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Asset fleet management in the process industry - a conceptual model

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Abstract: Fleet Management is widely known from vehicle fleet management. However, this term is not elaborated in more detail for the management of asset fleets in the process industries. Since the challenges and the potential advantages are similar, a conceptual approach for fleet management in the process industry is developed.
A participatory approach and the Soft Systems Methodology are used for the model development. The interests of various stakeholders have been identified and the scope for fleet management has been defined, the requirements for a fleet management system have been derived.
The developed model focuses on adding the fleet perspective to the perception of assets in an industrial setting. Advanced prognosis and optimization technology combined with a partly centralized and de-centralized management of assets may be able to improve the reliability and the operational performance of the process industry in the future.
The main contribution of this paper is the application of the fleet approach for assets in the process industry. The developed model utilizes experience and knowledge from different stakeholders. A holistic view of fleets in the process industry is given. The components of the conceptual model are depicted and the description of the overall system may be used as an outline for the subsequent implementation and further improvement of the fleet management model.

Keywords: Maintenance scheduling and production planning, Information processing and decision support, key performance indicator, energy efficiency

1. INTRODUCTION

Fleet management is a term widely used for the decision-making in the operation of a fleet vehicles, e.g. aircraft, ships, cars or trucks. While the type of the vehicle is less important, the important characteristic is that there exists a large number of vehicles that are utilized by one stakeholder/company for the same purpose. This may include the transport of people (car rental or taxicab companies or airlines) or the vehicles perform certain tasks (agricultural machinery rental companies). Typical points of interest in fleet management are financing, maintaining, scheduling, telematics or the management of cost-drivers that are linked to the vehicles, such as personal cost or fuel usage.

The idea behind aggregating and managing a larger number of vehicles is based on the economies of scale (see Figure 1). By scaling the operations up a cost advantage is obtained. The decreased cost per produced/transported unit originate from different effects:

- Decreased capital cost: Buying larger quantities of the same asset will lead to discounts
- Decreased maintenance cost: Inventory costs for replacement parts decrease
- Decreased crew size: The crew size does not increase proportionally with the capacity

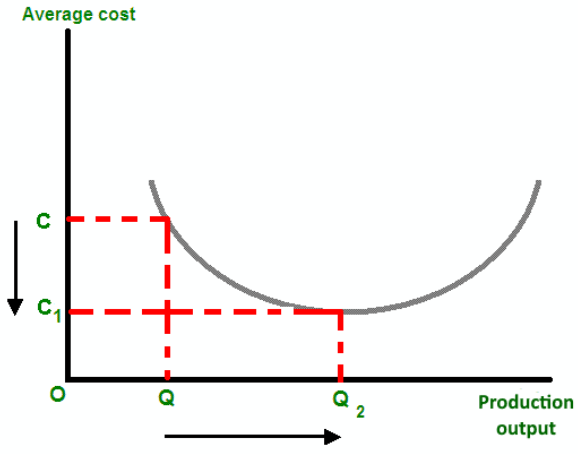

Fig. 1. Economies of scale: With larger output the average cost shrinks up to the saturation point

- Increased knowledge management: With an increased amount of assets of the same or similar type the workforce gains more knowledge

However, up-scaling will minimize the average cost just up to a certain level. Afterwards effects like a saturated

market or overwhelming complexity in the management exhaust the positive effect.

Across all industries companies benefit from economies of scale. The same applies for the process industry. During the past years a large number of mergers and acquisitions in the global chemical industry have been observed. According to Deloitte (2017) this trend will continue during the coming years. This leads to a large potential for fleet management in these companies.

By producing larger quantities of the same product or by using similar asset types the production cost per unit can be decreased and the operational efficiency can be improved. However, also the complexity in networks with multiple different asset classes is higher than for many vehicle fleet management systems. This development increases the demand for fleet management tools that include approaches for scheduling, monitoring and online coordination of various assets. Consequently, decision-support needs to be given.

Examples for asset fleets in the process industries are ubiquitous. An example that inspired this work are compressor fleets of oil and gas companies. Aggregating this large amount of assets bring certain synergies. It is an industrial-wide challenge and reaches from pumps in chemical production over heat exchangers in power plants up to crushers for the mining industry. With increasing interest of the industry of utilizing big data fleet management becomes more and more attractive. The presence of asset fleets requires a paradigm change for asset management. Asset fleet management needs to asses the fleet from a top-down perspective instead of the current bottom-up approach used in regular asset management.

The objective of this paper is to identify the requirements for fleet management in the process industry. This reaches from the acquisition of information from the existing disparate data systems, to the storage and processing of these information. In the next step this data is used for the calculation of several intermediate information. This intermediate information is the input for more complex optimisation algorithms such as maintenance scheduling or production planning. It is hypothesized that fleet management of assets will enhance the current state of the art asset management and meet a number of the challenges faced nowadays. By providing conceptual guidelines for decision-support systems an improvement within this industry may be achieved.

2. BACKGROUND

There are several definitons of Asset Management. The British Standards Institute published the Publibly Available Specification on Asset Management (PAS 55) which defines Asset Management as

"[...] systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its original strategic plan."

The Asset Management Council of Australia (Chambers et al., 2014) defines it as

"The life cycle management of physical assets to achieve the stated outputs of the enterprise."

The definitions of asset management cover a variety of different areas, such as financial or human capital aspects, general management and also operations and productions. Both definitions above focus on the management of physical asset, which are the focus of this paper, too. A good overview of this topic is given in Hastings (2015) and Schuman and Brent (2005).

Asset management in the engineering point of view focuses on physical assets. However, these assets also have a financial dimension. This takes into account that each asset has an economic value and they need to be managed in order to contribute to the overall process. In this section an overview about what assets are and how a fleet is defined are given. In the next step some basic concepts of physical asset management are introduced and the benefits and challenges are shown. In the end, a review on how asset management is done in the process industry is given.

2.1 Assets and Fleets

Physical assets that are considered in this conceptual model are items such as plants, machinery, buildings or vehicles. Also, this includes the technical software systems and the control systems, as well as the associated information for these items. (Hastings, 2015) All these items have in common that they serve a business or an organizational function, for example when they are part of a chemical or manufacturing process.

In order to manage assets properly, different activities throughout the life cycle of an asset must be done, starting from identifying which assets are needed, acquiring them and providing the maintenance support systems up to the disposal or renewing of an asset. The objective is to perform these activities as effectively and efficiently as possible.

The word fleet is originally used for a number of ships or aircraft under the command of a flag officer. For the purpose of fleet management the word is extended to any group of vehicles that is operated under unified control and by doing e.g. their routing can be improved. In this paper fleet is used as a an umbrella term that comprises all assets in a company that are operated for a similar purpose and that show certain similarities in their operational behavior. This definition is on purpose very flexible, since in the application of fleet management it has initially to be determined, which assets are part of one fleet, such that the benefits for managing them as a fleet over-weighs the effort.

Beebe (2010) highlights the key requirements for asset management as follows:

- Spatial generality: All types of physical assets
- Time generality: Both short term and long term
- Measurement generality: Both financial and capability dimension
- Statistical generality: Risk and basic measures are important
- Organizational generality: Takes place at all levels of the organization

If all these are fulfilled the resulting asset management system will be able to provide sound asset knowledge which supports decisions within the business context. For the operation side this involves the procurement and planning, but also maintenance actions and shutdown/turnaround planning within the company. The most measurable benefit is the financial improvement in the OPEX (Operational expenses). Furthermore, the awareness and management of regulatory compliance is improved. (Hastings, 2015)

2.2 Asset Management in the Process Industry

Schuman and Brent (2005) entitles asset management as "one of the last options to maximize cost savings in a competitive global economy due to its intrinsic complexity". While this statement is from 2005, it is not lacking actuality. The process industry is currently undergoing a significant development called "Industry 4.0". More advanced machinery monitoring is available and more and more information technology is implemented.

However, the new generation of technological developments brought by Industry 4.0 enables the implementation of a new dimension of asset management: The perspective of fleet asset management. But the complex nature of productions systems poses of course new challenges.

The current state of the art offers various asset management tools for the industry. They are oriented towards offline management and even though often continuous measurements of asset conditions are available, the integration of real-time data into the asset management is rarely done.

Fleet management will be an integral part of future ERP solutions and overall information systems. Such a system supports all management activities on all levels throughout the company. Hereby, it is important to identify certain Key Performance Indicators (KPIs) that are able to give insights into the complex system. (Folinas, 2007)

The difference between asset management and fleet asset management is the perspective. While the former has a focus on each individual asset, the fleet asset management approach is utilizing a top-down point of view, which is going from the entire fleet towards the single assets.

3. METHODOLOGY

3.1 Participatory Approach

In order to identify all the requirements for a fleet management system, a study was carried out and the point of view of different actors and stakeholders have been incorporated. The methodological approach here is participatory. This includes engineers from the R&D and operations departments from industries such as Oil and Gas, Chemicals and Pharmaceuticals. On the other hand different employees of various vendor companies have been interviewed regarding their point of view. With a total amount of 18 interviewees, a good overview of the industrial needs is ensured. Current challenges in the asset management and operation of large-scale process plants have been extracted. It has been researched, what are factors that hinder the increased productivity in these settings and how increased compliance requirements take part in this topic.

The focus for the requirements was in the following fields:

- What are current and future challenges in industry
- What is needed to build a functioning fleet management with respect to the needs in software and hardware

3.2 Conceptual Modeling

The identified requirements need to to be put into context and an effective system for fleet management needs to be developed. In this paper the Soft Systems Methodology which was introduced by Wilson (2001) is used. It has been used in several other application fields, e.g. (Mingers and Taylor, 1992) or (Hakami et al., 2013).

It includes

- the identification of the system scope
- identification of user requirements
- conceptual modeling
- determining information needs

It is important to access to state of the art in asset management and how managers deal with occurring challenges. Problems that are faced have to be determined from an external and internal point of view.

Building the conceptual model is done by first performing a CATWOE (Mingers and Rosenhead, 2001), a management tool that tries to capture different stakeholder perspectives.

On the basis of the CATWOE it is possible to define the so-called "root definition", which defines also the goal of the system while bringing up several perspectives and the inherent assumptions made. Checkland and Scholes (1990) emphasizes the enrichment of a root definition by the elements of a CATWOE analysis.

The design phase of the conceptual model outputs a logical system. This serves the different needs of an effective asset fleet management system. The derived functionalities are the next steps towards the development of a functional prototype. The methodology is displayed in Figure 2.

4. RESULTS AND DISCUSSION

4.1 Expectations for asset Fleet Management

The voiced requirements for an effective and efficient asset fleet management focus on different aspects. In the following, an overview of these aspects and examples are given, so that a basis for the conceptual model is set.

The requirements can be categorized into three groups:

Integration into existing data systems:

- Integration into existing information management system is necessary
- Connectivity to other software in company is important
- Fulfill the 3 Vs of big data: Volume, Velocity, Variety
- The complexity of the data has to be reduced.

Maintenance and optimisation

- Give insights into performance of single assets and the fleet in general

Table 1. Results of the CATWOE analysis

Aspect	Results
Customers	Several people along the operational hierarchy structure
Actors	People, interacting with the FMS
Transformation	The data which is momentarily captured needs to be processed in order to serve as the foundation for optimization algorithms that aid decision-making on an autonomous level. Since the system is complex information need to be broken down to a top-level view, accessible by specific fleet management KPIs
World View	The hypothesis is that by aggregating the information collection of similar assets, an optimized decision-making regarding maintenance, scheduling and production planning can be made
Owner	Specific departments within a company are the owner of the asset management system
Environment	Operation of process facilities are strictly regulated by governmental departments regarding the effects on the environment. A fleet asset management can be useful to also consider environmental parameters in the analysis of the acquired data

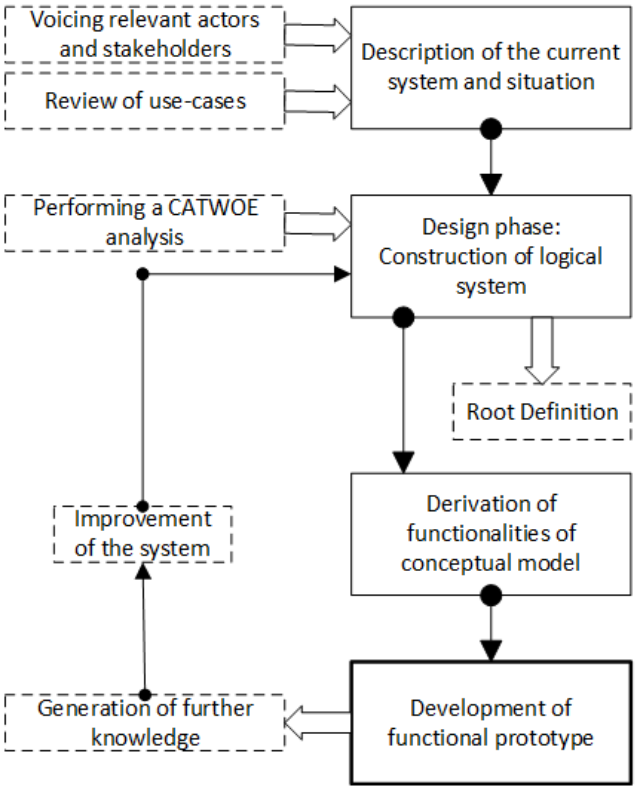

Fig. 2. Methodology for the development of the conceptual model

- Determine which assets perform differently compared to others and drive a standardization of the fleet
- Determining the impacts on the asset by capturing patterns of process operation and merging them with failure information
- Predict and prevent asset failures and poor operational performance
- Minimize impact and frequency of deteriorating performance
- Combine maintenance and operations for an efficient plant support strategy
- Predictive solutions with prescriptive guidance for users

Technological components and features

- Easy and quick access of the information for different user roles
- Customizable user-interface
- Allow statistical calculations and data manipulation, with pre-defined templates and free coding
- Possibility to create various dashboards to meet user needs
- Single user interface for all actions

General vision

- Improve the knowledge of the production process and the management of the assets at the same time and give an holistic view
- Give a comprehensive picture of the impact of the process conditions on the assets
- Utilize the novel big data approaches to solve reliability problems that were not possible to solve beforehand
- Give a common base for the work of strategy, operations and maintenance departments
- Enhance communication and foster collaborative work to manage critical issues

The core competences that have been derived from these voiced requirements include implementations of predictive and prescriptive maintenance, information aggregation and displaying based on the needs and interest of the specific user and various kinds of resource optimisation and decision-support systems.

4.2 CATWOE

The results of the CATWOE are displayed in Table 1. Based on these elements it is possible to define a root definition of the envisioned asset fleet management system:

"An asset fleet management system which is (mostly) owned and operated by an intermediate (technical) management level within companies of the process industries is deemed to support real-time decision-making regarding the operation and maintenance of technical assets within the company by means of automated acquiring, contextualising and processing operations data and external parameters. This forms a foundation for advanced decision-making with the goal of optimized operations and clarity in the displaying of information to different users (with different priorities) within the company"

4.3 Requirements for a Fleet Management System

The next steps toward an conceptual asset fleet management concept requires to view the system in terms how it should perform its different functionalities. Certain

Table 2. Requirements for fleet management

Requirement	Description
Robustness	The fleet management system needs to be able to cope with invalid and unexpected inputs and be adaptive for changes.
Computational speed	The system should run on a real-time basis. The trade-off between optimality and velocity will move towards optimality in the future because of increasing technological progress and more efficient algorithms.
Adaptability	The FMS needs to be able to fit existing assets (independent of their current state). It also needs to adapt to new technology and future developments
Extensibility	The FMS must be easy to extend and new assets need to be added to a fleet
Practicality	Optimization algorithms have to run within feasible boundaries. Scheduling and planning needs to adjust to external factors like availabilty of personnel (and consider the possibility of illness) or weather conditions
Heterogeneity	The architecture of the asset management system should allow changing equipment over time. However, aggregating similar assets in a fleet is giving valuable insights

requirements must be met in order to accommodate the plethora of different complex and dynamic processes in the domain of the process industry.

The different requirements for solving many of the challenges in asset management are clearly embraced by new asset fleet management solutions. The extension of the idea of asset management by the concept of fleet management opens new opportunities and fulfills points like an extended information system, condition overview and needed decision-making to bridge the bottleneck caused by the need of human decisions in the workflow for creating optimal maintenance schedules. Based on these requirements several core competencies for a model have been developed. These include the ability to process and store disparate data from different asset fleets within the company, independent from their location. These information shall be processed and enriched. In the next step state of the art methods can be used to obtain value from the data. This included various aspects of prognostics and diagnostics, e.g. the estimation of the remaining useful time for the asset. These information should then be the input for various optimization frameworks along the control hierarchy. From the interviews with different stakeholders it was imminent that the visualization is still very important and a "black box" which solely outputs the decisions is not wanted yet. It is important also to show the complex relations in the process by giving adequate KPIs, for example in Dashboards that adapt their level of detail to the specific user.

4.4 Main Elements of the Model

Fleet Perspective For the management of asset fleets it is integral to view them in a matrix structure, similar to matrix structures in organizational structures. Each asset belongs to a specific production line or a plant and it is important to look at them in this context, since they cannot be analyzed while neglecting the process they operate in. However, if there are many assets of the same type within a company, it is beneficial to look at them aggregated as a fleet.

Advanced Prognosis and Optimisation Technology The current state of the art asset management system is able to collect and process data remotely, but the actual decision-making or giving of recommendations how to operate the fleet is given by human experts. This is a bottleneck, because with increasing size of machines in a fleet the data becomes more complex. This fleet data forms a rich base for machine learning approaches in diagnostics of machinery and the prediction of failures. Based on this data, the remaining useful lifetime of an asset can be predicted more accurately. Furthermore, the condition of the equipment can also be assessed by evaluating the efficiency of the equipment compared to assets in the fleet of the same or similar type and process conditions. If the performance of a particular asset is decreasing, occurrences like fouling can be detected. All the outputs from the diagnostics part of the equipment must be fed back into the optimization part of the asset fleet management system. A holistic viewpoint is key to determine the best moments for maintenance, shifting more production load to equipment with a higher efficiency and to prolong the remaining lifetime of an equipment to bridge operation until a new window for maintenance actions opens. New problems may arise due to the size of the problem and improved algorithms and heuristics will be needed to solve this issue.

(De-)Centralized Management For comparable systems with assets at different locations there is usually a decision to be taken between the centralized and the de-centralized approach. While centralized approaches often involve intrinsic difficulties such as the effort for communication between machines and also the algorithms need to be more advanced to handle the complexity, de-centralized management on the other hand enables faster responses to dynamic conditions and has less communication requirements. Based on the existing structure in the process industry there is already a feed of information into one or multiple centralized information management systems. The actual controllers are in the plant itself and use the data obtained by the measurements. Out of safety reasons the lower control layers should remain in proximity to the assets. However, for higher control layers with a larger time-horizon a centralized management which is taking all available information in the fleet into account, is key.

5. CONCLUSION

This research presented a conceptual model for asset fleet management for the process industry. This was done by using the system analysis methodology of (Wilson, 2001). With this Soft Systems Methodology it was possible to target different stakeholders and user in a participatory approach and extract the expected requirements for a novel fleet management system. The collected ideas de-

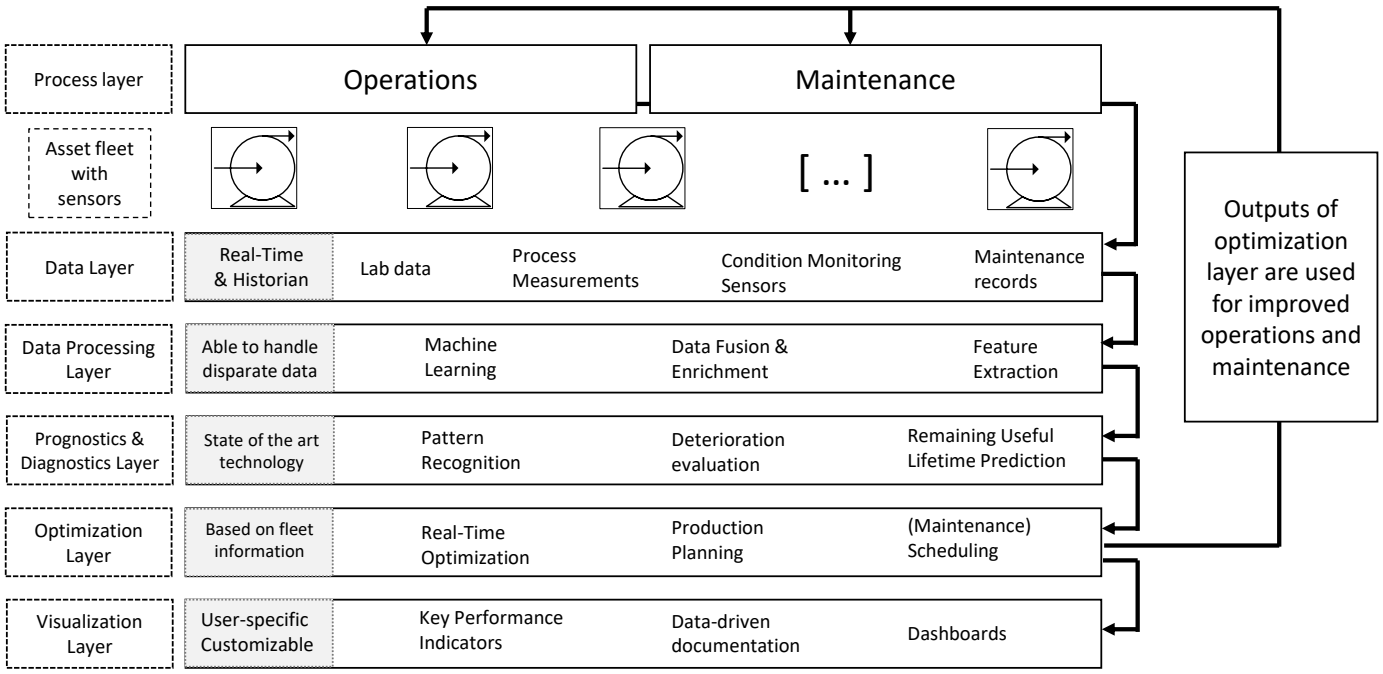

Fig. 3. Derived conceptual model for fleet asset management by utilizing data for optimization of operations and maintenance

mand a stronger view towards similar assets of a fleet. This includes the advanced usage of data from similar assets at different positions in the process and to make use of these information for the optimization of both operations and maintenance. The conceptual fleet management model is built upon the derived functionalities that include for example insights into performance of assets, predictions of their health status and solutions for the scheduling of maintenance over longer periods of time. Merging these functionalities into one functioning system for asset fleet management is just possible if several requirement and capabilities are fulfilled. This includes the robustness of the system while the computational speed must still comply with the current state of art. The system needs to be both adaptable and extendable. Practicality is important for the application in industrial settings and lastly heterogeneity is a prerequisite. The conceptual asset fleet management model focuses on three main elements, the fleet perspective, advanced prognosis and optimisation technology and the concept of centralized and decentralized management..

The developed model can be a blueprint for first implementations of an asset fleet management system. However, further developments in the field of machine learning, and machinery diagnostics and prognostics will give further input such that the mentioned improvement loop of the model will enable further development of this idea.

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