Sustainable Plant Asset Management

Considering sustainability aspects in asset operations and maintenance performance from an asset life-cycle perspective

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Purpose - The purpose of this paper is to discuss maintenance and operational management with a focus on asset life-cycle in perspective of sustainable development. A framework to integrate sustainability aspects into plant asset management especially with the focus on the asset life-cycle is developed. Sustainable asset- and maintenance-management can contribute to the principles of sustainable development as well as to the performance of plant asset management and corporate profitability.

Originality - Many underlying issues regarding sustainability performance in production and plant asset management are discussed rarely and are still undefined. The paper presents a generic framework to explore and specify the integration of sustainability aspects into the asset life-cycle.

Introduction

As complexities and uncertainties in business environment is increasing, business leaders have to take initiatives to adapt what is termed sustainable business (resp. corporate sustainability or CSR), i.e. to integrate stakeholders, environmental and social aspects into business planning and routines (Liyanage (2007), p. 304). Corporate sustainability can reduce risks and enhance business opportunities (Baumgartner (2007), Dyllick and Hockerts (2002)). Achieving competitive advantages in the current complex and dynamic business setting require that industries develop their policies and procedures in compliance with stakeholder demands. Typical stakeholder demands include environmental aspects like reducing emissions or waste and social aspects like occupational health and safety or others.

Producing companies which have usually high capital assets have to focus on the performance of their manufacturing assets and have to optimize their internal operational and maintenance processes. The basic goal of plant asset management is to maximize the capital turnover and to minimize losses in operations as well as to optimize capital investments and the decommissioning phase. Mainly in capital-intensive producing and heavy industries, plant asset management provides a critical support by keeping machinery and equip-

ment in a safe operation condition during the operations phase (Parida and Kumar (2006), p. 239). The optimal economic arrangement of the production factor asset is the basic challenge of plant asset management. Decreasing product life-cycles, increasing customer requirements regarding quality, delivery time and flexibility on one hand as well as the demand to increase profitability on the other hand require flexible companies hand in hand with a minimization of capital expenditure and investments (Biedermann (2001), p. 9). Environmental and social aspects are of increasing importance for plant asset management. (Liyanage (2007), p. 307; Schröder (2010), p. 33).
However in existing frameworks of asset- and maintenance management sustainability aspects are not integrated, especially how sustainability aspects can be integrated into the asset life-cycle. The need of a three-dimensional (economic, social and environmental) performance measurement system for plant asset management is very poor discussed (Löfsten (2000), p. 47; Parida and Kumar (2006), p. 239). Therefore we develop a framework in order to integrate sustainability aspects into plant asset management with a focus on the asset life-cycle. Sustainability activities in asset operations and maintenance encompass the minimization of resource inputs (materials, energy) and the generated emissions, as well as a social responsibility (improvement of the working environment) as well as the requirement to economic efficiency. Three different phases are usually distinguished in an asset life-cycle, the asset investment phase, the operations phase and the phase if dissemination resp. decommissioning (Nebl and Prüß (2006), p. 144). The focus is on the possible integration of sustainability aspects into the activities in the different phases:

1. Identify achievable potentials during the asset investment phase (including projection and acquisition) due to the integration of sustainability aspects.
2. Develop an asset performance measurement system during operations and maintenance phase considering sustainability aspects.
3. Outline the integration of sustainability aspects into the decommissioning phase.

The following is an outline of this paper. The first sections provide the background and a brief introduction into maintenance and plant asset management as well as into the asset life-cycle. Then the need of a long-termed corporate value and a stakeholder orientation especially in plant asset-management is outlined. The next section provides the basics of sustainable development before a framework for sustainability asset management will be discussed. The final section provides a summary of the paper and discusses the scope of future work.

Maintenance and plant asset management

Plant asset management as a corporate activity focuses on the tangible fixed assets (plants/manufacturing equipment) (Nebl and Prüß (2006), p. 35). Plant asset management contains activities and as well as decision-making and covers the asset life-cycle phases of investment (including asset design and asset provision), operations and maintenance (including improvement and administration) and decommissioning of tangible fixed assets (see Figure 1). The fields of activities as well as the aims of asset management are discussed in the following sections.

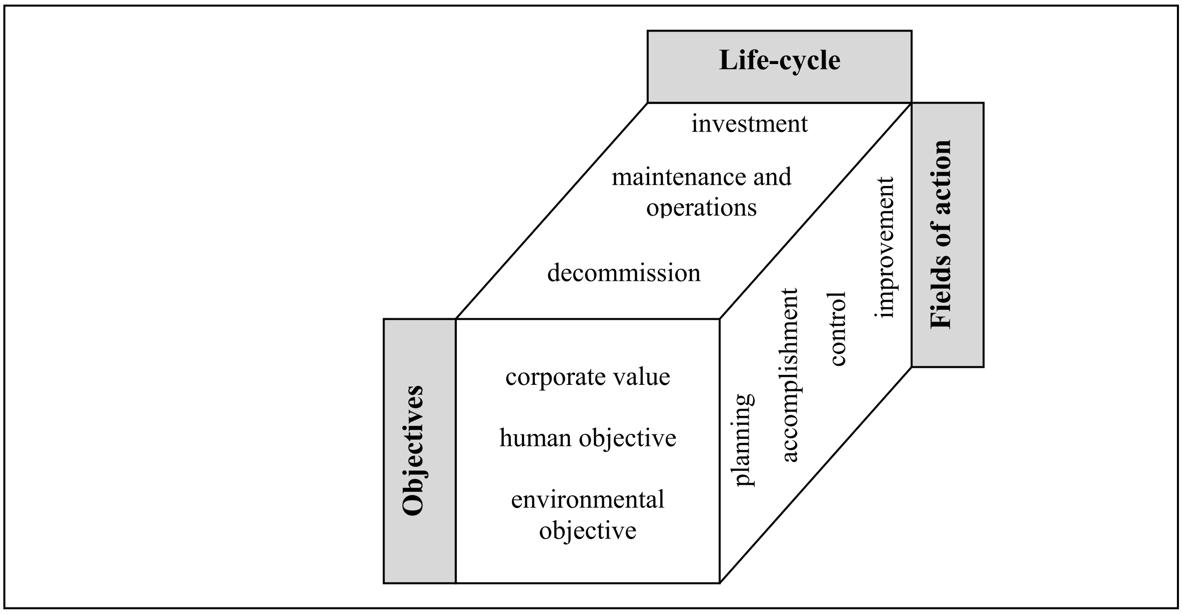

Figure 1.
Plant Asset management: objectives, life-cycle and fields of action (Based on Männel (1988), p. 6)

Asset management activities have to be designed, implemented and controlled through appropriate decision and management processes. Fields of action include planning, accomplishment, control and improvement of all activities related to plant asset management, the activities are supported with information systems (Campbell and Jardine (2001)).
Derived from the main objectives of a company (particularly the long-term increase of the corporate value), asset management sub-goals has to be formulated that make a significant contribution to the operational and sustainability performance of a company possible. In sequence of the asset life-cycle (investment, operations and maintenance, decommission) it requires an aligned asset management framework, which considers the operational human needs (human objective) and the environmental requirements (environmental objective). So a three-fold criterion sets the basis for sustainable business performance in maintenance and asset management (Liyanage (2007), p. 307) (see Figure 2).

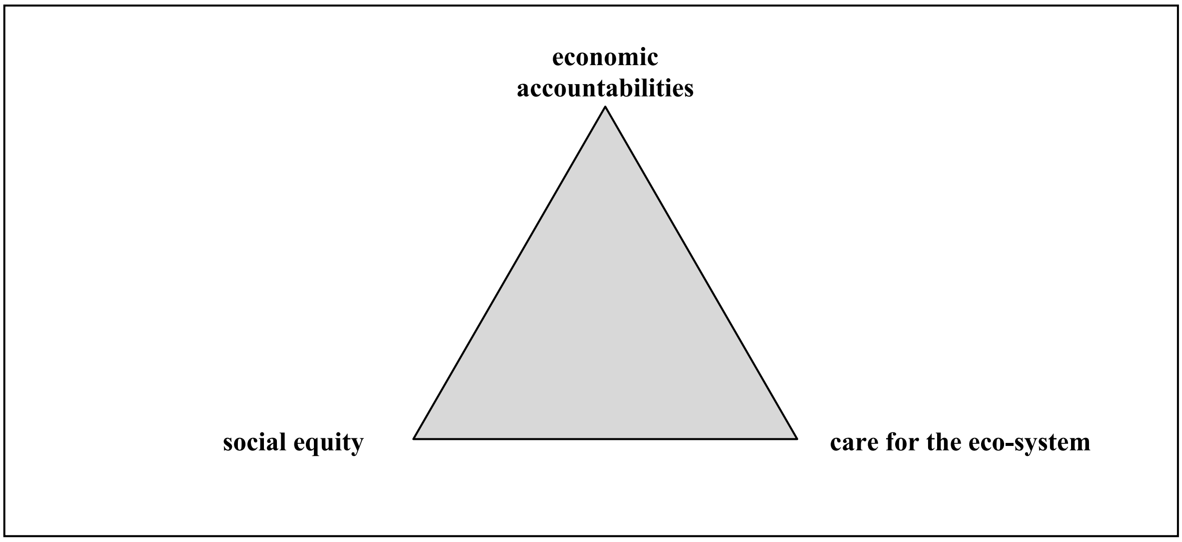

Figure 2.
Principal performance clusters that build key sustainability pillars (Liyanage (2007), p. 307)

Economic objectives encompass high asset availability, minimization of cancellation costs and maximization of return on investment. The social and environmental perspectives include environmental and social goals which are derived from regulations, stakeholder demands and strategic corporate goals.

Performance measurement and outcome of plant asset management

Basically, the outcome of plant maintenance shall not be assessed without further notice. Thus, the economic outcome of plant asset management can be defined as working performance less arising expenses/costs. While expenses and costs can be measured exactly, the working performance as result of maintenance activities can hardly be measured completely in economic terms. The outcome as a result of maintenance activities over the asset life-cycle occurs time-delayed (availability, conservation of value). Second, the reduced wear behavior or the increased asset reliability are only very limited accessible to a direct economic valuation. So many authors try to formulated the outcome of plant asset management with the maximization of economic performance indicators (e.g. overall equipment effectiveness, total effective equipment productivity) or the minimization of maintenance costs (Löfsten (2000), p. 47; Parida and Kumar (2006), p. 239). A sustainable view which includes nonmonetary performance indicators over all key sustainability pillars is less discussed in literature. This subject is also been considered in the framework.

Asset life-cycle

The life-cycle of a plant asset characterizes the economic life time of the asset in a company. The asset life-cycle consists of three phases similar to a product life-cycle in terms of consumer goods and it begins with the supply of the asset by an investment, the operations and ends with their decommission.

The first phase of the asset life-cycle is the investment phase. Based on investment needs and investment decisions the projection, purchasing, installation and commissioning of the investment object takes place. As part of the investment an asset is provided and installed. The aim of the provision is either the creation of additional production capacity or the replacement of worn or overage manufacturing resources. Also rationalization objectives can be realized by investing in new technologies (Nebl and Prüß (2006), p. 144).

The phase of using a plant asset (=operations) is the central aspect for maintenance activities. During the useful life the asset produces goods and services, but at the same time the given using stock of the asset decreases, i.e. the productivity of the asset is declining. Assuring the performance of the assets is the main task of maintenance. All activities which serve to perpetuation, re-establishment or improvement of the using stock are part of the plant maintenance. The tasks of maintenance are divided into inspection, attendance and repair. In the context of maintenance the tasks also have to include simultaneously some improvement and modernisation activities at the using stock (DIN 31051 (2003), p. 2).

The phase of asset operations and maintenance is followed by the phase of disinvestment. Here the decommission takes place, i.e. the asset is dissolved away from the operating process. The need for disinvestment results not only in technical (abrasion of the assets), but also in economic reasons (changing demands, ensuring competitiveness, financing).

Corporate value and stakeholder orientation

Asset management contributes to the economic success of a company (measured for instance with Return on Investment resp. Return on Capital Employed) due to the long-term improvement of the capital turnover (Biedermann (2006), p. 13). A pure focus on short-termed financial business ratios leads to an overemphasis of stakeholders of capital market. This in turn reduces the chances for sustainable business development. Therefore, in this paper the concept of company value is to expand. Non-monetary and non-economic objectives (e.g. in the field of social and environment) are to be considered in a comprehensive long-term oriented target system (see Table 2).

A stakeholder oriented asset management is characterized by focusing on targets of those stakeholders, who are interested in work and in the results of asset management. This stakeholder orientation is found in different management approaches and management models, as an example Total Quality Management can be mentioned. In the asset management Total Productive Maintenance (TPM) is established as an essential management strategy that ensures an effective asset management through integration of different stakeholders (planning production, material management, etc.) along the asset life-cycle (Nakajima (1995)).

One approach to an even broader view of stakeholders is the concept of sustainable development. In this paper the aspect of stakeholder should be seen in a more comprehensive way and also includes the principles of a sustainable development based on the system model of Robèrt et al. (Robèrt, Schmidt-Bleek et al. (2002)). This is also consistent with critical success factors for a sustainable asset management (Liyanage (2007), p. 311):

- Considering all costs over the whole life-time of an asset (Life-Cycle-Costs)
- Production quality
- Economic spare part management
- Work protection and safety at work
- Environmental protection and waste management

The principles of sustainable development based on the system model of Robèrt et al. will be discussed in detail in the following section. These principles give also an orientation for a sustainability-oriented asset management over the entire asset life-cycle.

Sustainable development

Sustainable Development became popular with the definition of the Brundtland report (World Commission on Environment and Development (1987)). It represents an ethical concept concerning fighting poverty while protecting the environment on a macro-level. It consists of environmental, social and economic sustainability (Elkington (1998)). Environmental sustainability deals with the mechanism and conditions that natural life sustaining systems can be maintained and their destruction can be prevented. Social sustainability means to meet human needs within the limits set by the conditions for environmental sustainability. Economic sustainability describes the important role of economy in order to meet environmental and social sustainability (Baumgartner (2003)).

Sustainable development is defined for the macro-level of societies. Figure demonstrates the link between sustainable development and corporate sustainability. Sustainable Development incorporated by the organization is called corporate sustainability and contains, like sustainable development, all three pillars: those of economic, environmental and social dimension. These three dimensions interact between each other (Ebner and Baumgartner (2006), pp. 13).

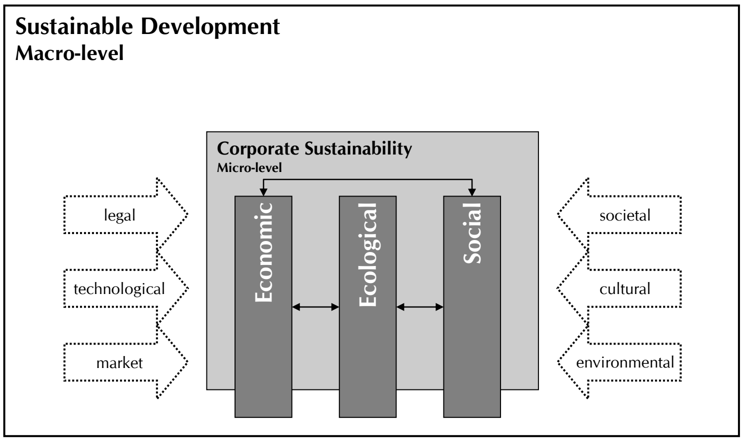

Figure 3.
Corporate Sustainability and its interdependences (Based on Ebner and Baumgartner (2006), p. 13)

Sustainable Development is the process to reach the goal of sustainability, which can be characterized by four ultimate sustainability objectives (Robèrt, Schmidt-Bleck et al. (2002), p. 199):

1. In the sustainable society, nature is not subject to *systematically* increasing concentrations of substances extracted from the Earth's crust,
2. to *systematically* increasing concentrations of substances produced by society,
3. to *systematically* increasing degradation by physical means,
4. and, in that society people are not subject to conditions that systematically undermine the efforts to meet their needs.

These four principles concretize the objective of the Brundtland–Definition of Sustainable Development. To meet these principles two general mechanisms - dematerialization and substitution - can be used. Dematerialization deals either with resource productivity or reduction of waste. Substitution differs from system condition to system condition. For condition 1 and 2 substitution means using more abundant materials from the earth's crust or compounds that are occurring naturally. For system condition 3 the substitution of certain activities, which are identified as nature destructing, is the task. And condition 4 includes health aspects through environmental pollution, availability and distribution of resources (Robèrt, Schmidt-Bleck et al. (2002)).

This means for the economic development to generate wealth, especially for poorer people in ways that are compatible with these principles (James (2001) p. 77). Sustainability requires an economic system that meets the needs of people, provides enough jobs and is able to rejuvenate itself in order to provide these services in the long run (Spangenberg (2001), pp. 30).

In order to develop a sustainable asset management framework it is necessary to be aware of the range of sustainability issues which have to be regarded and also designed in such a framework. For corporate sustainability, already various approaches exist which determine sustainability aspects. Baumgartner and Ebner identified based on popular concepts and papers of sustainability (GRI (2006); DJSI (2007); FTSE (2006); Labuschagne and Brent (2006)) relevant sustainability aspects for the economic, environmental and social dimension (Baumgartner and Ebner (2010)).

Framework for sustainability asset management

A comprehensive model of a sustainability oriented asset management has to include the environmental and the social dimension of the life-cycle of an asset in addition to economic aspects (Schröder (2010), p. 90).
Therefore we analyze the integration of sustainability aspects into the three phases of the asset life-cycle (asset design and provision, use, decommissioning), especially the achievable potentials of this integration are discussed. In figure 4 the conceptual framework for sustainable plant asset management is presented.

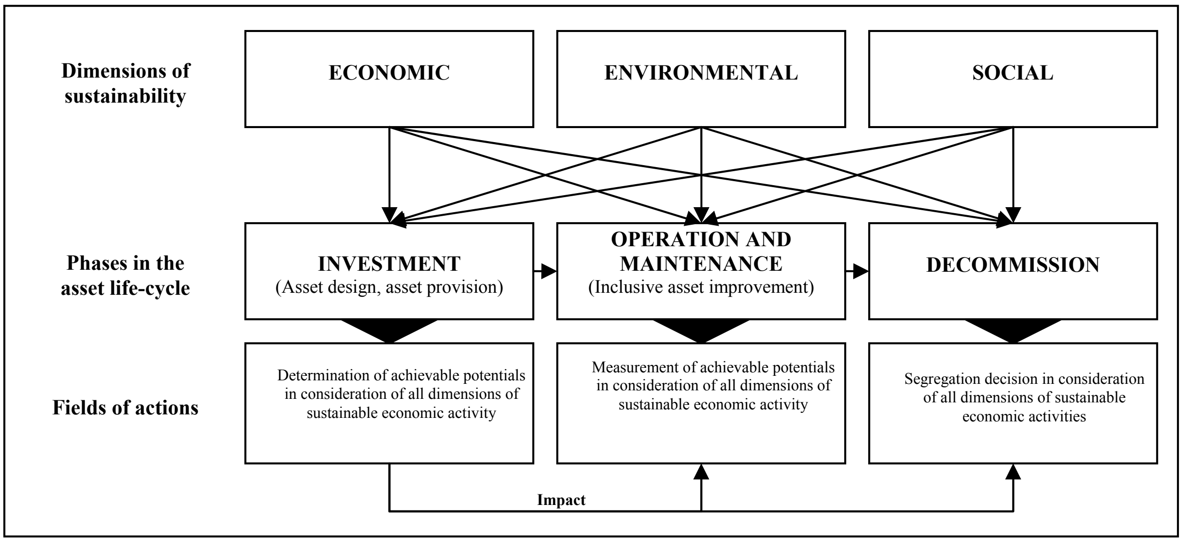

Figure 4.
Conceptual framework of sustainable asset management

A sustainability oriented asset management expands existing asset management concepts as it includes social and environmental aspects.

Life-cycle phase of investment, design und provision

Investment decisions have a high economic importance for the asset management. Risks of long-termed asset management in a dynamic business environment should be minimized. Thus asset investments fix the profile and effectiveness of profitableness and are therefore crucial for a company's future.

In addition to capital commitment investments lead to a change in the corporate cost structure. First, the intensity of higher fixed costs has a significant impact on the break-even-point. Second, capital-intensive plant assets with increasing fixed cost intensity show a much higher sensitivity to the activity level (fixed cost degression).
For the purposes of a life-cycle orientated asset management the pure focus on minimized capital expenditures is not desirable as the whole life-cycle costs under specific operating conditions should be minimized. In addition to inclusion of asset management risks (amortization risk, default risk, utilization risk and adjustment risk) also aspects of sustainability aspects should be included into an investment decision. Investment decisions have not only to be based on technical and economic aspects (Wolff (2000)). It is also important to note the environmental and social perspective. It may therefore be advantageous to accept

higher capital expenditures in the stage of asset design and provision in order to achieve lower costs in the period of operation and maintenance as well as in the phase of decommission due to improved planning (see Figure 5).

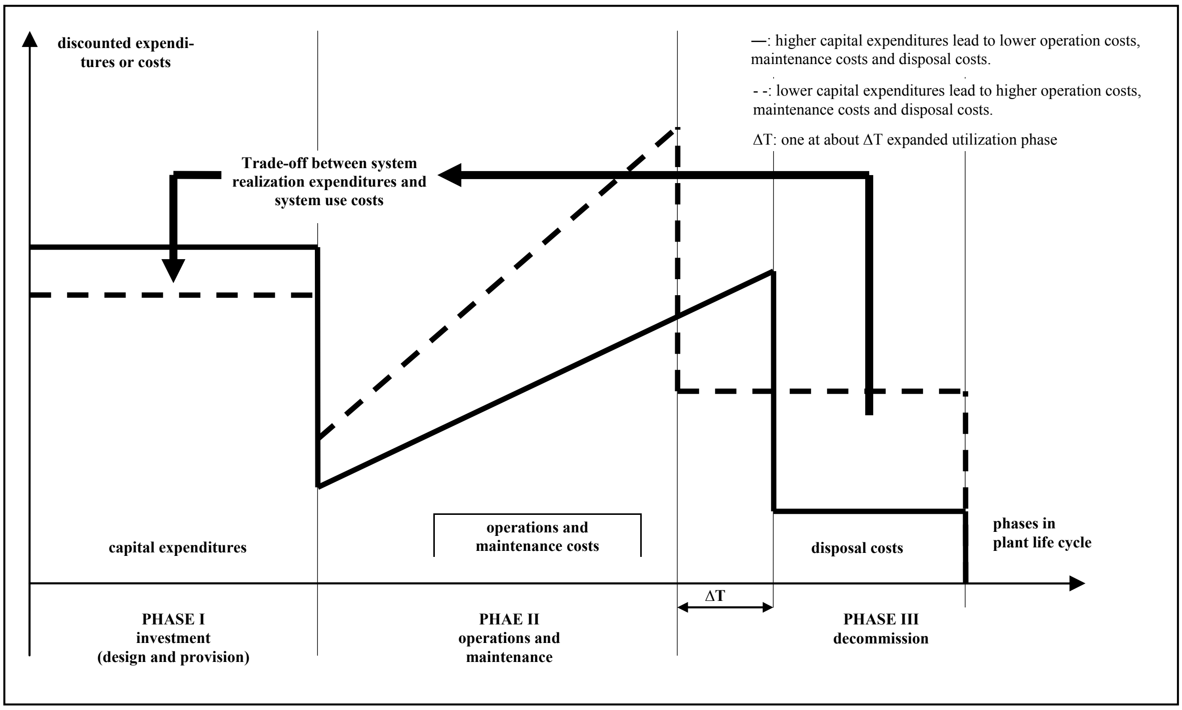

Figure. 5.
Asset life-cycle costs: trade-offs between capital expenditures and other costs (Based on Nebl and Prüß (2006), p. 148)

Therefore in the phase of design and provision a comprehensive and farsighted planning of the achievable performance potentials of the asset is needed. Table 1 gives an overview of aspects and objectives to identify the achievable potentials for the economic, environmental and social dimension.

Table 1.*Dimensions and objectives of achievable potentials in the panning and design phase*

	Economic dimension	**Environmental dimension**	**Social dimension**
Aspects and objectivs	- high dynamic performance - high flexibility - maximum availability or high reliability - high stock of available wear-out - minimization of the fixed capital - minimization of mainten-ance-costs	- minimization of the con-sumption of auxiliaries and consumables - minimization of energy de-mand - minimization of incidental emission quantities and their toxicity - minimization of incidental waste quantities and their toxicity - maximization of Reuse and Recycling - minimization of waste costs and disposal costs - consideration of take-back obligations of producers	- fulfillment of safety re-quirements - minimization of origin of danger for possible work accidents - ergonomic job engineering - staff motivation by aes-thetic composition - optimal maintenance-suitability

Plant asset management has a significant influence on the expected flexibility advantages of the systems. The technological capacity of assets - and thus their flexibility - is indeed determined primarily by asset design. But the practical achievement of the flexibility advantages depends on the compliance of the desired using stock of plant assets (Kaluza (1989), p. 113). For the maintenance it is important to assure the aspects of reliability, availability as well as an optimal maintainability. Also pay attention to safety issues in the field of work protection and environmental protection already in the planning phase. An integration of all working and environmental issues saves subsequently rendered corrective interventions, which are usually associated with several costs. Beyond these safety aspects, take in account the environmental and social sustainability aspects and particularly the consumption of operating materials, energy demand as well as waste and emissions generated by the plant assets.

From the perspective of decommission, in particular aspects of recycling come to the fore. Face of the increased sensitivity to environmental awareness and increasing disposal costs, it is especially necessary to consider the environmental dimension to find an optimal strategy.

Life-cycle phase of operations and maintenance

The efficient use of assets and maintaining the given using stock is essential in the phase of operations and maintenance. The starting point of an optimal design of this function must therefore be to measure the achievable potentials of the asset. For the purpose of a sustainability orientation environmental and social aspects must be considered (see Figure 4).

Performance measurement systems often rely on a pool of indicators. Most of these business indexes (performance indicators or pi's) represent the maintenance and production system concerning its productivity or efficiency. A performance measurement (PM) system in terms of a comprehensive sustainability perspective enhancing the economic dimension is missing in most evaluation models. Therefore in Table 2 also the environmental and the social aspects are considered. Each dimension is divided into several perspectives. In each perspective there are one or more proposed criteria how to measure this perspective. The criteria are divided into a strategic and an operational level. The strategic level includes the aspect of effectiveness or the development of potential for success and is therefore long-termed. Whereas the operational level focus on the efficiency and the optimal exploiting of potential for success and is therefore short-term oriented.

Table 2.
Criteria to measure and assess the phase of asset operations, maintenance and asset improvement

Dimensions of sustained economic activity	Perspectives	Strategic level	Operational level
Economic	finance reference values	maintenance budget (long-term aim for the whole company) maintenance costs (long-term aim for the whole company)	maintenance budget (for individual equipment, short-term consideration) maintenance costs (for individual equipment, short-term consideration)
	asset management reference values	Total Effective Equipment Productivity (TEEP) Overall Equipment Effectiveness (OEE) asset availability performance rate quality rate	dead time and duration repair times MTTR (mean time to repair) MTBF (mean time between failure) availability
	flexibility	qualitative evaluation of modification, reconstruction ability and redundancy (all assets)	qualitative evaluation of modification, reconstruction ability and redundancy (for individual equipment)
Environmental	environmental costs (absolute or per product unit [t, #, m³])	costs for emission treatment and waste treatment (overall view) costs for not productive material usage and energy usage (overall view) costs for integrated environmental protection actions (overall view)	costs for emission treatment and waste treatment (for individual equipment) costs for not productive material usage and energy usage (for individual equipment) costs for integrated environmental protection actions (for individual equipment)
	resource demand for auxiliaries and consumables (incl. water demand) (absolute or per product unit [t, #, m³])	long-term aim for the whole company	individual equipment, short-term consideration
	energy demand incl. not used consumptions and losing's (absolute or per product unit [t, #, m³])	long-term aim for the whole company	individual equipment, short-term consideration
	emissions (gases and dust) (absolute or per product unit [t, #, m³])	long-term aim for the whole company	individual equipment, short-term consideration
	waste (absolute or per product unit [t, #, m³])	long-term aim for the whole company	individual equipment, short-term consideration
	sewage (absolute or per product unit [t, #, m³])	long-term aim for the whole company	individual equipment, short-term consideration

Table 2 (continued).
Criteria to measure and assess the phase of asset operations, maintenance and asset improvement

Dimensions of sustained economic activity	Perspectives	Strategic level	Operational level
Social	staff satisfaction	index	individual equipment short-term consideration
	Work safety (to due to danger caused from the asset)	near accident (absolute, per staff member, per working hour, long-term aim for the whole company) work accident (absolute, per staff member, per working hour, long-term aim for the whole company) deadly accident (absolute, per staff member, per working hour, long-term aim for the whole company)	near accident (absolute, per staff member, per working hour - subarea/ individual equipment short-term consideration) work accident (absolute, per staff member, per working hour - subarea/ individual equipment short-term consideration)deadly accident (absolute, per staff member, per working hour - subarea/ individual equipment short-term consideration)
	staff development	staff fluctuation training days (absolute, per staff member, long-term aim for the whole company) costs for training (absolute, per staff member, long-term aim for the whole company)	training days (absolute, per staff member, subarea/ individual equipment short-term consideration) costs for training (absolute, per staff member, subarea/ individual equipment short-term consideration)

Life-cycle phase of asset decommission

In the action area of decommission an asset is taken out of service because of economic, technical or legal reasons. Basically there is distinguished between disposal and recycling (see Figure 6).

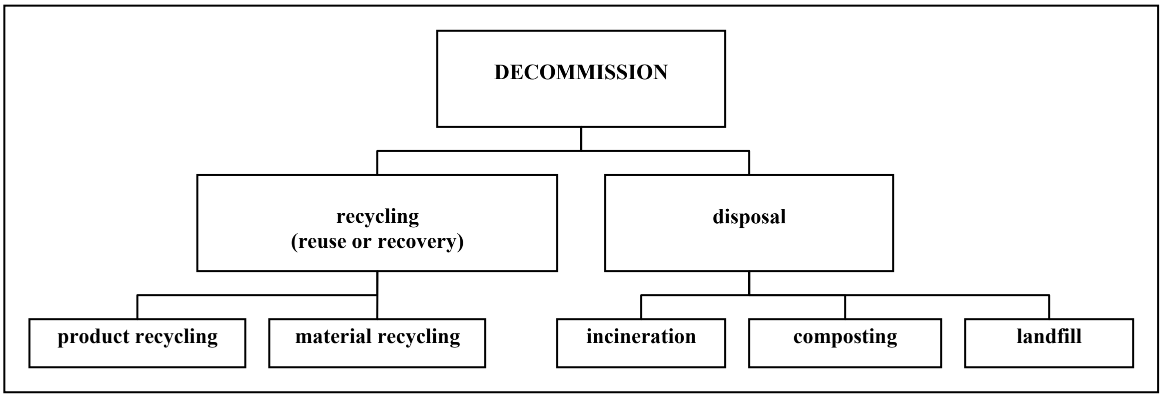

Figure 6.
Strategies of decommission

Recycling is a measure of material recovery, where in business cycle output of fabrics is used as inputs again. Recycling can be divided into four different forms: reuse, further use, recovery and reclamation. Reuse occurs without change of the form in the same application, further use occurs without change of the form but in another application (product recycling). In asset management we also speak of revamping and rehabilitation. This reboosting efficiency is then given preference if the same outcome is achieved with less effort compared to a new project planning. In the case of recovery there is a change of form. The material is used in a similar production process, in the reuse it is used in another production process. Recycling may therefore be in-plant or cross-plant (.

Therefore a part of decommission is to check whether the asset or components and assemblies can be taken to product recycling or material recycling. This test has to be done under the consideration of legislation, costs and environmental impacts. From the perspective of sustainable development usually the use (product recycling) is preferred to recovery (material recycling) and recovery is preferred to disposal. It is therefore necessary to check whether the asset or components and assemblies can be used in another area economically, technically and environmentally or as spare parts. This corresponds to the refeed in the use phase. If this is not possible, a recovery of the asset or components and assemblies should be aspired. Only components which cannot be reused or recycled should be disposed.

Summary

In this paper a sustainability oriented plant asset management is designed under consideration of the complex asset life-cycle. The authors focus on a stakeholder management system, which integrates sustainability aspects into plant asset management.

A comprehensive model of sustainability-oriented asset management needs to take into account all three dimensions of sustainable development throughout the whole life-cycle of an asset. Therefore there are three action areas, which are the determination of achievable potentials in consideration of sustainability of the asset design and provision, the measurement of the achievable potentials in consideration of sustainability during operations and maintenance and the decommissioning decision in consideration of sustainability of the asset segregation.

This paper should point out rarely discussed starting points of a sustainability oriented asset management, especially for asset intensity companies with an intense consideration of socio-economic and environmental aspects. On the other side this contribution indicates that further research is needed. In particular there is need for action concerning a comprehensive sustained and life-cycle oriented performance evaluation.

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