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Life cycle phases and design morphology for the implementation of a cooperative inventory pooling-system

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Abstract

Cooperative inventory pooling-systems are a promising solution for increased efficiency in spare parts management by reducing necessary inventory levels and costs. However, there is no methodical approach to enable interested companies to realize the advantages. No required modules and necessary tasks in the life cycle of the cooperation are specified. In this contribution, a specific life cycle model for a cooperative inventory pooling-system is presented. Necessary tasks and modules are described for each phase. We identified three inventory-pooling specific sub phases that are essential for the final implementation of the cooperation. Furthermore, we developed a morphology for the design of the cooperative inventory pooling-system, which provides a framework to describe the cooperation in its structural elements. The method and the framework introduced in this paper allow a structured and systematical implementation of cooperative inventory pooling-systems.

Keywords: spare parts management, cooperative inventory pooling, life cycle phases, cooperation design

1. Introduction

In almost every industrial sector, companies face increased cost pressure. A high availability of machines and technical systems with reduced downtimes in production, distribution and transportation is necessary to ensure efficient value creation and provision of services. The stockpiling of capital-intensive spare parts is therefore required, or service contracts have to be concluded with vendors. However, since the majority of spare parts face a sporadic, unpredictable and varying demand, both approaches cause high costs in spare parts management [1]. For example,

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only the warehousing of essential spare parts annually costs up to 2.5 % of the purchase price of a system [2]. A cooperative inventory pooling-system is one promising concept for improved efficiency in spare parts management.

Examples are found especially in the aviation industry due to its special characteristics [3]. However, a methodical consideration and classification of cooperative inventory pooling-systems in the life cycle of cooperation is missing and the implementation of such a cooperation is challenging without a methodical classification as a framework.

This contribution therefore describes a life cycle model for a cooperative inventory pooling-system with its specifications and phases. Furthermore, required modules and components are identified and derived to describe their use within the cooperation phases and a morphology for the design of the cooperation is presented.

2. Literature Review

Corporate cooperation describes a form of structured collaboration between companies to jointly achieve individual tasks and goals and increases in importance due to globalization [4, 5]. Possible advantages include reduced development, purchasing, production and service costs [6]. For this, selected business processes are adjusted and coordinated so that significant increases in efficiency and effectiveness can be achieved [7]. Each corparate cooperation can be classified with the following basic characteristics: direction, expansion, binding intensity, commitment, duration, target identity and cooperating divisions [8].

In the literature, different phases are identified and assigned to the life cycle of cooperation and phase models are derived accordingly [9]. Parise and Sassen define three major phases, where each phase requires different skills for successful implementation of the cooperation [10]. First, potential cooperation partners need to be detected, evaluated and selected in the Find phase. The second Design phase aims to structure the cooperation and sets strategic objectives. In the final Manage phase, the companies develop an effective operational framework with the cooperation partners to facilitate the completion of the agreed objectives.

Höbig and Zentes et al. define several phases as a basis for their model [5, 11]. With their approaches, a Decision about objectives and motivation of the cooperation is first needed. The second phase is the Partner Selection phase, where suitable companies are identified. Subsequently, the cooperation must be structured in the Design phase where the companies conduct negotiations. In the Operation phase, the business processes are coordinated between the companies and the achievement of objectives is evaluated. Zentes at al. consider changes and improvements as an ongoing process of the operational phase [5], whereas Höbig defines a separate Improvement phase for these actions [11]. Cooperation is often attributed a temporary character, which is why Termination and Dissolution must be considered as an independent phase.

Pooling of spare parts is a promising application field for cooperation and is frequently discussed in literature, focusing mainly on the determination of possible cost advantages and their allocation. Examples include Wang et al. and Karsten et al. [12, 13]. Wang et al. develop an inventory pooling model with a unified cost function to determine occurring costs for spare parts of critical systems [13], whereas Karsten et al. develop a set of cost allocation rules proportional to the companies' demands, which satisfy the cooperation requirements, stimulate the growth of the cooperation and are easily implemented in practice [12].

A first methodical consideration of the categorization and systematic classification of cooperative inventory pooling-systems is given in Kilpi et al. [14]. This defines cooperation types of different intensity and commitment on the basis of related airlines with similar aircraft models and thus comparable and repairable spare parts. In conclusion, this identifies and discusses three different models: the Ad Hoc Cooperation, Cooperative Pooling and Commercial Pooling. Ad Hoc Cooperation consists of two companies with a trustful relationship and without contractually agreed conditions. If necessary, the companies obtain the required spare part from the partner for a dedicated fee. With this loose form of cooperation, an initial coordination of the shared spare parts inventories can already be carried out in order to reduce individual inventories. In Cooperative Pooling, at least two companies agree on some contractual cooperation rules. These rules include, for example, reaction times in case of a spare part demand, restocking of the joint spare parts inventory with new spare parts and inventory distribution between the companies. Compared to the two previous types that were based on a partnership, Commercial Pooling is entirely market-based. Two or more companies sign a contract with an external company, which takes on the role of cooperation platform. This contract

usually includes the terms and conditions of cooperative pooling, but will be extended by such points as service fees or liability details in case of delivery delays.

The literature mentioned above shows the presence of different phase models for the life cycle of cooperation. Within each model, several phases and general actions that have to take place within these phases are identified and described. Furthermore, Kilpi et al. categorize cooperative inventory pooling-systems in the aviation industry [14]. However, a fundamental methodical consideration and classification of cooperative inventory pooling-systems in the life cycle of cooperation is in general missing. There is no specification of the life cycle phases for spare parts cooperation with a clear description of the actions required to realize the potential benefits.

In this contribution, we introduce a method with necessary life cycle phases for the implementation of a cooperative inventory pooling-system to satisfy the identified need for action. Required tasks in the different phases as well as needed components, modules and methods are derived and explained. Furthermore, a morphology for the design of the cooperative inventory pooling-system is presented.

3. Life cycle phases for the implementation of a cooperative inventory pooling-system

The considered cooperative inventory pooling-system consists of n different companies, each with their own initial spare parts inventory. In our presented method, we describe necessary life cycle phases for implementation of such a system. The method is based on the life cycle phases of Höbig and Zentes et al. [5, 11], considering only the phases up to successful implementation of the cooperative inventory pooling-system (Figure 1).

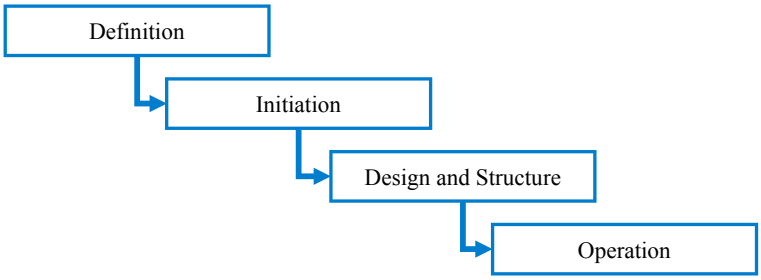

Fig. 1. Required life cycle phases.

In the following, necessary tasks and modules to implement a cooperative inventory pooling-system are described for the individual life cycle phases, wherein modules represent required tools for the realization of the tasks. Subsequently, the methods presented allow the development of the individual modules.

3.1. Phase 1: Definition

The Definition phase aims to specify the idea of the cooperation and the expected value for the cooperating companies, so that the basic scope of the cooperation is defined. In the given situation of a cooperative inventory pooling-system, the aim is to increase efficiency in spare parts management. Required inventories should be reduced while ensuring the same service level, thus reducing the amount of capital commitment for each company. Fundamental requirements for the cooperation have to be identified and defined. The evaluation of the basic aptitude of a cooperative inventory pooling-system to achieve the defined objectives is carried out using a provided checklist. This checklist helps the initiating company to check whether the general requirements are fulfilled in its own company (e.g. operation of an independent spare parts management) and in the market (e.g. availability of companies with comparable technical systems). If the check is positive, phase one is completed.

Table 1 summarizes the tasks and corresponding modules provided for potential interested companies for execution of these tasks and the applied methods for the development of the required modules in the first phase.

Table 1. Specifications of the Definition Phase.

Phase 1: Definition	
Tasks	Specify basic scope of the cooperation
	Evaluate basic aptitude of a cooperative inventory pooling-system
Modules	Basic Aptitude Examination
Methods	Surveys of Experts
	Literature Research

3.2. Phase 2: Initiation

The second phase is Initiation. Appropriate partners must be identified on the basis of the defined cooperation goals and derived requirements as well as competency profiles. A well-defined evaluation framework is essential for the selection of potential partners. We recommend a two-stage procedure: First, interested companies need to check their basic qualification (e.g. operation of an own warehouse for the stocking of spare parts and ability to implement changes in spare parts management) using a quick checklist. The first check can be carried out at little effort without providing detailed data. If the check is positive, the specific qualification will be evaluated on the basis of provided company information and spare parts data (e.g. demand and prices of spare parts). The result is an economic assessment of the appropriateness of the potential company. For this, we provide modules for the analysis of spare parts inventories for the cooperative inventory pooling-systems and the evaluation of economic aspects. The analysis of the spare parts inventories is fundamental and is the input for the economic assessment. A detailed description and first results of this module can be found in Hafner et al. [15].

A compilation of the tasks to be performed, required modules and corresponding methods for the modules are shown in Table 2.

Table 2. Specifications of the Initiation Phase.

Phase 2: Initiation	
Tasks	Identify appropriate cooperation partners
Modules	Basic Aptitude Examination
	Inventory Level Analysis
	Economic Assessment
Methods	Surveys of Experts
	Literature Research
	Discrete Event Simulation
	Process-Oriented Cost Accounting

3.3. Phase 3: Design and Structure

The third phase describes the Design and Structure of the cooperation. In this phase, a detailed structure must be defined and processes have to be designed. The resources of the companies (e.g. personnel and IT systems) need to be linked to the processes. Necessary operational processes (e.g. ordering of spare parts in case of need and ongoing servicing of the cooperation) are described in Fottner et al. [16]. In addition to this, however, the basic design of the cooperative inventory pooling-system is particularly important. We therefore present a morphology for the design of the cooperation in this contribution. As result of phase one and two, a basic analysis of the aptitude and an economic assessment of cooperative inventory pooling-systems are performed. Based on this, a specific incentive system is developed and guidelines are defined in this phase.

In Table 3 the tasks, required modules and methods for the third phase are summarized.

Table 3. Specifications of the Design and Structure Phase.

Phase 3: Design and Structure	
Tasks	Design the structure and define processes of the cooperation
Modules	Cooperation Design
	Process Framework
	Incentive System
Methods	Surveys of Experts
	Literature Research
	Event-driven Process Chains
	Methodical and Organizational Incentive System Design

3.4. Phase 4: Operation

At completion of the third phase, the cooperation enters the intended phase of Operation. After the previous three phases of implementation, the cooperation is now in a phase of operational relevance in which the defined and projected services are provided. There is a continuing need to assess the economic evaluation of the cooperative inventory pooling-system and to analyze the necessary cooperative inventory levels.

Table 4 summarizes required tasks, modules and methods in phase four.

Table 4. Specifications of the Operation Phase.

Phase 4: Operation	
Tasks	Implement structure and monitor status of the cooperation
Modules	Inventory Level Analysis
	Economic Assessment
Methods	Discrete Event Simulation
	Process-Oriented Cost Accounting

However, the discussed cooperative inventory pooling-system has the particularity that the defined objective in the operating phase is reached with a delay. Because of already existing spare parts inventories of the cooperating companies, the optimal status is not achieved immediately. In order to respond to the different operating points, we divide this phase into three sub phases.

3.4.1. Operation Phase I: Spare Parts Supply from Initial Inventory

In the first operation phase of the cooperation, companies normally have their own inventory of spare parts, which they have acquired in advance in individual conditions. The inventories of appropriate spare parts are pooled virtually, with each spare part being assigned to one dedicated company. At this stage, the ownership structure is clearly defined: The spare parts are property of the company that has acquired them beforehand.

Figure 2 (a) illustrates the situation with three exemplary companies that will cooperatively stock three spare parts (SP1, SP2 and SP3) in the future. For each spare part, the optimal inventory level for the cooperation was calculated with the Inventory Level Analysis module, but, as mentioned, this is still exceeded.

There are generally just a few transactions between the companies, since each company can use their initial inventory. If a company is no longer able to cover its spare parts demand from its own initial inventory, it has to purchase a spare part from a cooperation partner.

In Operation Phase I there is no monetary benefit for the companies from joining the cooperation, but additional costs arise. On the one hand, the spare parts demand will be mainly supplied from the companies' own initial

inventories as before. On the other hand, the companies already incur costs specific to the cooperation (e.g. service costs, personnel costs, etc.).

3.4.2. Operation Phase II: Mixed Spare Parts Inventory

As soon as the number of spare parts of a certain type decreases below the calculated optimal inventory level, a new spare part of the same type has to be purchased to ensure the required service level. Depending on the financing concept, the new spare part is financed by one or more members of the cooperation. With the acquisition of the first spare part and the realization of the optimal spare part inventory level for this specific part, the cooperation enters Operation Phase II. This phase is characterized with a mixed spare parts inventory. Some spare parts have already been jointly reordered and have reached their targeted optimal inventory level, while other spare parts are still supplied from the cooperation partners' initial spare parts inventories.

The inventory levels for our exemplary cooperative inventory pooling-system are shown in Figure 2 (b). Compared to the first operation phase, the inventory levels for all three parts have been reduced. Moreover, spare part SP1 has already been jointly reordered one time and has reached its optimal inventory level.

The reordered spare part and the respective spare part to be purchased in case of demand are allocated to the companies based on defined strategies. Depending on which spare part is assigned to a company, different types of payments are required.

3.4.3. Operation Phase III: Optimized Cooperative Spare Parts Inventory

The cooperation will reach Operation Phase III as soon as all spare parts initially acquired by each company in individual conditions have been used up. This phase is typified by two optimizations: First, all pooled spare parts were purchased during the cooperation with improved purchasing conditions. Moreover, the number of spare parts in stock for each part corresponds to the calculated optimal economic inventory levels (Figure 2 (c)).

In this phase, the fundamental structure and financing concept of the cooperation is finally implemented completely. This allows each individual company to fully benefit from the advantages of the cooperation. The jointly reduced inventory levels of spare parts significantly reduces the capital commitment of each company. In addition, the companies benefit from procurement advantages due to the increased volume and market power factor of the cooperative inventory pooling-system.

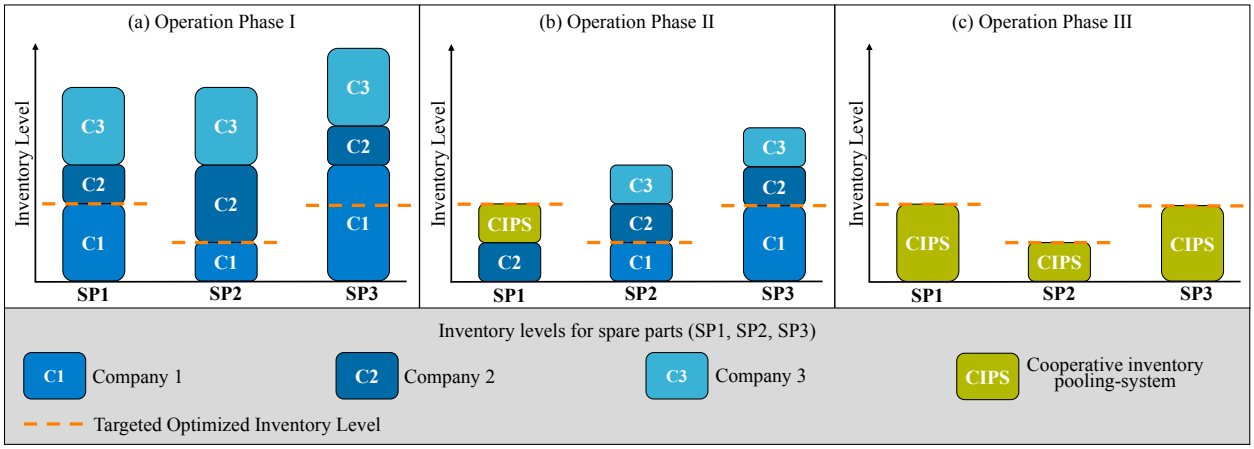

Fig. 2. (a) Inventory levels in Operation Phase I; (b) Inventory levels in Operation Phase II; (c) Inventory levels in Operation Phase III

4. Morphology for the design of the cooperation

For the design of the cooperation and as basis for the incentive system (Phase 3), a morphology with the relevant structural characteristics and the corresponding alternatives is developed (Figure 5).

Financing Method for Spare Parts	Single Company	Jointly on Basis of Demand	Jointly by Number of Companies
Spare Parts Price	Price of Assigned Specific Spare Part	Average Spare Part Price	
Prioritization of Spare Parts	FCFS	Minimization of Transport Distances	Prioritized FCFS
Increased SP Costs or reduced Revenues	Allocation to Service Fee	No Compensation	
Service Fee	Based on Specific Spare Parts Demand	Averaged by Number of Companies	Surcharge on Spare Parts Price
Warehousing and Opportunity Costs	Reduced Service Fee	Compensation on Sale	No Compensation

Fig. 3. Morphology for the design of the cooperation.

First, the Financing Method for the Spare Parts has to be defined. These can be financed by a single company, jointly on the basis of demand or jointly by the number of cooperating companies. If the spare parts are financed by a single company, a circulating system is required to ensure that the individual companies contribute equally to the advance payment.

A key structuring characteristic is the Spare Parts Price to be charged. It is likely that the spare parts stocked within the cooperative inventory pooling-system were purchased at different prices, since prices vary over time. One option is to pay the price of the assigned specific spare part. Alternatively, the average spare part price of each spare part is charged.

Directly linked to the spare parts price is the Prioritization of Spare Parts. This characteristic determines which spare part is assigned in case of demand. One possibility is to assign the spare part on a first-come, first-served (FCFS) basis. This prevents the spare parts from over-ageing, but may result in additional deliveries. Another possibility is the minimization of necessary transport distances. In this case, the spare part is primarily taken from the company's own inventory, otherwise it is delivered from the geographically nearest company. Alternatively, a mixed version of a prioritized first come, first served can be agreed. Spare parts are primarily taken from the own inventory. If this is not possible, the first come, first served principle is applied. Additionally, age thresholds can be defined for individual spare parts, which must be considered first.

If an average spare parts price is agreed, individual companies may have increased Spare Parts Costs or reduced Revenues, which may or may not be compensated by allocating these costs to the service fee of the cooperative inventory pooling-system.

The Service Fee for the platform can be calculated periodically on the basis of the individual spare parts demand or averaged on the number of cooperating companies. Furthermore, it is possible to pay the service fee as a surcharge on the spare part price. Here, a company pays the price for the spare part and the partial service fees to the financing company or companies. This method differs from the other variants, since the service fee is paid directly when the necessary spare part is ordered and not in advance or afterwards.

Finally, a potential compensation of Warehousing and Opportunity Costs must be agreed. Depending on the financing and storage location of the spare parts, the costs vary from company to company. These costs can be compensated by a reduced service fee or by reimbursement when the spare part is sold. If spare parts are evenly distributed among the individual companies, it seems reasonable not to compensate for these costs, since they will compensate themselves.

5. Conclusion and outlook

A cooperative inventory pooling-system is a promising method to reduce necessary costs in spare parts management. However, these advantages are not achieved directly and required phases and actions are unclear.

The state of science and technology shows appropriate models for describing life cycle phases of cooperation in general, but there is no methodical support and adaptation of the necessary phases for the implementation of a cooperative inventory pooling-system. Though, it is essential to show companies how the advantages of this specific cooperation can be realized.

The method we presented offers companies required support and tools in the identified and described life cycle phases to successfully implement a cooperative inventory pooling-system. Requirements and essential tasks in the individual life cycle phases are presented and explained transparently. The method illustrates how the potential positive effects of the spare parts cooperation can be realized. We identified three specific sub phases in the operational phase of the cooperation and their characteristics.

The presented morphology for the design of the cooperative inventory pooling-system provides a framework to describe the cooperation in its structural elements and lists possible alternatives with which companies are able to structure their specific cooperation.

In further scientific research, the required pending modules need to be developed to give interested companies the opportunity to implement a cooperative inventory pooling-system based on the presented method. Representative forms of cooperation have to be defined and trust problems among individual cooperation partners must be addressed, which may be reduced by using new technologies which arize with the concept of Logistics 4.0 (e.g. blockchain).

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