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Cooperative maintenance for small and medium-sized enterprises (SMEs)

A concept for new organizational forms of maintenance

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Abstract

Operational maintenance is responsible for ensuring the availability and reliable functioning and performance of technical units as required for specific operations. Not all companies recognize this connection. Particularly in the case of micro, small and medium-sized enterprises (SMEs), often little attention is paid to operational maintenance. Neglect of the technical units is accepted, which puts SMEs in a disadvantageous position compared to large companies.

The discussion of these problems and the consideration of organizational-structural aspects lead to new forms of partnership cooperation in the field of operational maintenance in SMEs. A "horizontal maintenance cooperation" for the bundling of maintenance resources in a network of companies represents a possible solution approach and contains great potential for SMEs compared to the usual approaches of in-house and external maintenance. This can be impressively demonstrated by means of practical case studies and simulations of different scenarios of planned and unplanned maintenance - the results are clear.

The joint maintenance within the framework of a horizontal maintenance cooperation of companies opens up completely new possibilities for the operational maintenance of SMEs. It is an important step on the way to responsible and professional maintenance management.

Key words

maintenance management;
in-house maintenance;
outsourced maintenance;
supplier maintenance;
maintenance resources;
maintenance assets;
cooperation based on partnership;
network;
small-to-mid-sized firms;
cooperative maintenance;
horizontal maintenance cooperation;
group maintenance;
maintenance costs;

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1. Introduction

The globalization of markets and the resulting increase in competition from abroad have changed the market conditions for many companies. Constantly increasing customer expectations with higher individualization, shorter delivery times and a tendency towards a decline in the previous markets are causing growing cost pressure. Increased just-in-time deliveries, continuous shortening of lead times, rising complexity and increasing automation of already capital-intensive technical units, as well as further extending operating times and continuous reduction of material stocks and deadline reserves, put an additional strain on the already highly stressed companies. The targeted selection of a suitable corporate strategy is therefore essential. At the same time, the development of innovative products and services as well as a continuous increase in productivity through the use of state-of-the-art technologies and a constant improvement in quality are required.

In view of the situation described above, always available and highly efficient technical units have taken on a new significance for many production, trade and service companies in a wide range of industries. Unexpected disruptions or failures of particularly important technical units are therefore imperative to avoid. Unfortunately, however, important technical units are often operated at their performance limits, especially in SMEs. It is not uncommon for this to result in interruptions that can even lead to a breakdown of the entire service provision process. Increased bottlenecks in value creation are the result. Apparent reserve capacities are often misjudged and possible consequences are not considered.

In this context, operational maintenance plays a "key role". As an integral cross-sectional function, it plays a decisive role in determining the competitiveness and thus the future of a company. Nevertheless, little attention is paid to operational maintenance, especially in SMEs. In many cases, it is downright neglected. The actual potential of operational maintenance is not recognized. Frequently, however, the necessary maintenance assets are also lacking, although professional and responsible maintenance also offers many advantages for SMEs.

2. Determination of maintenance

Maintenance[13] contributes to the preservation and restoration of the TARGET condition as well as to the determination and assessment of the ACTUAL condition during the entire life cycle of technical units. In this context, maintenance is intended to ensure the operationally required availability and reliable functioning and performance of the technical units at costs that are as economically justifiable as possible.

2.1. Maintenance in practice

Maintenance as a whole represents a very complex and ever-changing subject area with different circumstances. This is true because every single application of maintenance is individual and based on numerous different criteria and characteristics. Maintenance theory does not differentiate between companies according to their size or the industry they belong to, but always assumes the ideal situation with sufficient maintenance assets[14] and, regardless of this, only offers appropriate solutions for certain companies. In practice, however, specific maintenance solutions are required, especially depending on the size of the company.

- In large companies, the maintenance of technical units is carried out as part of an overall organizational concept for performing operational tasks. The organizational structure includes the organizational structure and process organization of maintenance. For the formation of organizational units, sufficient personnel maintenance resources with the corresponding responsibilities are usually available. The process organization of maintenance for the coordination and execution of all maintenance activities is predominantly carried out by the company's own maintenance employees according to a clearly structured spatial and temporal order. In addition to in-house maintenance[15], third-party companies are also used to compensate for certain capacity bottlenecks by means of outsourcing (third-party maintenance[16]), to achieve a rapid return to the service provision process in the case of technical units with a high degree of automation and complexity, or to achieve a reduction in costs. For this purpose, entire service packages are usually agreed and outsourced.
- In large companies, the systematic linking of appropriate maintenance elements and the use of advanced technologies ensure the availability required for specific operations and the reliable functioning and performance of the technical units. In addition, the use of specially formulated and adapted maintenance concepts results in fewer malfunctions and failures of the technical

[13] Maintenance - defined as a "combination of all technical and administrative measures as well as management measures during the life cycle of a unit of consideration to maintain its functional state or return it to this state so that it can fulfill the required function" [DIN 31051, 2003, p. 3]. A unit of consideration is "... any part, component, device, subsystem, functional unit, equipment or system that can be considered on its own ..." [DIN 31051, 2003, p. 5] and thus forms the actual maintenance object.

[14] Maintenance assets - Maintenance assets are understood to mean sufficient personnel and technical maintenance resources (this mainly refers to personnel capacities with the appropriate expertise and necessary qualifications, but also special tools, operating and auxiliary resources, as well as spare parts, etc.) to be able to carry out maintenance tasks professionally at any time.

[15] In-house maintenance - refers to the performance of maintenance activities as long as the maintenance activities are performed by the operating company's own employees of the technical units. These can be production employees and operators of the technical units to be maintained as well as the employees of the company's own maintenance department - provided that there is a company's own maintenance department.

[16] Third-party maintenance - refers to the performance of maintenance measures by maintenance personnel from outside the company for maintenance services. Maintenance can be carried out by employees of the manufacturer of a technical unit, specialized maintenance service providers, local craftsmen or outsourced maintenance departments of the operating company [see Bloß, 1995, pp. 126-129], [see Matyas and Brunner, 2005, pp. 141-147].

units and in lower indirect maintenance costs[17] in addition to the direct maintenance costs[18]. The necessary financial resources are budgeted in advance and used for the maintenance of the technical units.

- In large companies, operational maintenance makes a significant contribution to value creation. Maintenance is strongly oriented towards maintenance theory and represents an integral cross-sectional function in the company. This leads to a continuous development of the human and technical maintenance resources, which results in a positive development of the operational maintenance and thus fully meets the essential expectations of the companies.
- Medium-sized companies generally have a less distinctive organizational structure for carrying out operational tasks. Nevertheless, a division of tasks is possible, so that the organizational structure and process organization of maintenance is nevertheless carried out according to the general basic organizational structure forms. In-house maintenance employees also form organizational units which, within the framework of an existing process organization, are responsible for the coordination and completion of all maintenance activities according to a clearly structured spatial and temporal order. In parallel, medium-sized companies also use third-party companies for maintenance tasks if special expertise and appropriate qualifications are required or if this can compensate for a lack of personnel capacity to return the technical units to the service production process more quickly.
- Increasingly systematic planning and more precise coordination of maintenance measures, together with greater use of advanced technologies, will make it possible to better ensure the availability and reliable functioning and performance of the technical units required for specific operations. The necessary financial resources are largely planned for this purpose and spent on the maintenance of the technical units as required.
- The increasing requirements lead to an increase in the importance of maintenance for medium-sized companies. The contribution of operational maintenance to the creation of value is therefore increasingly recognized, but in addition to the lack of personnel maintenance resources, the training and continuing education of maintenance employees represents a weak point. Furthermore, maintenance services provided by third-party companies incur significantly higher direct maintenance costs due to higher hourly billing rates. In conjunction with their longer response times and the additional effort often required, this has a noticeable effect on indirect maintenance costs. In most cases, therefore, only temporary outsourcing of specific, definable maintenance tasks takes place. As a result, the essential expectations of companies with regard to professional and responsible maintenance are only partially met.
- Micro and small enterprises often do not have an overall organizational concept for carrying out operational tasks. Rather, they are characterized by the fact that various operational functions are performed by one and the same employee. An organizational structure with clearly defined goals, which also includes the organizational structure and process organization of maintenance, is therefore usually not in place. Due to a few specific individual tasks, a division of tasks is uneconomical or not possible for personnel reasons. In terms of operational maintenance, there is therefore often a lack of in-house maintenance personnel, so that the main share of maintenance tasks is borne by production employees and operators of the technical units.
- Despite the integration of maintenance tasks, it is always necessary to outsource maintenance services to third-party companies in addition to autonomous maintenance. As a result, maintenance-related tasks are distributed among those actors who can compensate for the lack of maintenance capability and who can perform maintenance activities in a timely manner and in line with requirements as far as possible. However, the long response times and significantly higher hourly billing rates of the third-party companies that are often associated with this are a great burden on the companies. Coordination and a systematic approach to maintenance execution as well as the use of advanced technologies also overburden companies. This circumstance leads to the fact that neither a systematic procedure nor advanced technologies are used, the operating times are extended again and again and the enterprises reduce the employment of third-party enterprises often for cost reasons. The outsourcing of

[17] Indirect maintenance costs - are those costs whose effects have a negative impact on the company's success and whose causes lie in malfunctions or failures of technical units. A distinction is made between downtime costs, which represent a significant proportion of the failure costs [cf. Lauenstein et al., 1993, p. 129], and contribution margin losses as a result of revenue losses, which account for a large proportion of the consequential failure costs [cf. Bloß, 1995, p. 73].

[18] Direct maintenance costs - divided into costs for planned measures with a preventive effect and costs for planned and unplanned measures to eliminate malfunctions or failures.

maintenance services to third-party companies therefore only occurs in special cases, so that responsible maintenance is not always guaranteed and monetary values are destroyed. In terms of the technical units used, this means that in many companies the availability required for specific operations and reliable functionality and performance are not always ensured, yet high maintenance costs are still incurred. It is not uncommon for maintenance measures that are not carried out or are carried out incorrectly to cause major damage that can even threaten the existence of micro-enterprises and small companies in particular. In the case of micro-enterprises and small companies, therefore, the essential expectations of operational maintenance are not met.

- The ever-increasing workload and the permanently changing market conditions force companies to continuously face the competition. Large companies and some medium-sized enterprises cope very well with these challenges. However, micro, small and many medium-sized companies are coping poorly. They concentrate on their core business and its main business processes, but neglect important secondary business processes such as maintenance. For this reason, maintenance is carried out at a very low level in a not insignificant number of these companies. The state of operational maintenance there resembles a "maintenance desert".

Figure 1: Maintenance desert at SMEs (Source: Own representation)

2.2. Conclusion

The determination of maintenance shows that for the large companies and part of the medium-sized companies, the practical implementation of maintenance is neither a strategic nor an organizational problem. The remaining SMEs, however, have major problems with the practical implementation of maintenance. For structural and financial reasons, the maintenance organization of many SMEs is often unable to meet the demands placed on it. The frequently insufficient maintenance assets and the specific maintenance solutions that are usually necessary in practice often overtax the companies - a targeted implementation of maintenance is therefore not possible. Maintenance theory does not address this problem and therefore does not offer appropriate solutions for these cases. Depending on requirements, the missing maintenance resources must therefore be procured externally from third-party companies. This approach often results in lower availability of the technical units and higher maintenance costs for the companies.

The knowledge gained with regard to operational maintenance now necessitates considerations in order to find a suitable way for SMEs to maintain their technical units. Cooperation in partnership with other companies plays an important role here. However, the possibilities of cooperation are only partially used for operational maintenance. Therefore, a more detailed examination of the "partnership cooperation of companies" is necessary in order to find an adequate solution with regard to maintenance at SMEs.

3. Partnership cooperation

Collaboration between companies on a partnership basis opens up a wide range of opportunities for increasing effectiveness and efficiency in the most diverse areas of value creation. It does not matter whether the companies are manufacturing, trading or service companies. It is also irrelevant whether the companies cooperate within one industry or whether they operate across industries.

However, there are no concrete indications in theory with regard to the cooperative collaboration of companies for the purpose of operational

maintenance. The fact that operational maintenance is nevertheless the subject of cooperative relationships and that this plays a major role for companies in operational practice is not mentioned in this context.

Therefore, it is necessary to identify different approaches based on cooperative maintenance using general criteria and characteristics of maintenance, cooperation[19] and networks[20], which also includes a possible solution as a suitable approach for the operational maintenance of technical units at SMEs.

3.1. Cooperative maintenance

Cooperative maintenance refers to the partnership-based cooperation in operational maintenance, regardless of the actors and the intensity of the corresponding cooperative relationships. As a rule, cooperation takes place with the manufacturers of the technical units and with maintenance service providers. In individual cases, these can also be local craft enterprises or outsourced maintenance divisions of companies.

The general criteria and characteristics are thereby "specially" adapted to the cooperative collaboration in operational maintenance, so that the structural foundations of cooperative maintenance are created and, in turn, various approaches to cooperative maintenance can be derived from this. Fig. 5 shows the general basic scheme of cooperative maintenance.

3.1.1. Complementary maintenance cooperation

Complementary maintenance cooperation[21] refers to an approach of cooperative maintenance with third-party companies for maintenance services [cf. Fröhner et al., 2004, pp. 74-79].

The definition of maintenance has shown that complementary maintenance cooperation in particular represents the current situation in practice and is therefore a common approach to the maintenance of technical units. There are gradations here in the proportion of outsourcing of individual maintenance tasks up to complete outsourcing of maintenance.

Fig. 6 shows the specific basic scheme of a complementary maintenance cooperation through the highlighted criteria characteristics.

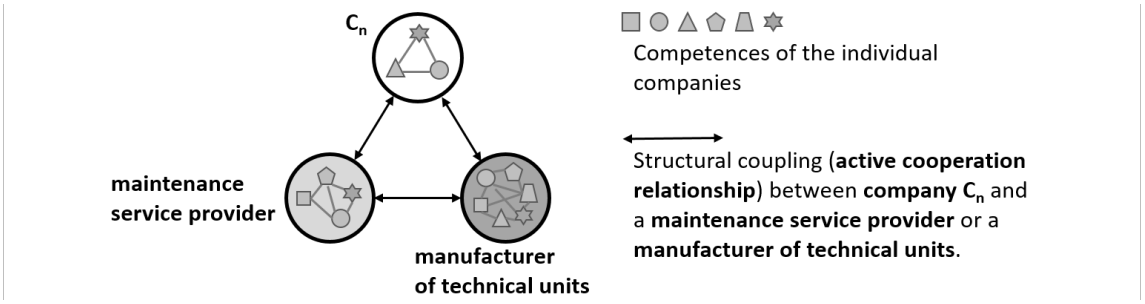

Figure 2: General basic structure of complementary maintenance cooperation (Source: Own representation)

3.1.2 Cooperative maintenance network

[19] Cooperation - is generally used to describe any form of collaboration [cf. Gräber-Seißinger, 2008, p. 341]. The often very diverse arrangements between two or more actors (cooperation partners) are usually associated with positive attributes and thereby presuppose coordinated action, interaction and cooperation [cf. Wojda et al., 2006, p. 5]. Cooperation thus represents an effective means of increasing potential opportunities while at the same time distributing or mitigating risks.

[20] Network - is in the extended sense a system whose underlying structure can be modeled as a mathematical graph. The graph is composed of a set of elements (nodes - points, positions), which are coupled with each other by means of connections (edges - lines, relations). A closed train of nodes and edges is called a "mesh" [cf. Payer, 2008, p. 5]. In a narrower sense, networks usually emerge on the basis of cooperation. Thus, networks, starting from individual (partial) cooperations, usually represent a higher level of partnership cooperation. For this reason, largely the same characteristics apply to networks as to cooperations: individual benefit, reciprocity, strength orientation and partial coupling [cf. Payer, 2008, p. 13].

[21] Komplementär - complementary - from franz. complémentaire - engl. personally, liable partner - mutually complementary; here: Refers to the relationship between partners that are both mutually dependent and mutually exclusive, for example, manufacturer and operator of a technical unit. However, complementary maintenance cooperation is not to be treated as a focal point here. Reference is made to [Fröhner et al., 2004], which deals exclusively with complementary maintenance cooperation. Thereby it is explained how the activities of maintenance can be divided among the manufacturers of technical units, maintenance service providers, logistics service providers and the operators of technical units. In addition, the mentioned work deals with the information, material and financial flow between the individual cooperation partners. Unfortunately, the work is no longer up to date, as individual subsections have meanwhile become obsolete due to the increasing spread of multimedia communication structures. Nevertheless, it provides a good overview of complementary maintenance cooperations.

A cooperative maintenance network also characterizes the partnership-based cooperation of companies in the field of maintenance. For this purpose, maintenance employees from regionally located companies meet regularly for (maintenance) meetings and exchange information on maintenance-related topics [cf. Weißenbach, 2009, p. 21].

In a cooperative maintenance network, the main focus is on getting to know potential partners for closer partnership cooperation and the exchange of information. The coming together takes place through regular meetings in the different companies of the network. At these meetings, the representatives of the individual companies have the opportunity to discuss various aspects of maintenance, to present their own maintenance and to critically question it with their professional colleagues. In informal discussions and through organized presentations, news and experiences are exchanged or various suggestions for improving one's own maintenance are collected. It seems to make sense if such network meetings are prepared and guided by an moderator. The moderator sets the dates for the meetings in agreement with the participating companies and issues public invitations [cf. Weißenbach, 2009, pp. 21-22].

In Fig. 7, the specific basic scheme of a cooperative maintenance network is represented by the highlighted criteria characteristics.

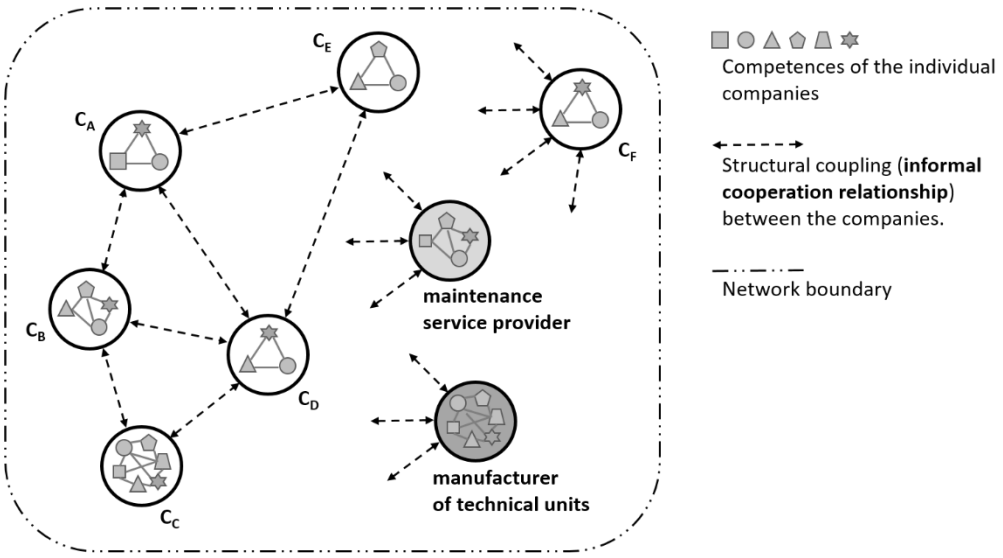

Fig. 3: General basic structure of a cooperative maintenance network (Source: Own representation)

3.1.3 Solution approach: Horizontal maintenance cooperation

Horizontal maintenance cooperation refers to the "bundling of maintenance resources through partnership-based cooperation in a horizontal orientation of two or more legally and economically independent companies in the local environment for the purpose of joint and cross-company maintenance of technical units" and also represents an approach to cooperative maintenance.

Several companies in a local environment with similar technical units pool their maintenance resources and expertise and organize maintenance jointly within a defined framework. This means that a cross-company group of experts, consisting of maintenance staff from the cooperating companies, forms an operational network and ensures the availability and reliable functioning and performance of the technical units of all partners involved. This eliminates the need for cost-intensive outsourcing of maintenance services from third-party companies, which is then only necessary in special cases [cf. Weißenbach, 2007a, p. 11].

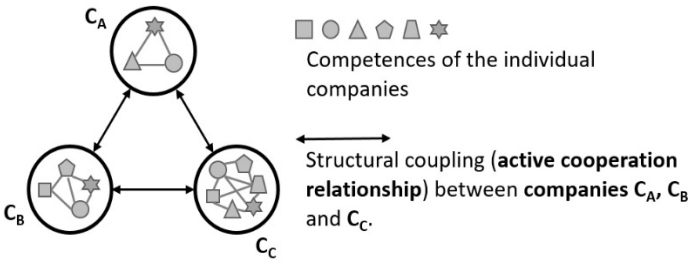

Figure 4: General basic structure of horizontal maintenance cooperation (Source: Own representation)

Fig. 8 shows the specific basic scheme of a horizontal maintenance cooperation with the highlighted criteria. The general design criteria of cooperative maintenance for horizontal maintenance cooperation have been supplemented by additional criteria and characteristics of cooperation and maintenance, or new characteristics have been added.

3.2. Conclusion

Based on the cooperative maintenance, the complementary maintenance cooperation could be identified as a common approach in the operational maintenance of technical units. Likewise, the cooperative maintenance network of companies could be identified as an instrument for getting to know each other, exchanging information and discussing different aspects of maintenance. Furthermore, it was possible to derive a horizontal maintenance cooperation as a possible solution approach for the operational maintenance of SMEs on the basis of the cooperative maintenance and by extending the design criteria and characteristics.

The task now is to assess the prospects of success of a "horizontal maintenance cooperation" and to check its effectiveness or performance in terms of the maintenance costs incurred and the availability of the technical units.

	Criterion / characteristic	**Expression**			
Criterion for the design of cooperations and networks	**Basic form**	cross-company	in-house	intercompany	
	Alignment	horizontal	vertical	diagonal / complementary	
	Intensity	low: non-binding cooperation / recommendations	moderate: exchange of information and results	high: coordinated, collaborative approach	
	Liability	loose cooperation with low risk / verbal agreements	closer cooperation with stronger commitment and defined goals / contractual arrangements	intensive cooperation up to the abandonment of commercial independence / capital interdependence up to the abandonment of the company	
	Extension	local	regional	national	international
	Duration	temporary (short-term)		permanent (durable)	
	Access possibility	open cooperation: free access		closed cooperation: access only after prior admission	
	Target identity	redistributive cooperation: through pooling of resources		reciprocal cooperation: through the exchange of services	
	Ability	synergetic cooperation: with mutual benefit		additive cooperation: with optimizing effect	
	Coupling	bilateral		trilateral / multilateral	
	Number of partners	small number (2 partners)	manageable number (2-10 partners)	larger number (more than 10 partners)	
	Power	hierarchical	heterarchical	without hierarchy	
	Structure	monolithic		polycentric	
	Network of relationships	simply		complex	
Maintenance-specific design criteria	**Local distribution of maintenance**	central		decentralized	
	Personnel task distribution	in-house maintenance	third-party maintenance	combination of in-house and third-party maintenance	
	Integration of maintenance activities	simple maintenance work	simple maintenance, inspection and repair work (routine work)	complex inspection and repair works as well as improvement works	
	Spare parts warehousing	central	decentralized	combined	
	Use of a maintenance planning system	central	decentralized	without maintenance planning system	

Figure 5: General basic scheme of cooperative maintenance
Source: Own representation based on [Ndouma, 1997, p. 15, p. 54-55] and [Wirth and Baumann 2001, p. 94]

	Criterion / characteristic	Expression			
Criterion for the design of cooperations and networks	**Basic form**	cross-company		in-house	intercompany
	Alignment	horizontal		vertical	diagonal / complementary
	Intensity	low: non-binding cooperation / recommendations		moderate: exchange of information and results	high: coordinated, collaborative approach
	Liability	loose cooperation with low risk / verbal agreements		closer cooperation with stronger commitment and defined goals / contractual arrangements	intensive cooperation up to the abandonment of commercial independence / capital interdependence up to the abandonment of the company
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	Integration of maintenance activities	simple maintenance work		simple maintenance, inspection and repair work (routine work)	complex inspection and repair works as well as improvement works
	Spare parts warehousing	central		decentralized	combined
	Use of a maintenance planning system	central		decentralized	without maintenance planning system

Figure 6: Specific basic scheme of complementary maintenance cooperation

Source: Own representation based on [Ndouma, 1997, p. 15, p. 54-55] and [Wirth and Baumann 2001, p. 94]

	Criterion / characteristic	**Expression**			
Criterion for the design of cooperations and networks	**Basic form**	cross-company	in-house	intercompany	
	Alignment	horizontal	vertical	diagonal / complementary	
	Intensity	low: non-binding cooperation / recommendations	moderate: exchange of information and results	high: coordinated, collaborative approach	
	Liability	loose cooperation with low risk / verbal agreements	closer cooperation with stronger commitment and defined goals / contractual arrangements	intensive cooperation up to the abandonment of commercial independence / capital interdependence up to the abandonment of the company	
	Extension	local	regional	national	international
	Duration	temporary (short-term)		permanent (durable)	
	Access possibility	open cooperation: free access		closed cooperation: access only after prior admission	
	Target identity	redistributive cooperation: through pooling of resources		reciprocal cooperation: through the exchange of services	
	Ability	synergetic cooperation: with mutual benefit		additive cooperation: with optimizing effect	
	Coupling	bilateral		trilateral / multilateral	
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	Integration of maintenance activities	simple maintenance work	simple maintenance, inspection and repair work (routine work)	complex inspection and repair works as well as improvement works	
	Spare parts warehousing	central	decentralized	combined	
	Use of a maintenance planning system	central	decentralized	without maintenance planning system	

Figure 7: Specific basic diagram of a cooperative maintenance network

Source: Own representation based on [Ndouma, 1997, p. 15, p. 54-55] and [Wirth and Baumann 2001, p. 94]

	Criterion / characteristic	Expression			
Criterion for the design of cooperations and networks	**Basic form**	cross-company	in-house	intercompany	
	Area	market research and marketing	research and development	funding	personnel
		procurement and materials management	production	sales and service	maintenance
	Alignment	horizontal	vertical	diagonal / complementary	
	Type	community of interest	consortium	virtual company	strategic alliance
		franchising	supply chain management SCM	joint venture	
	Intensity	low: non-binding cooperation / recommendations	moderate: exchange of information and results	high: coordinated, collaborative approach	
	Liability	loose cooperation with low risk / verbal agreements	closer cooperation with stronger commitment and defined goals / contractual arrangements	intensive cooperation up to the abandonment of commercial independence / capital interdependence up to the abandonment of the company	
	Extension	local	regional	national	international
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	Power	hierarchical	heterarchical	without hierarchy	
	Structure	monolithic		polycentric	
	Network of relationships	simply		complex	
Maintenance-specific design criteria	**Local distribution of maintenance**	central		decentralized	
	Personnel task distribution	in-house maintenance		third-party maintenance	
		combination of in-house and third-party maintenance		composite maintenance (by a group of competence bearers of local companies)	
	Integration of maintenance activities	simple maintenance work	simple maintenance, inspection and repair work (routine work)	complex inspection and repair works as well as improvement works	
	Spare parts warehousing	central	decentralized	combined	
	Use of a maintenance planning system	central	decentralized	without maintenance planning system	

Figure 8: Specific basic scheme of horizontal maintenance cooperation

Source: Own representation based on [Ndouma, 1997, p. 15, p. 54-55] and [Wirth and Baumann 2001, p. 94]

4. Horizontal maintenance cooperation

A horizontal maintenance cooperation is a new approach to cooperative maintenance and supplements the conventional options of in-house and third-party maintenance. The companies involved in the cooperation pool their maintenance resources for the purpose of joint and cross-company maintenance of the technical units. Horizontal maintenance cooperation is thus a suitable maintenance solution for SMEs.

4.1. Prospects for success of horizontal maintenance cooperation

There are no clear statements on the prospects for success of horizontal maintenance cooperation - neither in the theory of partnership cooperation nor from operational practice. The benefits that a joint maintenance program[22] can bring to the participating companies within the framework of a horizontal maintenance cooperation have therefore yet to be determined. An initial, purely qualitative assessment is therefore carried out with the aid of an adapted benefit analysis.

Expert knowledge is consulted to carry out the success assessment. The effects that can be achieved by the joint maintenance within the scope of a horizontal maintenance cooperation are assessed in the positively occupied main categories of strengths and opportunities and in the negatively occupied main categories of weaknesses and risks. The main categories are in turn divided into subcategories according to technical, economic, organizational and social aspects.

The aim here is to determine a success benefit value (absolute numerical value) for each of the strengths and weaknesses or opportunities and risks with the aid of a systematic assessment. These values are intended to help assess the prospects for success of integrated maintenance within the framework of horizontal maintenance cooperation.

4.1.1. Results of the success assessment

With the help of a comparison of the benefit values of the positively occupied main categories strengths and opportunities and the negatively occupied main categories weaknesses and risks, the success benefit values are determined with regard to the positively and negatively occupied main categories.

- The technical aspects are assigned special strengths (25.66 points) and great opportunities (22.70 points).
- Likewise, the economic aspects are confirmed special strengths (20.32 points), but also large chances (17.68 points).
- The organizational aspects are considered to have medium strengths (12.46 pts.), but especially great opportunities (21.72 pts.).
- The social aspects are also rated as having medium strengths (15.58 pts.), but also great opportunities (20.67 pts.).

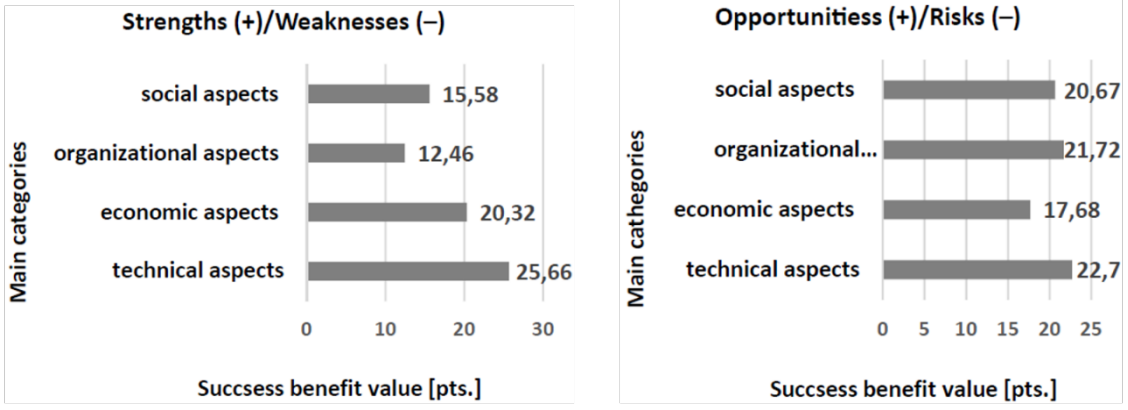

Figure 9: Results of the determination of the success benefit value (Source: Own representation)

4.1.2. Interpretation of the results

The assessment of the success of a horizontal maintenance cooperation shows that a great benefit for the SMEs involved is attributed to the partnership cooperation in the field of maintenance. The maintenance experts surveyed evaluated the strengths, opportunities, weaknesses and risks of horizontal maintenance cooperation using technical, economic, organizational and social aspects. Based on the exclusively positive success benefit values of the individual main categories, it can be seen that they see significantly more strengths and opportunities

[22] Collaborative maintenance - defines the way in which operational maintenance is carried out as part of a horizontal maintenance collaboration.

than weaknesses and risks for the participating companies in the partnership-based cooperation of SMEs and the simultaneous bundling of maintenance resources and expertise, and regard it as a sensible alternative to in-house and third-party maintenance of complementary maintenance cooperation. The greatest potential benefits are attributed to technical and economic aspects. However, the maintenance experts also expect very positive benefits in the organizational and social aspects.

Overall, the maintenance experts believe that partnership-based collaboration among SMEs in the area of maintenance has particular strengths and therefore offers great opportunities for improving operational maintenance at SMEs. From more intensive maintenance, they expect an increase in the level of maintenance, which can ensure reliable functionality and performance and thus the high availability of technical units required for specific operations. At the same time, the maintenance experts expect lower maintenance costs, which, in addition to improving the financial situation by increasing profits or reducing debt, can ultimately also lead to an increase in the competitiveness of the companies.

4.2. Effectiveness and performance of horizontal maintenance cooperation

The application of a horizontal maintenance cooperation can be examined on the basis of typical tasks of planned and unplanned maintenance and with the help of selected example companies (A to E). In this context, the combined maintenance of a horizontal maintenance cooperation is compared with the use of maintenance service providers and the manufacturer maintenance of the complementary maintenance cooperation with regard to the maintenance costs and downtimes incurred.

4.2.1. Effectiveness of the integrated maintenance system

With the help of several case studies of operational maintenance, the effectiveness of integrated maintenance in the context of horizontal maintenance cooperation between SMEs can be demonstrated. It does not matter whether the integrated maintenance is used exclusively or in combination with a maintenance service provider or with the manufacturer's maintenance (third-party maintenance).

As a result, the maintenance costs incurred in connection with the integrated maintenance are on average 23.3% lower. As a rule, the downtime of the technical units is also reduced by an average of 15.2%. This in turn has a positive effect on the availability of the technical units.

Table 1: Summary of results of the case studies (Source: Own representation)

	Relative change [%]	
Case study $\overset{versus}{\Longrightarrow}$ Case study	**Downtime**	**Total cost of maintenance**
Planned maintenance		
1.1 $\overset{versus}{\Longrightarrow}$ 1.2	+ 20.0	− 7.1
1.1 $\overset{versus}{\Longrightarrow}$ 1.3	+ 10.0	− 17.2
Unplanned maintenance		
2.1 $\overset{versus}{\Longrightarrow}$ 2.2	− 4.3	− 8.8
2.1 $\overset{versus}{\Longrightarrow}$ 2.3	− 34.3	− 27.7
3.1 $\overset{versus}{\Longrightarrow}$ 3.2	− 37.6	− 35.0
3.1 $\overset{versus}{\Longrightarrow}$ 3.3	− 37.6	− 37.7
3.2 $\overset{versus}{\Longrightarrow}$ 3.3	0.0	− 4.2
3.4 $\overset{versus}{\Longrightarrow}$ 3.5	− 9.6	− 19.3
3.4 $\overset{versus}{\Longrightarrow}$ 3.6	− 43.6	− 52.8
Arithmetic mean [%]	**− 15.2**	**− 23.3**

4.2.2. Efficiency of the integrated maintenance system

The effectiveness and thus the positive benefits of horizontal maintenance cooperation can already be demonstrated by case studies. However, it is not possible to make any reliable statements about the performance of integrated maintenance in the context of horizontal maintenance cooperation over a longer period of time.

However, with the help of a simulation, the dynamic maintenance events of different scenarios of planned and unplanned maintenance can be investigated in order to examine the performance of a horizontal maintenance cooperation. The objective of the simulation study is to examine a horizontal maintenance cooperation of SMEs with regard to the total costs of maintenance as well as the availability of the technical units.

- Scenario 1: Planned and unplanned maintenance tasks are performed by in-house maintenance and third-party maintenance. A complementary maintenance cooperation takes place. Scenario 1 represents the current actual situation in practice.
- Scenario 2: Planned and unplanned maintenance tasks are also performed by in-house and third-party maintenance. However, the integrated maintenance is additionally used so that, in

addition to complementary maintenance, horizontal maintenance cooperation also takes place.

- Scenario 3: The planned and unplanned maintenance measures are carried out by in-house and group maintenance; external maintenance is not used. In this case, purely horizontal maintenance cooperation takes place.
- Scenario 4: The execution of planned and unplanned maintenance measures corresponds to scenario 3, but an expected ten percent learning curve effect is taken into account for the maintenance employees of the horizontal maintenance cooperation. Again, a purely horizontal maintenance cooperation takes place.

The results for the selected example companies (A to E) show that, depending on the selected scenario and after setting a 10 % learning curve effect, integrated maintenance results in a reduction in total maintenance costs of 37.3 % on average. If, in addition, possible revenues for services rendered by own maintenance employees are taken into account, the maintenance costs can even be effectively reduced by 58.5 % (without company B). Using Company B as an example, it can also be seen that earnings can also be generated through the provision of integrated services. The downtimes of the technical units are reduced by an average of 4.2%. Availability increases slightly - by an average of 0.6%. However, there is still potential for improvement through further learning curve effects and with the help of optimization measures.

Table 2: Summary of results of the scenarios (Source: Own representation)

	Relative change [%]			
Scenario $\overset{versus}{\Longrightarrow}$ Scenario	**Downtime**	**Availability**	**Total cost of maintenance (excluding revenues)**	**Effective maintenance costs (with revenue)**
Company A				
Sc. 2 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 0.3	0.0	− 13.2	− 34.9
Sc. 3 $\overset{versus}{\Longrightarrow}$ Sc. 1	+ 1.8	− 0.5	− 33.9	− 64.8
Sc. 4 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 9.3	+ 1.5	− 41.1	− 71.2
Company B				
Sc. 2 $\overset{versus}{\Longrightarrow}$ Sc. 1	+ 5.1	− 0.7	+ 39.6	− 103.2
Sc. 3 $\overset{versus}{\Longrightarrow}$ Sc. 1	+ 7.9	− 1.1	+ 9.7	− 187.0
Sc. 4 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 0.9	+ 0.2	− 2.2	− 188.5
Company C				
Sc. 2 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 2.5	+ 0.4	− 53.4	− 53.4
Sc. 3 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 1.9	+ 0.3	− 68.9	− 68.9
Sc. 4 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 43.3	+ 7.8	− 71.3	− 71.3
Company D				
Sc. 2 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 2.0	+ 0.2	− 49.8	− 49.8
Sc. 3 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 5.7	− 0.6	− 60.9	− 60.9
Sc. 4 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 0.2	0.0	− 61.9	− 61.9
Company E				
Sc. 2 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 5.9	+ 0.7	− 36.2	− 39.8
Sc. 3 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 0.2	− 0.2	− 57.0	− 62.3
Sc. 4 $\overset{versus}{\Longrightarrow}$ Sc. 1	− 5.3	+ 0.6	− 58.8	− 62.2
Arithmetic mean [%]	**− 4,2**	**+ 0,6**	**− 37,3**	**− 58,5** (without C_B) **− 78,7** (with C_B)

Due to the simplifications made, the results obtained both for the selected case studies and for the simulation are to be assessed primarily as "tendencies". They do not represent the exact values to be expected. Nevertheless, they do show that the combined maintenance within the framework of a

horizontal maintenance cooperation of SMEs has great potential compared to the usual procedures of complementary maintenance cooperation (third-party maintenance by the manufacturers of the technical units or by maintenance service providers) and can be advantageous for SMEs in particular.

However, it must be examined to what extent a high workload of the maintenance personnel involved in the integrated maintenance can have an effect on the personnel availability of the participating companies. Although maintenance employees who are underutilized without the integrated maintenance can be better utilized with the integrated maintenance, it may also be necessary to increase the personnel resources of the participating companies. There is even a tendency to assume this. In the simulation, for example, all maintenance employees of company B could be utilized to capacity, even though only four technical units per company were considered in the selected scenarios. This was also the case for company B, which aligned its personnel maintenance capacities with a significantly higher number of technical units. The maintenance employees who were otherwise only employed in the example company B were still well utilized by the group maintenance. This initially led to reduced availability of the technical units at company B, but also to considerable income for the compound services provided. This example demonstrates the economic efficiency of additional maintenance personnel for compound maintenance.

4.3. Factors for the success of integrated maintenance

The success of a network maintenance in the context of a horizontal maintenance cooperation is determined by various factors. During the investigation of the selected case studies and the simulation, particularly significant factors have emerged. These factors can be referred to as the strategic success factors[23] of the integrated maintenance in the context of a horizontal maintenance cooperation of SMEs.

The success factors of integrated maintenance have a significant influence on the total costs of maintenance as well as on the availability of the technical units and are explained in the following:

- The response time of maintenance personnel has a major influence on maintenance and has a wide range of effects:

  The shorter the response time, the faster the maintenance staff are on site, the earlier they can start maintenance activities, the more quickly the technical units can be returned to the service production process and the lower the costs of maintenance.

- The physical distance of the maintenance personnel to the site of operation influences the travel time and the start of maintenance:

  The shorter the geographical distance and the more densely the participating companies of the horizontal maintenance cooperation are distributed in a region, the shorter and more cost-effective the travel time of the maintenance personnel and the faster the start of maintenance activities.

- The expertise of the maintenance personnel influences the speed of maintenance execution:

  The more comprehensive the expertise and the higher the level of qualification of the maintenance staff, the faster and more professional the maintenance work. In addition, the continuous expansion of knowledge through regular assignments in compound maintenance leads to learning curve effects.

- The hourly rates charged to maintenance personnel have an impact on direct maintenance costs:

  The greater the difference between the agreed hourly billing rates and the hourly billing rates of the manufacturer maintenance or maintenance service providers, the lower the maintenance costs incurred.

- The utilization of maintenance personnel has different effects on maintenance:

  The less busy the individual maintenance employees of the companies involved are, the more quickly they can be deployed, the more profitable their deployment is and the more likely it is that revenue can be generated in the form of earnings.

Each of the success factors mentioned above has a decisive influence on operational maintenance on its own. However, the factors always occur in combination, so that with an optimal constellation they enable considerable improvements for the participating entrepreneurs of a horizontal maintenance cooperation.

[23] Strategic success factors - Strategic success factors are generally understood to be those factors which determine the company's success on a sustainable and long-term basis and which can be used to gain competitive advantages over competitors [according to Rehkugler, 1989, p. 627].

4.4. Conclusion

With the aid of the structural principles of cooperative maintenance, it was possible to identify horizontal maintenance cooperation as a new maintenance solution for SMEs and also to determine its prospects of success with the aid of a systematized evaluation procedure. For this purpose, maintenance experts from a wide range of industries were consulted and specifically asked for their assessment. Furthermore, it was possible to define the type of approach as compound maintenance. With the help of typical case studies of planned and unplanned maintenance, it was possible to demonstrate the effectiveness of compound maintenance in comparison with the usual procedures of complementary maintenance cooperation with third-party companies (manufacturers of the technical units, maintenance service providers). With regard to the maintenance costs incurred, a considerable reduction could be determined; with regard to the downtimes incurred, a reduction was also shown.

The expected performance of the integrated maintenance system was verified by simulating the dynamic maintenance process over a longer period of time. On the basis of the selected example companies (A to E), it was shown that a significant reduction in maintenance costs is possible through the compound maintenance. The downtimes of the technical units are also reduced; availability, on the other hand, increases somewhat.

5. Concluding remarks

Maintenance theory does not differentiate between companies according to size and industry affiliation, but always assumes the ideal situation with sufficient maintenance assets available. However, increasing trends, such as higher levels of automation and more complex technical units, multi-shift operation and increased just-in-time deliveries with decreasing material stocks in intermediate warehouses, as well as a constant reduction in throughput times, require specific maintenance solutions.

In practice, the operational maintenance of large companies is usually more successful than the maintenance of SMEs. For organizational-structural and financial reasons, SMEs are often at a disadvantage. However, maintenance theory does not provide appropriate solutions for SMEs, so that their expectations of operational maintenance are not met either. In order to remain competitive, however, SMEs need their own maintenance solutions. New solutions must take into account the specific circumstances of SMEs and also meet the requirements of professional and responsible maintenance.

Cooperation between companies in a spirit of partnership plays a major role in operational maintenance. Nevertheless, it is unclear to what extent operational maintenance is also the subject of cooperative relationships. However, the outsourcing of maintenance services to third-party companies is a common practice in operational maintenance, regardless of the size and industry affiliation of the companies. By transferring the general design criteria and characteristics of cooperative relationships to the conditions of operational maintenance, the formal definition of cooperative maintenance is possible. The resulting structural fundamentals prepare the basis for various approaches to cooperative maintenance.

Horizontal maintenance cooperation is one such approach to cooperative maintenance and refers to the bundling of maintenance resources of locally based companies for the purpose of joint and cross-company maintenance of technical units. However, the prospects of success of horizontal maintenance cooperation between SMEs are not known either from the theory of partnership cooperation or from operational practice - there are no clear statements on this. However, expert knowledge can be used to assess the prospects of success. Horizontal maintenance cooperation in a network of locally based companies (integrated maintenance) holds great potential - especially for SMEs.

The effectiveness of the network maintenance can be demonstrated with the help of case studies based on typical tasks of planned and unplanned maintenance. By simulating different scenarios, it is also possible to determine the expected performance of the integrated maintenance in the context of horizontal maintenance cooperation between SMEs. Compared to other approaches, compound maintenance enables a long-term reduction in maintenance costs as well as an increase in the availability of the technical units.

All in all, the partnership-based cooperation in a horizontal orientation of independent companies with a small spatial distance to each other for the purpose of joint maintenance is not only a suitable, but also an extremely sensible approach for operational maintenance in SMEs. The organizational-structural and financial disadvantages of SMEs compared to large companies can be compensated. The sustainable advantages of the compound maintenance of a horizontal maintenance cooperation are rooted in its success factors. Maintenance theory has not yet addressed this approach. In the future, however, horizontal maintenance cooperation between SMEs could play an important role in operational practice and be used to ensure the availability and reliable functioning and performance of technical units that are required for specific operations.

In this way, operational maintenance will have a noticeable impact on product quality, customer loyalty and, not least, on the general competitiveness of companies. Horizontal maintenance cooperation can also contribute to the sustainable and economic development of companies.

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