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Life Cycle Cost Model for Considering Fleet Utilization in Early Conceptual Design Phases

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Abstract

Cost prediction is commonly used when making decisions during the product development process. Oil and gas service companies must consider all life cycle costs for their business models. In addition to capital and operational expenditures, consideration of product utilization is essential. The cost of product failures, maintenance and repairs greatly impact the overall cost model. This paper describes an approach for simulating service availability and corresponding necessary fleet sizes based on existing life cycle cost models. A detailed case study presents the model viability and highlights key leverage points for cost reductions.

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Keywords: Life Cycle; Cost; Fleet size; Simulation; Service availability

1. Introduction

Oilfield service companies develop and manufacture technologies used for drilling and producing oil and gas. Typically, products are not sold; they are rented to customers as part of comprehensive service packages. Consequently, the companies are faced with operational costs to maintain, repair and transport products [1]. Over the entire life cycle of these technologies, operational costs are often many times greater than one-time capital expenditures. Project teams, therefore, must take all life cycle costs into account for a cost-efficient product. Life cycle costs are defined as “discounted cumulative total costs incurred by a specified function or item of equipment over its life cycle” [2].

Most costs are determined in the product’s design stage. It is challenging, and in some instances not possible, to influence costs at a later stage [3-5]. In addition, estimated costs derived in early development stages are often not precise. Companies use models to compare different concepts and identify cost drivers. Spreadsheet-based software has been developed [1]. In addition to capital and operational costs, consideration of product utilization is essential. The time of product nonuse dictates the fleet size (number of uniform products) for a specific service demand. Increasing product utilization and minimizing the fleet size offers significant life cycle cost-saving potential.

State-of-the-art fleet size calculations are used in several industrial sectors. At the end of the 1970s Walmsley [6] published a fleet-size model for inter-city services. The model calculated the predicted number of trains to fulfill the service demand of a city network. In 2001, Field et al. from MIT [7] used a series of mathematical derivations to demonstrate the need for a fleet-centered approach in life cycle assessment of products in general. Halvorsen-Weare et al. [8] developed a model to optimize the fleet size of vessels that maintain offshore wind farms. Various models in the airline [9], car [10] and railway industries [11] were also recently published. These models are mathematical based, which makes them difficult to set up, modify and explain. In addition, their range of application is specific to products in one particular industrial sector.

The challenging estimation of fleet sizes concurrent with the early development process is rarely described in literature. Maintenance, repairs and other downtimes as well as

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operating service information need to be considered. This paper describes an approach to simulate the fleet size for different designs during the early development phases of oil and gas technologies. On basis of the life cycle costing model, the design utilization is simulated using the logistic software "Tecnomatix Plant Simulation". To facilitate use and avoid manual input errors, an interface between the Microsoft Excel-based Life Cycle Costing (LCC) model [1] and Plant Simulation is created. A case study shows example simulations.

2. Approach

In addition to the information from the existing LCC model, simulated service availabilities intend to support decision-making within the development process. The availability of a product greatly affects its life cycle cost. If a product is not available, follow-up costs can occur [12]:

- Warranty charges
- Revenue loss
- Costs to provide an alternative

For a service company, which owns its products, warranty charges do not need to be considered. Nevertheless, warranty or sustaining efforts can lead to significant cost throughout the product's lifetime. In addition, meeting the demand for a product is assumed to be satisfied by a specific number of products (fleet size). To optimize cost, the fleet size must be as small as possible, yet large enough to perform all assigned jobs reliably.

When a product is in maintenance, repair or on transport, it is not available for services. This situation must be considered when planning the fleet size. Ultimately, the increased number of products represents the previously mentioned costs for providing an alternative. The fleet size depends on the availability of the product. If product availability is low, more products and thus a greater fleet size must be manufactured and maintained, which should be considered in all life cycle cost calculations.
Product availability is calculated using the total utilization ratio. This value, in contrast to technical availability, contains organizational downtimes (e.g., transports). The total utilization is the quotient of useful life and busy time [13].

$$\text{Total Utilization Ratio} = \frac{\text{Utilization time}}{\text{Occupied time}} \tag{1}$$

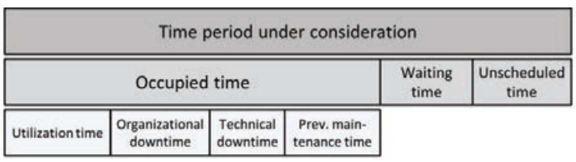

Fig. 1: Classification of different times in availability calculation [13]

The time period under consideration contains occupied, waiting, and unscheduled time. Occupied time includes all periods when the product is occupied, due to use or maintenance, or through organizational and technical downtimes. Against the background of the goal to minimize the fleet size, fully utilized products - without waiting and unscheduled times - can be assumed. The occupied (occ.) time results in the sum of utilization time, downtimes (downt.) and maintenance (maint.). The Total Utilization Ratio (TUR) can be expressed as follows:

$$\text{TUR} = \frac{\text{Occ. time - org. downt. - techn. downt. - prev. maint.}}{\text{Occ. time}} \tag{2}$$

The occupied time amounts 365 days per year. Maintenance and technical downtimes are deposited in the life cycle costing model. Organizational downtimes are considered via allowance values, e.g., for transports. As a result, all input quantities for the total utilization rate and the assimilated availability are determined.

3. Models

3.1. LCC Model

The life cycle costing model for drilling products (following named tools), introduced in 2014 [1], is an Excel-based spreadsheet with macros, programmed with Visual Basic for Applications. The model considers capital expenditures (CAPEX) as well as operational expenditures (OPEX), depicted in Fig. 2. CAPEX consists of the material cost of all parts in addition to assembly times. OPEX are divided into material, labor and third-party costs. Materials are differentiated as wear and consumable parts. Wear parts, which are mostly expensive components, are inspected during maintenance and are only replaced when necessary. In contrast, consumables such as O-rings and screws are replaced without inspection at a defined maintenance level. Labor cost is the product of working hours for maintenance and repair and the accordingly hourly rate. Third-party cost represents all repairs and inspections performed by external suppliers.

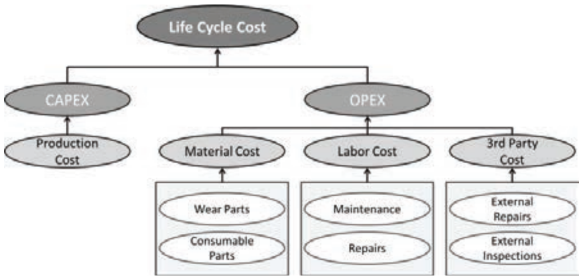

Fig. 2: Composition of cost in current model

All OPEX costs are normalized to hours of using the tool. For drilling services a common unit for lifetimes and maintenance intervals are circulation hours (CH). CH is the timeframe when the tool is in the well and drilling fluid is pumped through the system [1].

This approach makes cost estimations independent from changing market conditions. If operational costs would be