Sourcing of Maintenance Services in Production Networks

Multi-Criteria Decision between Make, Buy, Concurrent Sourcing and Co-operate

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Abstract: This text sheds light onto the sourcing decision for services in production networks. Focusing on maintenance services, it first derives criteria and sourcing alternatives from management theory and then tests the outlined decision framework empirically in the chemical and mechanical engineering industries. Moreover, an online software is proposed to help practitioners with decision-making.

In economies characterized by division of labour, businesses cannot be treated as isolated entities. Every business has been relying on co-operation with every other link of the value chain since long before buzzwords such as Lean Production and Supply Chain Management occurred. Only through collaboration is a company able to provide its products and services to its clients. Rather than being a rigid chain, the resulting structure is a dynamic network in which every company is linked with more than two other businesses. The degree of association varies, however: Some companies decide to use the market mechanism and others merge into a single company in order to facilitate the value creation. In recent years, a different organisational form became more common: co-operation.

This co-operation is most often aimed at jointly creating physical goods and optimising the network-wide production processes. For a single company this means a higher degree of mechanisation and automatisation, which leads to high complexity and an interdependent system of machinery. At the same time, the requirements for equipment availability and reliability increase, since the introduction of just-in-time production has drastically reduced inventory levels, over-capacities and redundancies. These factors result in an ever-growing importance of the maintenance process. The decision of how to source such maintenance services could be quite similar for all production network members as they face similar problems. This in turn would allow for the decision to be made for the value chain as a whole rather than for a single member.

In Germany's chemical industry, maintenance services are often provided by a company's own employees. In contrast, businesses in the airline industry have been co-operating with competitors, suppliers and clients to maintain their aircrafts since the 1960s. Maintenance in the wind turbine industry requires a nationwide provision of spare parts and qualified personnel. Original equipment manufacturers, operators as well as third party service companies offer such services.

Differences in outcomes of the sourcing decision are apparent. Hence, for a company facing this decision it is not only crucial to understand how the decision can be made but also which influencing factors and alternatives must be considered. Moreover, it is worthwhile examining if other network members need to be consulted. The co-operation model prevalent in the airline industry might be adoptable in the wind turbine industry as well. Furthermore, the company needs to understand if such a decision can be made at a single point in time or if it requires constant monitoring and revision.

The provision of input factors is broadly discussed in business literature, quite often this involves catchphrases such as Make-or-buy decision and Outsourcing. Nevertheless five areas were identified that require further research. First, the discussion predominantly revolves around the two alternatives: Make and Buy. Alternatives, such as concurrently sourcing from internal and external suppliers or co-operating with other companies to satisfy demand, are hardly considered. Second, the literature examines decisions made on a single company level. Decisions on and implications for the network level are rarely discussed. Third, the sourcing object studied is a physical good rather than an intangible service. Fourth, most research designs rely on case studies or empirical surveys, forcing the researcher into reporting existing practices rather than creating scientific insight. Current research using multi-criteria decision-making models based on criteria and alternatives deduced from management theory is absent. Fifth, practitioners do not view the sourcing decision as strategic, nor do they formulate formal decision-making processes or revise a decision once made, even when environmental variables have changed.

This dissertation sheds theoretical and empirical light on the sourcing of maintenance services over time. It aims at constructing a decision-making process helping members of a production network to make a joint sourcing decision.

Its theoretical and practical contribution can be found in six areas. First, Concurrent Sourcing and Co-operation are not omitted but considered viable alternatives alongside Make and Buy. This text puts great emphasise on not only showing pros and cons of a certain alternative, but linking them to strategic management literature. Second, rather than concentrating on the company level, the focus is on the network level. Concentrating on a single or just a few members of the value chain is not sufficient. Third, this research examines a service, namely the maintenance process, which is often seen as non-strategic and therefore typically does not attract great management attention. Fourth, multi-criteria decision-making models are combined with simulation as well as empirical and theoretical research to create a framework that does not rely on the inductive approach of case studies. Fifth, this research contributes to practice by explicitly showing a formal decision-making process that can be adopted by companies in which such a process has not been implemented. Sixth, simulation of environmental factors will allow judgement if the alternative chosen will need constant monitoring and revision.

Consequently, the main research question is formulated as follows: *Both from a theoretical and empirical point of view, how can the members of a production network jointly decide on how to source services, particularly maintenance services, over the course of time?*

This text will first derive a decision-making process for sourcing maintenance services both on the single company and the production network level. Subsequently this process will be scrutinized empirically and put into an online tool to help practical implementation.

To do so, the research question is broken down into eight sub questions. The first one is *which criteria influence the decision between narrow and wide boundaries of the firm*.

The text outlines how division of labour and specialisation create the boundaries of a firm. The resulting need for coordination leads to the application of coordinating mechanisms such as market and hierarchy. 22 determinants for the choice between narrow and wide boundaries are derived from combining transaction cost economics, the resource-based view, the knowledge-based view and economies of scope and scale. In general, *economies of scope and scale* lead to wider boundaries. *Transaction cost economics* is in favour of wide boundaries if only a small number of suppliers exist, transaction specific investment is required and uncertainty about behaviour and environmental factors is immanent. In contrast, if the same transaction is conducted frequently and credible safeguards against opportunism are in place, companies will choose narrow boundaries, even if uncertainty and the need for transaction specific investment exist. The resource-based view advocates for wide boundaries if resource interdependence is high and if wide boundaries guarantee high utilisation of strategic resources. On the other hand, these strategic resources also narrow the firm's possibilities: Narrow boundaries are the result of little interdependence between an activity and the firm's strategic resources and capabilities. The knowledge-based view supports wide boundaries, since transfer and conservation of knowledge is easier within a company than across markets. However, if a leap in technology is likely or the required knowledge is completely codifiable, then narrow firm boundaries will result.

After these general influencing factors on the boundaries of a firm were shown, conclusions for sourcing decisions can be drawn by answering the following sub question: *How can these general assertions be used to derive sourcing criteria for physical input factors?*

If physical goods are produced, a business will choose the alternative Make if it is produced in high volumes and transfer of implicit knowledge between steps of the value creation process is required. Even more so, if the final product needs to be protected from imitation and high uncertainty about environmental and behavioural factors exist. Narrow boundaries and the alternative Buy are chosen if the required knowledge is not company specific and easy to codify. Also if the final product or its production are not closely linked to the strategic resources of the firm, transaction-specific investments are not required and uncertainty is low. Concurrent Sourcing is preferred if high environmental uncertainty does exist, internal and external knowledge is required and disruptive technological innovation is possible in the sector. As a prerequisite the business is

willing to invest in financial safeguards against opportunism and not able or willing to build a long-term, trusting relationship with other members of the value chain. Organisation in a network, constituting the choice of Co-operate, emerges between businesses sharing common values and goals. The partners are willing to engage in long-term, trusting relationships and are willing to surrender some competencies to the network. Typically these companies are found in capital and knowledge intensive, fast moving industries.

The next step is to clarify, *if differences between physical goods and intangible services have an influence on the sourcing decision.*

If the sourcing object is a service rather than a physical product the choice of a sourcing alternative is quite different. This is a result of the constitutive characteristics of a service, which influence almost all firm-boundary determinants. First, high uncertainty is prevalent for all parties during the whole service process. High complexity follows from the immaterial nature of the service offering and the service outcome. This, in combination with the bounded rationality of client and provider, necessarily leads to incomplete contracts and therefore to high uncertainty. Second, immaterial input factors are important to produce a service. It is quite challenging to coordinate knowledge, an immaterial strategic resource, along the whole value creation process. This leads to implications for the choice of a firm's boundaries: If the knowledge required is not easy to codify and therefore difficult to transfer, integrating the external factor into the service process will be problematic. It is under these circumstances that internal organisation and commands are chosen as the coordinating mechanism.

To illustrate the sourcing of a specific service, the following discussion focuses on the sourcing of maintenance services to provide answers to the question: *To what extent can the general assertions about the sourcing of services be applied to the sourcing of maintenance services?*

The particularities of the maintenance process increase the complexity in comparison to the provision of other services. Not only lacking information about type, scope and duration of the service, but also about the timing of demand, this is especially apparent in the case of capacity planning for breakdown maintenance. At the same time the duration of breakdown maintenance bears vast implications on the production process such as the availability of strategic resources. Hence, maintenance can be seen as a capability in the sense of the resource-based view.

The maintenance process needs to access both, firm specific and object specific knowledge. Specific knowledge, for example about the entirety of all machines, and strategic resources are quite often interdependent and therefore responsible for wide firm boundaries. Object specific knowledge, for example about the functionality of a single machine, is in contrast expected to lead to narrow boundaries. Also the relationship between transaction partners demands consideration. Due to high transaction costs, a business will choose the Make option, if the creation of a trusting relationship with the

service provider fails or if transaction specific investments are only required from one partner.

The questions arise, *if the criteria and alternatives derived from theory can also be applied in practice when sourcing maintenance services,* and *which other factors influence the sourcing decision on a company level.*

The following discussion is based on a survey conducted amongst 1043 companies of the chemical, mechanical engineering and wind turbine industries. More than 90 per cent of the 230 respondents accepted the decision-making criteria derived from theory. It can be concluded, however, that the criteria differ in their importance towards selecting an organizational form for maintenance services. The most important criteria are exact knowledge about and availability of the equipment as well as transparency of costs and services performed. Note that these criteria stem from different theoretical perspectives, emphasizing the importance of the chosen research design that simultaneously considers four theoretical explanations for firm boundaries.

The arithmetic average of any criteria weight does not differ significantly between industries, size of workforce, value creation steps, maintenance budgets or the chosen forms of maintenance organisation. This contradicts two of the three interviewed industry experts who claimed that differences between industries do exist. However, it was possible to show that the priorities for some criteria differ between companies that emphasise the importance of their maintenance services and those who do not. In times of economic crisis only few companies would change their sourcing strategy, since the criteria weights remain relatively stable: If the demand for a company's products were reduced by 20 per cent, only 9.5% of companies surveyed would change the organisational form of their maintenance services.

The evaluation for each sourcing alternative was derived from combining the four theoretical lenses. The survey provided empirical evidence for five of the seven criteria the evaluations were conducted in regards to. In comparison with the exclusive in-house performance of maintenance tasks, the alternative that exclusively sources from external providers ranks better in offering up-to-date knowledge and the latest maintenance technologies as well as transparency of costs and services performed.

Using a value function to combine criteria weights and the alternatives' evaluations, the suggestion for most companies is to source their maintenance services from in-house resources. If mixed organisational forms such as Co-operation and Concurrent Sourcing were also considered, only few companies would choose to solely source from external suppliers or to team up with partners in a Co-operation. It is Concurrent Sourcing, however, that would be suggested to most companies in the mechanical engineering industry. Internal sourcing is chosen by 56% of the respondents in the wind turbine industry and by 55% in the chemical industry, respectively. In general, the mechanical engineering companies are more likely to prefer mixed organisational forms than those of the chemical industry.

Since it is the goal of the text to examine sourcing decisions in production networks, the following will concentrate on the network level and answer the questions *how decisions can be collectively made in production networks* and *what are the differences in decision-making compared to the company level.*

Combining the network member's individual goals and the network's own goals, the overall network sourcing goals are derived. Subsequently, eight groups of aggregation mechanisms are discussed that allow for aggregating individual decisions to a group decision. In addition, environmental factors are discussed that may have an impact on the group decision over time. Last, combining the theoretical assertions of this text, a decision-making process for selecting a suitable coordination mechanism for maintenance services is outlined (Figure 1).

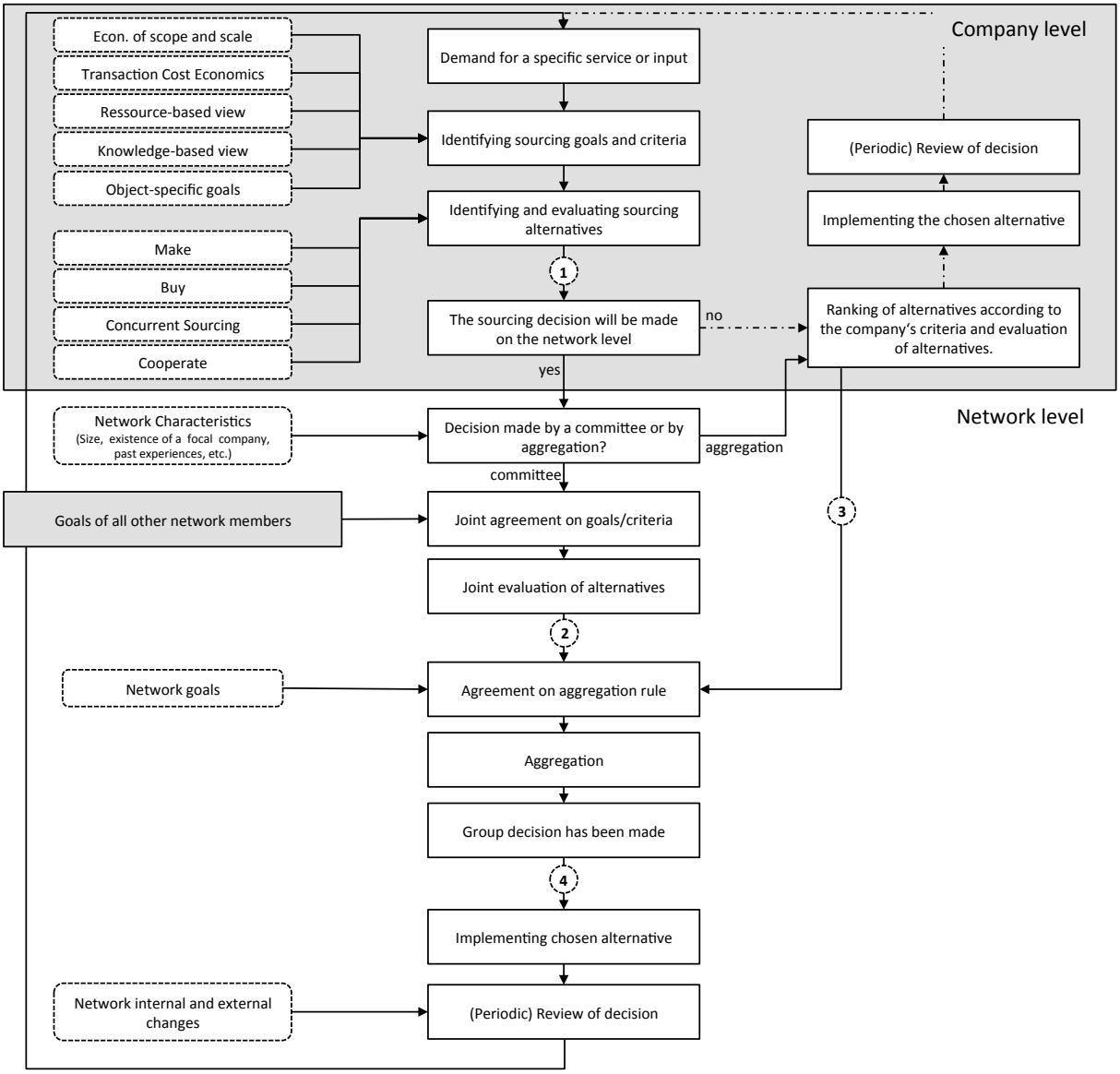

Figure 1: Decision-making process for sourcing services in a network.

A simulation was used to show *which aggregation mechanisms are useful to transform the decision of individual companies into decisions of a whole network and if the decision made can be described as stable over time.*

First, the empirical study performed showed, that about half of the respondents are open towards co-operation with other companies in order to jointly decide on maintenance service related topics. However, this openness differs between industries. Almost three in four wind energy companies (73.9%), and 55.7% of mechanical engineering companies would engage in co-operative activities. Whereas the majority of chemical companies are opposed (57.1%) to it.

The aggregation mechanisms that could transform a single company's decision into a network decision were evaluated using three criteria. This evaluation was conducted in networks comprising of randomly chosen respondents of the survey. Moreover, scenarios were used to simulate the stability of the decision over time. The results show that the decision made cannot be considered time stable. In the best-case scenario the alternative changed for 2.3% of the networks, in the worst case, 16.6% would choose a different alternative.

Lastly, the text studied *if a decision-aiding tool could be developed to help practitioners evaluate alternative sourcing options for maintenance services*.

Following the proposed decision-making framework, the software first asks the user for general information about the company and then demands weighing criteria. Next, the online software requests evaluations for the alternatives Make and Buy. With the inputs given, the tool calculates evaluations for Concurrent Sourcing and Co-operate. The showing the decisions of similar companies (e. g. of the same industry or size) the software provides information to decision makers. In addition, the tool can create networks by combining random companies and evaluate the performance of the proposed aggregation mechanisms.

This text shows the importance of more research in this field. For example, this research was not aimed at showing how suitable co-operation partners can be found or how to best organize maintenance operations in a network. Looking at simulated networks and scenarios was necessary in the context of this text; however, it could be supplemented with case studies form existing maintenance co-operations and production networks. Data and experience gained from the long-term usage of the decision-making process and the online software would allow their further development.

In conclusion, this text provides theoretical and empirical insight on sourcing decisions at the company as well as the network level. It shows how decisions can be made over time and which criteria and alternatives could be considered in order to do so. The proposed decision-making process does not automatically select an alternative for a given company or network. It can be seen, however, as an instrument to support the management's decision-making in such a way that it creates a framework for the discussion and a certain transparency for the decision-making process.