Terotechnology

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Abstract. The paper analyzes the position of terotechnology in the overall approach to the planning, design, manufacturing, installation, service, maintenance, decommission and recycling of the technical system. Position of terotechnology, on the other hand, is placed in relation to the economics, life cycle cost and maintenance. The aim is to define terotechnology as optimization process of the ratio between the total effective or potential production of the system and cumulative cost in the lifetime of system. As a static phenomenon the ratio can be optimized apart the market influence and business strategy and policy. The optimization process indispensably includes reliability, adaptability and availability of the system.

I. INTRODUCTION

Terotechnology is rather new term in scientific (technical and economic) and managerial practice. The term has got widely accepted meaning as managing of possession of technical complex system that is able to perform certain, previously defined, activity (function), during certain period. The term "system" originated from a Greek word "systema", which means an organized whole. The Oxford Dictionary defines a system as 'group of things or parts working together as a whole; set of ideas, theories, principles, etc. according to which something is done; orderly way of doing things'. In essence, a system consists of interrelated parts working together to fulfill a need. Origin of the term Terotehnology is, for the first part "terein", from the Greek language, in meaning to look after, too maintain, to sustain, to bring back, to keep something in previous or acceptable condition. Therefore the term "terotechnology", according the term parts means technology of maintenance what is far narrow meaning compared to managing of system possession.

II. DEVELOPMENT AND DISTINCTIONS

So, the story has begun from the problem of maintenance (M) of the system. The maintenance of the complex system with significantly high degree of complexity and possible very high risk of the system failure is a very demanding problem that should be considered, taking care of possible risks, in a very comprehensive managerial way.

Thus the term maintenance management (MM) appeared in technical and economic practice. Analyzing management of the complex system maintenance one has could get aware of the other characteristics of the system that are of higher influence to the maintenance activities results than the management of maintenance activities itself. Those characteristics of the complex system are defined in the design stage of the system project and even in earlier stage (project problem definition).

The need for approach to the system design, considering the system maintenance along, has defined the design for maintenance (DFM) techniques. Optimization of maintenance activities could be done from two different attitudes. The first attitude is considering optimization from the most effective maintenance point and the second is from the highest production (service) point. If one considers the maintenance goal as the most effective production (service) using maintenance than the maintenance is defined as total productive maintenance (TPM) that is enhanced preventive maintenance called productive maintenance.

Production or any other form of service, based on the certain form of possession, surely is not the goal of the system possessor. The possessor only goal could be certain economic value defined as profit (political benefits are, in this paper, neglected as possible goals). In realized profit obtained by the system performance indispensable part, element of business activity that unavoidably decreases profit, is the total cost of the system during its whole life span. This characteristic of the complex system use shifts the center point of analysis from the issue of maintenance to the issue of the complex system life cycle costing (LCC).

Life Cycle Cost includes all maintenance costs (including all costs of the Total Productive Costs) but contains also the total acquisition costs, operations costs, training costs, inside handling and transportation costs, technical data costs, decommission and disposal costs. Life Cycle Cost approach summarizes all system costs from the very first initial idea about the need for the complex system possession to the last disposal and environment protection costs. It seems that LCC

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approach comprehends everything that is necessary for the complex system possession analysis. It is, with no doubt true, bat some very important details that are indispensable to asset all characteristics of the system possession problem, although those details are included in an implicit way in the asset in the similar manner as they are included in the TPM approach, DFM approach and MM approach as well.

One of those very important details of the system possession analysis is the point (criterion) of optimization. From the LCC approach point of optimization is the lowest possible cost for the previously defined magnitude of the system realized performance.

Superior complex system optimization criterion compared to LCC approach optimization criterion is Terotechnology derived one that can be defined as optimization of the ratio (1) that can be called as terotechnological efficiency (η_T).

$$\eta_T = \frac{TULC(Q)}{Q} \qquad (1)$$

TULC - total production cost during the system useful life;
Q - total quantity of production.

III. LIFE CYCLE AND FUNCTIONAL ASPECTS

Relation (1), termed terotechnological efficiency, can be used as the complex system project (design) optimization criterion. As stated earlier, this approach can be considered as true value for money, and it is the resultant comparison of total cost with functionality. This draws upon the following functional aspects which require some judgment, and are less quantifiable:

Technical performance;
Reliability;
Economic life;
Safety;
Logistics factors.

Technical performance is result of feasibility study, design task or preliminary design and reflects the future owner or possessor expectations regarding the terotechnological efficiency (η_T), expressed as design claims. This requires a user assessment of the 'duty' or 'duty cycle' of an asset, and requires a technical comparison of offers against the required duty. In cases where the design and specifications are developed by the user there is potential to be more objective in this comparison. Prior to the drafting of specifications, the users should agree on both attribute and variable criteria, and apply weightings to their respective importance. These attributes and variable criteria should be included and differentiated in specifications; however the weightings should not necessarily be identified, as they are used as an aid to decision making.

Reliability implies the degree by which an asset meets a customer's expectation in respect of functionality and performance. It is often expressed as Mean Time Between Failures (MTBF) of operating units in an asset, or of the complete asset. Reliability claims by suppliers should be validated by test or empirical data. However demand of proven track record can unfairly exclude new suppliers or innovation. Reliability does not influents to the system design through the degree of dangerous failures avoiding.

From the point of failures, the operational life of the system can be divided in three different operating periods.

The first operational period is burning in period (debugging period), where the failures frequency is very high. In this period the most failures that occur are early failures, but even chance failures can appear. Early failures are corrected on the basis of corrective maintenance activities in the debugging period. Debugging period can be included in the system useful (economic) life, and that completely depends on the nature of the system. The nature of the system in this paper is the characteristics of the system expressed as the system vulnerability and susceptibility to possible risks of the failure appearance, hazards to human lives, cost of the debugging period and possibility of the system to survive the failures and at the end possibility of corrective maintenance application in service conditions.

The second operational period is useful life period where the chance failures appear and their frequency is constant or slightly increases. The third operational period of the system is wearing out period, where wearing of the system components appears. This operational period of the system can be included in the useful operational life what mainly depends on the possibility of corrective maintenance activities application. Operating the system in wearing out failures appearance period can be very attractive because of prolonged use of the system components.

Avoidance of failures appearance is impossible, but it is possible to avoid damages and costs caused by failures. In the burning in period damages could be avoided using longer debugging, granting periods or redundancy. Avoiding of damages caused by chance failures can be achieved using the system redundancy only. Avoiding of damages caused by wearing out failures can be done using components inside the useful life of the components.

Economic life of the system, as previously mentioned, mainly depends on the corrective maintenance application and possible risks caused by failures. But, economic life (useful life) can be and rather often determined by other reasons. Assessment of the economic life of an asset is important in the determination of the point at which an asset becomes more economical to replace rather than to maintain. The point of obsolescence can be reached by:

Economic obsolescence;
Functional obsolescence;
Physical obsolescence;
Technological obsolescence (superseded technology;
Social or legal obsolescence.

The determination of economic life, under these circumstances, becomes an issue of: cost benefit analysis; management judgment; the degree of use; and corporate policy, what means that noneconomic reasons become prevailing ones.

Safety as functional aspect also has risk management implications. Early judgment on the safety risk implications may extend or obviate the implications of social or legal obsolescence, referred to earlier under 'Economic Life'. Incremental safety features can justify additional cost when direct social benefits are considered which might impact on human factors in operation, or extend economic life.

The functional aspects of logistics relate to: quality assurance; effective communications between buyer and supplier; effective mechanisms to deal with (problems in design and manufacture/construction, changes to requirements, changes to technology and/or standards); likelihood of supplier meeting time performance; sensitivity of variables; location/geography/access implications; and future supply and demand.

IV. COSTS

The cost of the system production is an issue in this paper instead the product cost. The cost of a production often is confused with its value. True value can only be established when the function performed by the system and its constituent parts is compared to the total cost of providing those functions. The life of the system can be identified across the three areas according to Fig 1. and Fig 2. as following:

Acquisition (Development, Design and Manufacturing);
Commission (Operation);
Disposal, (Decommission).

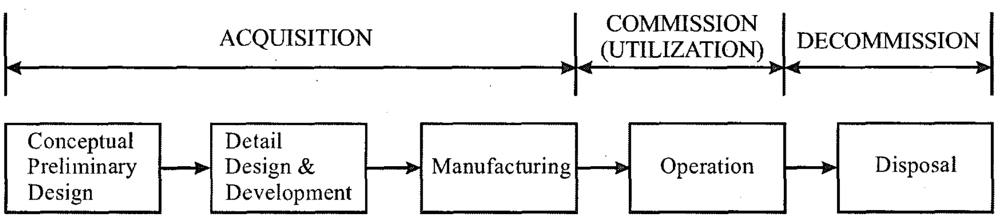

Fig. 1 The system life cycle

Total cost identification is of utmost importance to identify the ownership implications at the earliest stage. Often this is at the design stage, rather than to adopt a 'wait and see' approach.

The 'wait and see' approach frequently leads to a course of uneconomic remedial action. The three essential elements of total cost are: acquisition, cost-in-use and disposal cost.

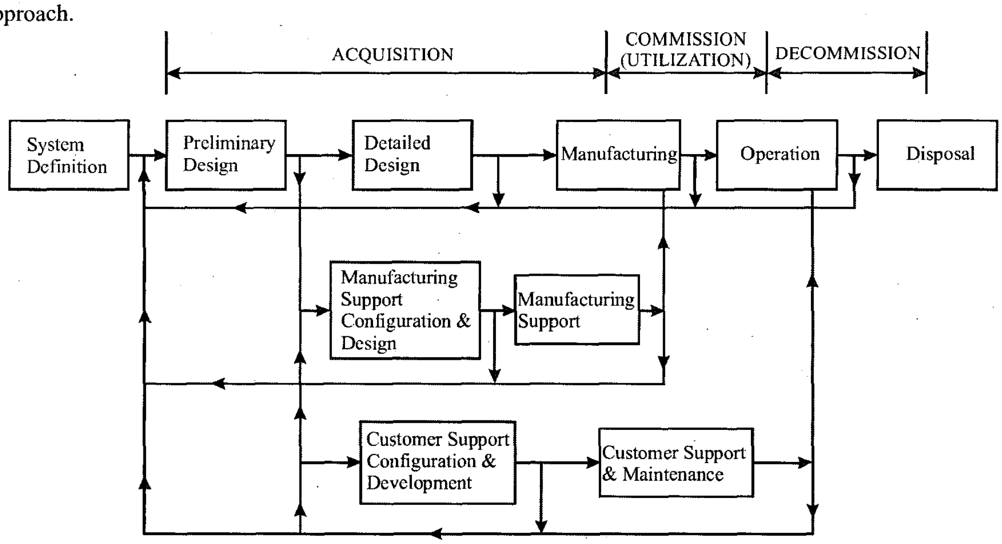

Fig. 2 The system life cycle process

Acquisition costs are those associated with the development, design, and initial procurement of the system, including: price, costs of capital, freight/transport internal and external costs, permits and fees survey costs, land costs including demolition and relocation, design costs, consulting and contractor costs, legal fees, manpower, materials, components costs, direct communication costs, transaction costs, warehousing costs, initial inventory management costs, initial quality inspection and testing cost, initial handling and insurance costs, proportion of organization overhead cost (Administration, etc), proportion of capital asset cost (plant, buildings), any modification costs to meet immediate requirements, installation and commissioning costs, initial training costs, manuals and support literature, appraisal costs (including travel and time to examine options), initial consumable costs, initial spare parts costs, safety compliance costs, quality assessment costs.

Commission costs (Costs-In-Use) usually comprise: operating costs, maintenance costs, alteration and refurbishment costs and support services costs. Operating costs are usually associated with: fuel or energy sources and charges, operational manpower costs, security costs, safety costs and training costs. Maintenance costs relate to the costs of retaining the asset in a fit, efficient and operable condition. This might vary over the life of the asset according to corporate strategies on maintenance liability and appraisal. These costs will include: consumables, maintenance spare parts, environmental compliance costs, recalibration costs, overhaul and repair manpower and overheads costs, logistics costs of spares including inventory management, warehousing, quality inspection, purchasing, handling, and receipt, loss of productivity/revenue/use during maintenance, systems monitoring costs, QA Audit costs, warranty conditions, training costs for operations and maintenance staff; contract maintenance costs, cleaning manpower rates, comparative costs associated with types of surface coverings, capital expenditure on dedicated cleaning equipment, including discrete operating – maintenance - replacement costs, cleaning consumables, protective clothing, accommodation/storage facilities for cleaning equipment - materials, associated administrative overheads in personnel management, inspection, purchasing, and administration and amortized portion of capital costs of other associated cleaning equipment if not absorbed elsewhere. Alteration/Refurbishment Costs can be: upgrade costs including retrofits and computerization or alteration resulting from future change, or modification to a standard or to a purpose built, or where replacement costs cannot economically be justified over an expected life span; and includes re-training costs. Support Costs include: insurance, rates and taxes, management fees and charges and safety compliance costs.

Decommission (Disposal) The net effect of costs and inputs may have a positive or negative effect on the total cost of ownership, but must be considered to include: residual/salvage, value, asset residual valuation costs, disposal method costs, auctioneers/agents fees, associated transport and freight costs, decommissioning costs, management and administration costs, associated manpower costs, statutory compliance costs, any demolition/destruction costs and environmental re-establishment costs.

V. CONCLUSION

The paper presents main meanings of the system approach from basic terms and definitions, brief history of the maintenance techniques and management with the causes for the system approach change to the basis for the system possession or ownership optimization. The paper, in the second part, briefly deals with costs of the system whole life mainly based on the LCC approach.

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