Regular comparisons of actual cumulative expenditure (manually or through a computer aided management system) with this budget curve, read in conjunction with similar time control comparisons, serve as management guides to the acquisition project's status.

6.6. Useful Life Phase, Operational Aspects

6.6.1. Table 4 lists various processes that underlie the monitoring and control of the operational life of an asset. Here, effort is concentrated on the optimization of the asset's performance in order that the enterprise can fully exploit the planned return on its investment. Table 4 shows, for example, that production plans depend on the forward survey of demand by marketing specialists and that this forecast distils into, and its accuracy is checked by, the plant loading schedule required to meet current firm orders for the product. The production plans are conditioned by inputs from specialists including operational research, work study and cost control in deriving the most economic plant loadings consistent with the optimum deployment of labour, materials and other key resources including energy.

6.6.2. Well-designed systems for the collection of operational performance data are imperative both for the short-term appraisal of plant health and for longer term use in the organization's global application of terotechnology. The former provides vital inputs to maintenance decisions, adoption of latest techniques to upkeep machinery, whilst the latter may be a key element in future investment or replacement decisions, change of designs production line/ equipment due to change of products, implementation of latest cost-effective performance monitoring systems, statutory needs on environmental and energy savings etc. The systems can vary between simple daily log sheets that might be compiled by an operator to record output and the sophisticated computer controlled continuous data logging and plant surveillance schemes now typical in modern process plant design, operation and maintenance. Plantwide equipment-specific maintenance tasks based on reliability-oriented studies such as Reliability Centered maintenance (RCM) or Risk-based Inspection philosophy are to be ascertained. RCM recommends operational, design changes, failure finding task also besides developing right maintenance tasks. Planned maintenance including Preventive Maintenance (PM) and Condition Based Maintenance (CBM)/ Predictive Maintenance (PdM) are the main tasks that cover most of the assets with higher thrust on CBM using Condition monitoring techniques since these technologies have developed fast in depth of analysis, features of analysis and have global presence of suppliers. Any change of equipment/ full production line (may be CNC based/ automated), owners might change maintenance techniques in the light of experience to optimize costs, performance, reliability and other considerations which have direct link to Life Cycle Costing (LCC). In the process, the long-term interests of terotechnology are best served in terms of cost-effectiveness and the data needed to arrive at decision-making Key performance Indicators (KPIs) are available in the CMMS (Computerised Maintenance Management System or SAP or any ERP package that cover monitor various KPIs of most of the important functions of the organization.

6.6.3. The production of goods and services, through the operation of the asset, is the organization's prime objective. Consequently, those responsible for its operation interact with all other parts of the management organization and all should seek to service the operation of the asset. In order to ensure that the asset is well served, the operating department should carefully monitor operation as per guidelines and specifications based on which the assets are actually acquisitioned and ensure that appropriate operation data are collected and disseminated throughout the management organization through existing ERP media. Information should allow effective communication between departments. In an environment of terotechnology, data available in ERP / CMMS is made available to all users of data such as finance, supply chain, purchase, HR, maintenance, operation, reliability, quality, marketing etc.

6.6.4. The departments responsible for the operation of the asset is involved in decision making throughout the asset's lifetime. The management services techniques, including operational research, work study, programming, planning, scheduling and cost accounting and control, reliability and maintenance etc. all have a role to play in guiding these decisions, in providing input and feedback to other departments.

6.6.5. Whilst output achievements are precise in nature, forecasts are less definitive. When the forecast is made before the asset is acquired, it can contain very significant uncertainties and similar problems beset forecasts projecting the distant periods of an asset's life. Any forecasts on asset must carry the inputs on performance indices (volume, rate, operational specifications), reliability and maintenance needs and strategies throughout the life. Consequently, medium and long-term forecasting requires the application of mathematical modelling techniques to assess not only quantitative matters like output and market size but also the related, more intangible, qualitative aspects of probability and sensitivity which really indicate the degree of risk in acting on the forecast. Similarly, the mathematical approach to stock control through optimizing buffer storage and lead time, prompt reordering, improved transportation and distribution by means of linear programming and better service by means of the use of queuing can have significant effect on the amount of capital tied up in stock. Latest supply chain techniques, procurement and spare management and control tools would assist irrespective of size of organizations and type of products or services, the enterprise delivers.

6.6.6. The work study techniques of work measurement and method study are used to optimize the employment of labour and the utilization of the asset and their results are also invaluable in production planning and control.

6.6.7. Quality assurance procedures for the asset's products can reflect on the asset itself. "For example, increasing reject rates might indicate a declining quality of the asset showing the need for intensified and right maintenance strategy or early replacement. This part of the quality problem creators is given less importance in organizations. Equipment running out of specified parameters are bound to generate defects which can't be controlled by formal QC tools. Alternatively, for example, there may be operator failures which would signal to the personnel departmental function needing skill development/ training/ motivation. Terotechnology covers these aspects in order to bring significant benefits to the organization.

6.7. Useful Life Phase, Maintenance Aspects

6.7.1. The maintenance of assets has significant cost implications which are inseparable from the operation of the asset. Even if the asset is temporarily out of use, time, weather and general environment together cause continuing deterioration and consequently maintenance costs continue until a disposal decision is reached. Traditionally, maintenance managers have based their strategy on what is known as the bathtub curve effect. This hypothesis suggests that maintenance costs per plant item are high during its early life due to burn-in/ infant mortality problems, they reduce significantly in midlife but exhibit random failures, and rapidly increases in wear-out phase as the item's aging process starts. Terotechnology offers the opportunity to reduce the cost impact of the curve through the following:

- a) Improved design using RID (Reliability In Design) strategy, employing better operation and maintenance strategies using recommendations of RCM (supporting data/ feedbacks available in CMMS / ERP).
- b) Operation and Maintenance Improvement, Cost-saving from Reliability Analysis.
- c) Reliability Management for all assets (tangible and intangible) & Quality Assurance programme including all functions and especially Quality Control function.
- d) Value engineering in every stage of value-adding process in an integrated process plant
- e) Improved functional specifications (Physical Assets, Human Resources in all important functions)

6.7.2. Most of these have traditionally been regarded as unrelated to the maintenance and operation department. The primary benefits of the application of terotechnology have been higher reliability (taken care at engineering and design stage as VALUE-focus), resulting in reduced maintenance costs and

better designs optimizing early costs as a proportion of the lifetime maintenance cost. Optimizing the disposal or replacement dates of components or the entire asset can also reduce the life end cost peak.

6.7.3. The application of terotechnology to the maintenance function (mainly COST-focus, reduction of cost in all activities) itself provides valuable guidance on strategy decisions where, for example, the selection of the maintenance aspects can be made in an objective (rather than intuitive) way, here, due consideration can be given to the impact of various aspects on the following:

- a) Maintenance centre may be viewed as Profit Centre (blanketing the wrong concept so far as money-eater). Plant management and promoters now understands the Cost of Unreliability, Stock-out, Sudden rise of maintenance overheads and so on).
- b) Labour resource requirements (internal/ external/ special skills)
- c) Spares inventory costs / Stock-out Costs
- d) Breakdown probability and risk (Asset diagnostics/CBM/Reliability Analysis)
- e) Asset Availability for production (Repairs & Reclamation techniques/CBM/ Reliability Analysis)
- f) New Technology demands new Maintenance Strategies (some intensive online care, some periodic diagnostics)

The maintenance aspects in Tero-technology should reflect these and the system / process of maintaining the critical assets be then updated accordingly.

6.7.4. The considerations particularly applicable to the maintenance function are given in Table 5.

6.7.5. The maintenance function's prime objective is to keep the asset in good, safe, efficient condition by maintaining it as per the asset-specific strategies mandated by any reliability-oriented approach like RCM and within the budgetary provisions consistent with the financial objectives of the organization. This would lead to feedback information ensuring the application of terotechnology throughout the organization.

6.7.6. emphasizes the close relationship between operational and maintenance aspects of asset management. It appears self-evident that an asset which is heavily worked will require more intensive maintenance care than its lightly loaded counterpart but this is not always the case. Often the decline in condition of an asset relates to exposure to weather or other particular environmental factors. Also, in the case of process plants with electro-mechanical assets, for example, heavy continuous load can be less deleterious than intermittent light load. Terotechnology demands a disciplined approach to all maintenance decision-making for inter-disciplinary set-up, varying load, environmental conditions, lately technological upgrades in assets.

6.7.7. Operational research techniques (see 6.4.1) are used to examine the maintenance needs of different operating aspects and to forecast replacement dates for major parts of the asset, thus providing a basis for likely lifetime maintenance costs which can be used for budgetary control. Costing based on LCC would be more appropriate if reliability analysis is carried out based on failure pattern available till date in an operating plant and fit correct maintenance tasks reducing only then the cost associated with restoring such condition following breakdowns. O.R. techniques can be applied then to compare the output of reliability and availability calculations, optimizing thus maintenance frequency appropriate to the particular conditions.

6.7.8. The resources needed to execute the maintenance strategy also have to be programmed and scheduled. Network analysis techniques, with computer processing, provide the means for doing this

work, whilst quantitative inputs derived from the application of work study techniques allow the programme to be modified according to manpower availability. Similarly, stock control, cost control, tribology and other technical aspects can be built into the maintenance management model and supplementary computer programme used to produce the necessary maintenance documents. Typically, bar chart programmes, labour resource charts, cash flow programme, parts and materials orders and schedules, and detailed work instructions are produced.

6.8. Lately, the execution of maintenance strategies in plants has become quite easy due to adoption of ERP package which records all operation, maintenance, quality, overheads, personnel/HR, store, procurement, finance data etc. Various charts and process flow diagram, material balance, work orders, planning and scheduling etc can be extracted at ease on demand and for decision making.

6.8.1. The operation and maintenance aspect under the umbrella of Terotechnology in any manufacturing industry takes a centre-stage. The current thoughts in acquiring and employing the assets for value addition (of course ultimately generating revenue from this process) won't match with the previously adopted operation and maintenance strategies decades ago. In Life Cycle Costing process in manufacturing enterprises, there is a possibility of leakage of desired profits in every activity, not just only in maintenance. The expenditure on maintenance in managing risk is directly related also to the probability and consequences of failure. The enterprises in service businesses won't extract much value in employed few assets but in service functions like customer feedbacks, supply chain, marketing. So, maintenance aspects discussed here that need serious attention are for manufacturing plants.

6.8.1.1. The fundamental concept in manufacturing excellence in any industry in the era of faster Technology and Digitalization is to rely on the current Operation and Maintenance tools/ techniques available for critical assets. It is now very clear that RCM recommended PM or PdM tasks are vital to stop failures during operation, in turn to sustain in-built Reliability, then in turn maintain Availability needs and also to check asset-produced poor quality. Reliable assets only can enhance Business Excellence KPIs including profit, reputation, culture, saving environment and energy and not through any other means.

6.8.1.2. Business strategy objectives must then highly rely on Plant Maintenance Management System and all these tasks are to be performed by People in the organization. People are the Prime Mover of business and their relevant skills development; motivational issues need separate consideration. The realization of Terotechnology concept is on the hands of the People and they be dealt with seriously. Any amount of resourcing of latest technology, farming up plant reliability and maintenance initiatives, keeping various Diagnostics/ Condition Monitoring tools in place, acquiring latest software & hardware and other infrastructure; nothing can succeed without serious concerns on well being of employees. The People's involvement, with skills and high-tech exposure, is very essential to sustain / improve assets health ending up with reliable products.

LCC recognises and combines the concept engineering, design, transit, installation and commissioning, the ongoing operation and maintenance and the eventual cost of decommissioning/ disposal. Every part of this costing process involves people. Hence there will be ongoing needs of investment in people besides in physical assets in order to achieve business excellence.

Table 4- provides the need of investment on people in every stage of asset's life in order to minimise production cost at the end.

Human Resources in Implementation of Terotechnology Concept
(in addition to the core fields of engineering/ finance /personnel/ marketing)

Table-4

Asset Life Cycle Phase	Activities / Contributions	Specialised / Professionally Certified Exposure	Interacting Functions
Concept and Viability estimation	Techno-economic proposal, LCC estimation, BEP, Warranty analysis, Insurance liability, Cash flow, EBITDA etc (refer Table-1), Reliability & Maintenance Leadership	Financial analysis, Machinery Exposure/ Specifications (from previous works or specialised training on assets) for LCC, Reliability Leadership	Finance, Engineering, Maintenance, Reliability
Acquisition (System Functional Approach Not Elemental)	Risk analysis, ALA, RUL, Cost-Benefit analysis, Inventory management, Statutory – Energy & Environment, MOUs and Agreements	Exposure to latest standards on Life Assessment, Govt norms in contracts and Agreements, Energy & Environment standards of Govt./ local authority	Finance, Projects, Engineering, Maintenance, Reliability, OEMs, Govt Authority
Transit, Installation & Commissioning	Transportation, complexity & Packaging, Govt/local authority transit rules, Acceptance testing norms & standards, Storing before installation,	Safety in transit of critical assets from shop to plant site, storage & preservation techniques, Installation process, precision tolerance needs, external agency evaluation, acceptance testing and OEM's mandates, Safety, Reliability in commissioning, acceptance standards, precise alignment, health parameters etc.	External agencies, Local authorities, Project, Maintenance, Reliability
Operation & Maintenance	Performance Analysis, Energy management, CMMS, Reliability, Availability and Maintainability studies, Spare management, Technical Skills development of employees, SMPs & SOPs, New Technology and Digitalization, World-Class initiatives on O&M, Vendor evaluation, Specialised service needs, ERP exposure, Asset Criticality Analysis	CMMS, ERP package, Reliability & Maintenance KPIs, Knowledge latest initiatives RCM, RBI, TPM, TQM, RID, FMECA, RCA, RAM study, etc., exhaustive failure modes analysis. Sometimes, however, a formal risk assessment must be made and decisions made based on those outcome, OEE, Operational Excellence	Engineering, Maintenance, Reliability, OEMs, Consultants, Specialised services agencies, Procurement, Stores, IT
Decommissioning & Disposal	As-on-state Asset Analysis (ALA/RUL assessments), Performance of assets, Risks,	Life Assessment/ Remaining Life Assessment (ALA/ RUL)), Warranty, OEMs, Acquisition documents, Risk analysis, Economic viability at Disposal state, Repair or Replacement analysis, Buy or Make in house,	Engineering, Maintenance, Reliability, OEMs, Consultants, Specialised services agencies,

Workshop (internal/ external)	infrastructure	Procurement (for disposal of assets)
----------------------------------	----------------	--

6.9. Disposal Phase

6.9.1. Disposal is invariably a consequence of outdated technology, aging of assets, and demands new investment appraisal and decisions in order to timely assess risk, equip the production line with reliable assets. Even after employing latest repairs or reclamation techniques employed in restoring the assets, it is quite likely that assets don't perform as before. So, a scientific identification and evaluation is carried out to identify the state of equipment deterioration, possibility of repairs if any and finally if needed to replace with new one to restore the entire manufacturing process. The process of decommissioning an asset in any process plants draw promoter/ management to this crucial phase. This phase therefore takes note of possibility of running a viable business and a very important task in Terotechnology.

6.9.2. Disposal is often a maintenance decision based upon the unacceptable increasing maintenance cost of an item/ asset in aging phase of life. In such scenario, repair or replacement decision is vital.

6.9.3. Decommissioning or Disposal decisions are guided largely by the outcome of the reliability, availability and Risk analysis considering asset's manufacturing capability and an essential part of modern Asset Management in order to truly stick to desired Life Cycle Costing. In addition, continuing cost-effective utilization, product demand and profitability have to be considered.

6.9.4. Before taking decision on disposing of an asset, the latest scientific methodology ALA (Asset Life Assessment) or RUL (Remaining Useful Life) or RLA (remaining Life Assessment) be carried out. Asset life assessment has now become a strategic tool for any economic decisions while disposing off, acquiring an old plant, and revamping existing old assets.

The assessment may be of qualitative or quantitative in nature depending on the data available in Enterprise Resources Planning (ERP) system, reports, manuals, drawing, Reliability and Condition Based Maintenance (CBM) databases etc. At times, external expertise may be needed to assess and draw a risk mitigation strategy outlining the actionable parameters with quantitative presentation on the scope of execution, duration, and likely costs of mitigation.

International standards following API 579 (FFS – Fitness For Service) guidance is valuable in this regard. Various levels of study are possible depending the size, complexity and budget available in the plant. The following important tasks are to be included in assessment:

- A. Level-1 assessment covers design and fabrication documents, use of various NDT/ NDE techniques. Maintenance history etc.

- B. Level-2 assessment is elaborate and to cover the following:
 - i. Previous inspection and maintenance strategy and history.
 - ii. Failure analysis and associated investigations.
 - iii. Obsolescence and availability of spare parts support.
 - iv. Records of the reliability initiatives like RCM, RBI, FMECA, RCA etc.
 - v. Operational best practices.
 - vi. Competency of people handling the assets.

- C. Level-3 assessment is costly and higher-level demanding higher technological and engineering analysis inputs. Only complex and critical equipment with lots of uncertainty in the available current data, the Level 3 stage of assessment is sought and the techniques to cover are:
- i. Engineering analysis like Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Rotor Dynamic Analysis, Structural Analysis, Metallurgical Tests, Laboratory Tests, Fracture Analysis, Stress Analysis, Detailed Vibration Diagnostics, and On-site Performance Analysis etc. using modern advanced software
 - ii. Assessment is most detailed, demanding, time-consuming, and costly but confidence level is high.

6.9.5. In the case of replacement of all or a significant part of the asset, or the acquiring new assets or new plants to integrate with the current one, the terotechnology cyclic process from start to end should begin again.

The considerations which apply in the disposal phase are given in Table 6

Table 4 : Useful Life Phase, Operational Aspects

(Clause 6.4.1)

Sl.no (1)	Primary Analysis (2)	Consideration (3)	Techniques (4)	Interacting Interests (5)
i.	Production management	Profitability in context of original project appraisal Future demand of product	Order processing	Finance Sales, Marketing Operations, Maintenance
		Output forecasts and achievements, Documentation Documentation	Technical manuals including: Operating instructions (SOPs), System drawings, P&ID, flow charts, Control limits, Loadings	
		Reliability, Availability Down-time costs, Maintenance frequency, Maintainability	Overheads, Spare Costing, Maintainability Analysis, Plant history	Cost accountants, Reliability, Maintenance
		Obsolescence Disposal and replacement of components	Life assessment (ALA)	Reliability, Maintenance

		Safety	Operator instruction	Safety, Operation, Reliability
ii.	Output performance	Production capability	Material needs	Purchasing, Supply Chain, Operation
		Plant loading	Work Study	
		Operating regime	Stock Control	Maintenance, Operation, Design
		Plant performance	Control Limits	
		Production efficiency	Data logging	
		Output quality, Rejection rate,	Asset Performance (Reliability, Availability)	Reliability, Operation, Maintenance
		Statutory restraints, Environmental factors	Standards, Govt rules book	Statutory bodies, Individual related dept
iii.	Resource optimization	Man, Material, Methods, Money etc.	Operational research Production planning	PPC dept, Operation, Sales
		Manpower	Recruitment and employee training	Personnel/HR, trade unions, labour relations
		Energy Materials	Energy management	Engineering, Operation, Maintenance
			Quality assurance methods,	Purchasing, quality Assurance, Marketing
			Marketing programme	
		Cash		Finance
iv.	Feedback to new projects		Data logging	Design
			Reports , Plant history files	Operations, Maintenance, Engineering, IT/ CMMS

Table 5 : Useful Life Phase, Maintenance Aspects

(Clause 6.5.4)

Sl.no (1)	Primary Analysis (2)	Consideration (3)	Techniques (4)	Interacting Interests (5)
i.	Maintenance	Documentation (computerised/ digitized data sheets of assets, OEMs, Manuals, History records – running/ maintenance/ failures/ downtime etc.)	Quality records, CMMS, Reliability & Maintenance dept Analysis packages for RAM data)	Quality Assurance, Reliability, Maintenance, Operation
			Plant inventory Technical manuals/ drawings giving: spares Lists maintenance instructions (SMPs), structural safety Limits workshop overhaul instructions work instructions Reports of work done	Supplier, Project Management, Maintenance, Purchase/ Procurement
		Maintenance requirements	Statutory inspection Maintenance scheduling Resource allocation, (in CMMS/ERP)	Maintenance, Planning Dept, Operation, Reliability
		Maintenance Strategy: Basis for Strategies, Preventive (PM), CBM, Corrective, Breakdown,	RCM, RBI, Reliability analysis, P-F Curve (Figure-1), PMO (PM Optimization)	Maintenance, Operation, Reliability
		TA (Turn Around) Management	PM Deferred list and strategies of capital Spare, Asset Condition Assessment	Maintenance, Operation, Reliability, OEMs/ Suppliers, Purchase

	Expertise from OEMs, Consultants Reviews	O&M manuals, Shop testing reports/ certificates, Consultants reports	Maintenance, Operation, Reliability, OEMs/ Suppliers	
	Maintenance/Repair guarantees	Design appraisal Defect Elimination reports, Failure investigations and Fault analysis (FTA, RCA, FMECA), Reclamation Techniques, Tribological solutions standards	Maintenance, Operation, Reliability, OEMs/ Suppliers	
	Spares turnover and stock-holding	Stock control, EOQ	Stores, Purchasing, Maintenance	
	Working methods	Work study, SMPs, SOPs	Specialists, Operation, Maintenance	
	Resource acquisitions:	Maintenance resources (spare, consumables, manpower, specialised services like Laser, Balancing, Inhouse workshops and tools etc.	Purchase, Finance, maintenance	
	Manpower	Recruitment Training schedule, Need identification methods, Talent retention	Personnel/HRD, Maintenance, Suppliers/ OEMs	
	Maintenance costs	Reliability (uptime and downtime analysis, overheads, manpower, spares, tools, specialised services)	Reliability, Maintenance, Finance, Operations	
ii.	Life cycle of asset	Operational feedback on: availability process efficiency product quality	Maintenance history, Taxonomy, Criticality Analysis Data, Process Design data, Quality specifications, Upgrades and Reengineering	Operations, Maintenance, Reliability, Suppliers/ OEMs,

documentation

Asset history Plant modifications Design aspects		Design, Supplier Design Maintenance, Reliability,
Unit replacements	Repair/replacement optimization	Maintenance, Engineering, Suppliers
Major reliability and maintenance capital/ revenue schemes, Life extension/ reduction	Reliability & Maintenance Data and Analysis, Reengineering, Modifications Notes	Planning, Operations, Finance
Obsolescence/ Disposal Maintenance programme	Reliability & Risk Analysis, ALA study,	Operations, Finance Maintenance

Table 6 Disposal Phase

(Clause 6.6.5)

Sl.no (1)	Primary Analysis (2)	Consideration (3)	Techniques (4)	Interacting Interests (5)
i.	Economics of disposal	Consideration of project based on poor performance, high maintenance cost	ALA/ RUL/ RLA analysis, Performance Analysis, Reliability & Risk analysis, Refer 6.6 Clauses	Marketing Operations, Maintenance
		Obsolescence of product of asset	Refer 6.6 Clauses, See Table 3	Sales, Operations, Maintenance
		Repair replacement optimization, Net cost of disposal	Refer 6.6 Clauses See Table 5	Operations, Maintenance, Reliability
ii.	Suitability for further use	Maintenance policy Survey of condition, Residual value, Scrap Value	Costing of Assessed Assets, Refer 6.6 Clauses See Table 5	Maintenance, Operation Finance
		Special hazards: structural chemical and	See Table 3	Safety Statutory

dangerous materials
buried wastes electrical

Controls
Inspectorates
Local/Govt.

Documentation

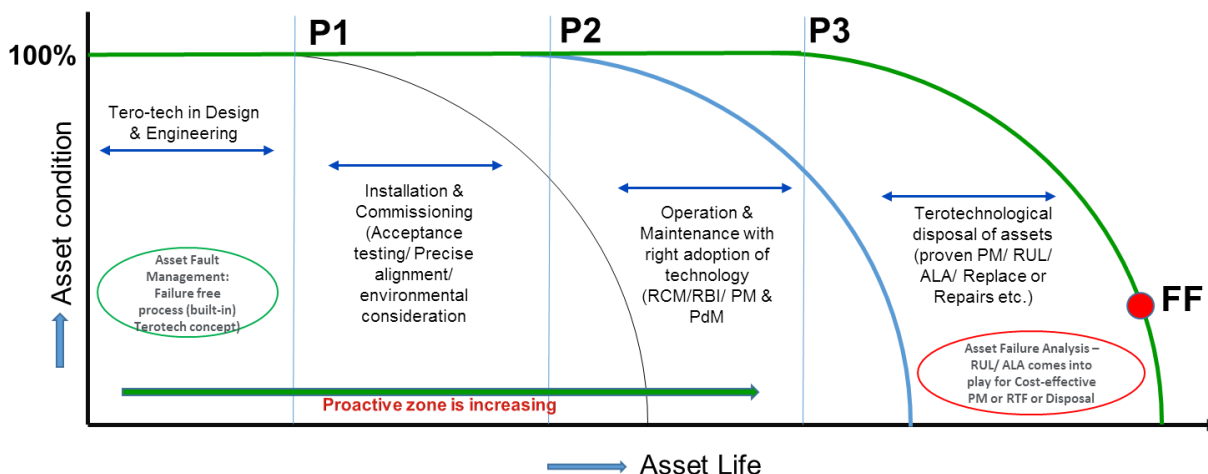
Asset History,
Reliability & Risk
Analysis reports,
Insurance,
Depreciation,
See Tables 3 & 4

ANNEXURES

Terotechnology Impact in Life Cycle of Asset: P-F Curve

Figure - 1

Note, how point 'P' (PF- Potential to Failure) shifts to right of the curve in Tero-tech enterprises, enhancing asset's useful life till it reaches FF (Functional Failure)



Business/ Manufacturing Excellence Through Terotechnology

Figure 2



ANNEX A

COMMITTEE COMPOSITION
Management and Productivity, MSD 04

<i>Organization(s)</i>	<i>Representative(s)</i>
International Management Institute, Nagpur	Dr. B. A. Metri
International Management Institute, Nagpur	Prof Rajeew Aggarwal (<i>Chairman</i>)
Indian School of Business, Hyderabad	Prof. Chandan Chowdhary
Asper School of Business/ISB	Prof. Kiran Pedada
Centre for reliability and Diagnostics, Mumbai	Dr. Tarapada Pyne
Cubic Turnkey Private Limited	Shri Tejas Sura
Directorate General, Factory Advice and Labour Institutes (DGFASLI), Mumbai	Shri Satyendra Singh
Indian Institute of Materials Management, New Delhi	Shri V. K. Jain
International Institution of Technology and Management, New Delhi	Shri V. K. Gupta
Indian Institute of Management, Mumbai	Prof. Milind Akarte Prof. Ravindra Gokhle Prof. Ruchita Gupta Prof. Pratap Sunder (<i>Alt.</i>)
Indian School of Business, Hyderabad	Shri Samik Roy Shri Dhiraj Gyani (<i>Alt.</i>)
Microsoft Corporation India Pvt. Ltd., New Delhi	Shri N. K. Chanji Shri Kumud Jacob Lugun
National Productivity Council, New Delhi	Dr. Onkar. S. Mondhe, IOFS (PM) Dr. H. S. Negi (<i>Alt.</i>)
Ordnance Factory Board, Kolkata	Ms. Manjula Subramanian Shri Govind Srinivasan (<i>Alt.</i>)
Paramount Dataware Pvt. Ltd., Chennai	Shri Divakaran P. Kaiprath
Perstorp India	Shri S. Venkatesh Shri Manoj Belgaonkar (<i>Alt.</i>)
Siemens Ltd., Mumbai	Dr. Naliniprava Tripathy
IIM Shillong	Prof. Ved Prakash
In personal capacity, New Delhi	Ms. Renu Sharma
In personal capacity, (187, (RPS) DDA Flats, Sheikh Sarai Phase-I, New Delhi 110007)	
In personal capacity, (Osimo Tower, Mahagum Moderne, Sector 78, Noida – 201301)	Shri Anupam Kaul
In personal capacity, (Sector B/5, Rohini, New Delhi)	Shri Jagdish Prasad
BIS Directorate General	Mr. Anuj Swarup Bhatnagar , Scientist 'F' and Head (MSD) [Representing Director General (<i>Ex-officio</i>)]

Member Secretary

Shri Ashish V Urewar,
Scientist 'C' (Management and Systems), BIS