Decision-making for assessing flexible switches of inbound supply concepts in the automotive industry

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Abstract

The inbound logistics of the automotive industry is characterized by a build-to-order strategy, different supply concepts and varying part-specific characteristics. Latter may yield to the need of switching the supply concept. The corresponding decision problem examines whether a switch should be executed in consideration of profitability. This paper provides a framework structuring the decision problem for practioners. Switching obstacles in terms of changeover costs and times are presented exemplary for a switch from in-stock supply to just-in-sequence. Four types of switching decisions are defined and possible solving methods are presented. To enable flexible switching decisions, flexibility measures are derived.

Keywords: Switching inbound supply concepts, Investment decision-making, Automotive industry

Motivation

Inbound logistics describes the link between suppliers and the production plants of a manufacturer. Especially in the automotive field, inbound logistics is characterized by a high number of variants, different supply concepts and a build-to-order strategy with an underlying lean thinking philosophy (Miemczyk and Holweg, 2004). Additionally, part-specific characteristics vary over time (e.g. the demand or number of variants). Consequently, the current inbound supply concept may not remain optimal over time. Switching the supply concept may become a viable option to deal with these variations (see e.g. Wagner and Silveira-Camargos, 2011). The challenge of this decision problem consists in integrating the uncertain and dynamic development of these part-specific characteristics into the decision process in such a way as to remain competitive (Abele *et al.*, 2006). The cost-efficiency and speed to execute a supply concept switch reflects the flexibility degree of the inbound process. As flexibility generally causes costs, its valuation and its integration into the decision process is an important task. Without the integration of flexibility into the decision problem, firms may decide differently or even wrong and thus miss potential costs savings (Nembhard *et al.*, 2005).

This paper poses the following research question: How can a decision for switching the supply concept be made in consideration of the inbound logistics flexibility? To answer this question, the following sub-research questions are examined: What are the (most critical) obstacles to overcome before switching the supply concept to another? What are adequate methods to solve supply concept switching decisions? What does flexibility mean in the context of supply concept switching? What are leverages to increase flexibility for switching the supply concept?

Procedure for decision-making on switching supply concepts

The procedure applied in this paper is illustrated in Figure 1. In practice, this procedure can be used as a basis when dealing with the question whether to switch the supply concept or not. Four different steps can be distinguished. First, all possible supply and transportation concepts and their combinations need to be determined. In this paper, main supply and transportation concepts are derived from literature and briefly explained. Afterwards the realizable switching alternatives are identified. Second, the obstacles when switching from one concept to another are identified, since they build the basis for further switching decisions. These obstacles mean necessary activities that enable the switch to the new supply concept. The activities are measured in time and costs. Third, the available cases of switching decision are differentiated, e.g. whether it is a one-time decision, a back-and-forth switch, or an investment for increasing flexibility. A recommendation on how to solve each decision type is given. These solving methods are based on literature regarding investment decision-making under uncertainty. In the fourth step, the case of flexible switching is examined in more detail. The meaning of flexibility is discussed on basis of literature about transformability and flexibility of manufacturing systems. Measures to increase flexibility regarding supply concept switches are derived. The presented procedure also reflects the structure this paper is following.

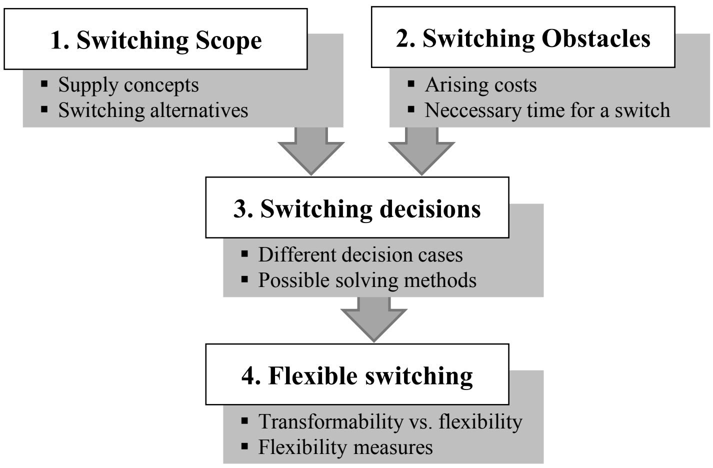

Figure 1 – Applied Procedure

Switching scope

To identify the scope of switching supply concepts, it is first necessary to identify all existing supply and transportation concepts and their possible combinations. At the beginning, let the inbound logistics be defined as “Activities associated with receiving, storing, and disseminating inputs to the product, such as material handling, warehousing, inventory control, vehicle scheduling, and returns to suppliers" (Porter, 2004, p. 39). In other words, the inbound logistics is the physical linkage between supplier and manufacturer. To execute the mentioned activities, supply and transportation concepts are needed. A supply concept defines the way the material is delivered from the supplier to the manufacturer. A transportation concept defines the physical routes taken to transport the material, the means of transport, and the activities executed by service providers (e.g. material handling in a hub). The scope of the inbound logistics including the main supply and transportation concepts from literature is pictured in Figure 2.

As Figure 2 shows, supply concepts can be divided into direct delivery and in-stock delivery. Direct delivery covers lean concepts such as just-in-time (JIT) or just-in-sequence (JIS). JIT addresses the provision of solely homogeneous material at the assembly line just at the time it is needed (Wagner and Silveira-Camargos, 2011). JIS can be seen as an extension of JIT, because the material is also provided just in time, but the heterogeneous material is sorted according to the production sequence of the manufacturer (Werner *et al.*, 2003). In-stock delivery includes at least one warehousing stage in the process. A good overview of standardized supply concepts can be found in Klug, 2010 and VDA-5010. On the transportation side, three main transportation concepts can be distinguished. Direct relation describes a transport which goes straight from the supplier to the manufacturer without any stops. In a milk run system the goods from different suppliers are collected in a tour and afterwards carried to the manufacturer. Therefore, a milk run is especially suitable for small order quantities from each supplier to achieve a full load by all collected goods (Klug, 2010). Hub and spoke refers to a transportation concept with an additional transshipment point. This transshipment point is used for the handling and re-sorting of material from different suppliers (Schulte, 2009).

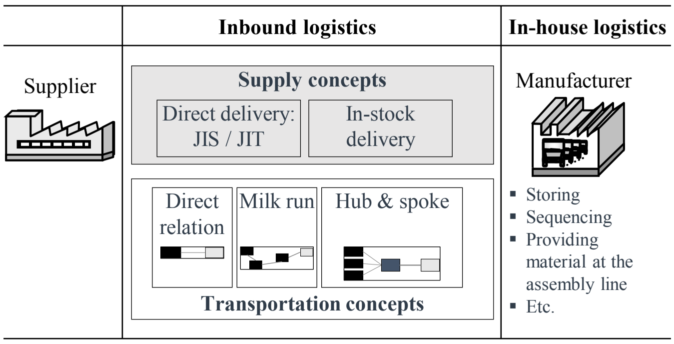

Figure 2 – Scope of inbound logistics

In a next step, the identified supply and transportation concepts need to be listed in a switching matrix. This matrix helps to display all possible switching alternatives. An exemplary switching matrix is illustrated by Table 1 based on some of the supply and transportation concepts from literature described above. The table shows, for instance, a possible switching alternative from JIT direct delivery to JIS direct delivery. This would be reasonable for the case of an increasing number of variants of the considered part. The homogenous material provision at the assembly line would not be practical anymore (since more space is needed for more variants), whereby a switch to JIS becomes viable.

Of course, not all fields in the matrix imply possible switching alternatives – in which *possible* means *technical feasible* and does not mean reasonable. The fields in the diagonal of the matrix displayed in grey mean an impossible switch, because the initial concepts correspond to the switching alternatives themselves. Furthermore, the columns and rows of JIT and JIS milk run are entirely marked with grey stripes. This implies an example for concepts that are not applied so far. Nevertheless, both concepts may be interesting and possible switching alternatives in the future. To integrate new concepts in switching decisions, these concepts first need to be technically enabled and planned. Therefore, the derived switching matrix is not a fixed planning tool, but can be adapted over time and within the further planning process.

To identify the reasonability of a switching alternative, the preferred supply concept needs to be identified (see e.g. Maas *et al.*, 2016). This decision is also important, but different to the one addressed in this paper. The switching alternatives regarded in this paper are assumed to be given. Additionally, it is assumed that the switching alternative is more cost efficient than the initial supply concept at a certain point in time. This cost efficiency may fluctuate over time due to uncertain developments.

In practice, each manufacturer needs to define an own switching matrix. The applied transportation and supply concept combinations can differ from manufacturer to manufacturer and not all concepts listed in literature are applied at each manufacturer. The used concepts can also be specified to the needs of a manufacturer. But not only the concepts themselves differ, but also the switching alternatives. As pictured in Table 1, depending on the number of available supply and transportation concepts there may be a lot of different switching alternatives possible.

Table 1 – Exemplary switching matrix for inbound concepts

Switch from \ Switch to			Direct delivery				In-stock delivery	
			JIT	JIT	JIS	JIS		
			Direct relation	Milk run	Direct relation	Milk run	Direct relation	Milk run
Direct delivery	JIT	Direct relation			X		X	X
	JIT	Milk run						
	JIS	Direct relation	X				X	X
	JIS	Milk run						
In-stock delivery		Direct relation	X		X			X
		Milk run	X		X		X	

X	Possible switching alternative
	Not used until now; may become a possible switching alternative
	No alternative, because corresponds to the initial concept
X	Example switch: From JIT direct relation to JIS direct relation

Switching obstacles

To conduct a supply concept switch, a number of obstacles has to be overcome. To identify these switching obstacles, it is necessary to reveal the actions which are needed to put such a switch into practice. Each action preparing for a switch causes time, costs, or both. Therefore, the amount of costs and time for each action can be seen as a measurement of the obstacle dimension. A two-step procedure was applied to identify the switching obstacles: First, the general obstacle categories were defined. One of the rare references dealing with costs for introducing supply concepts, is the work of Wagner and Silveira-Camargos (2011). This work served as a basis, although they regarded the specific case of costs occurring before changing from JIT to JIS. Second, the obstacle categories were specified for the case of switching from in-stock delivery to JIS delivery. Each obstacle was evaluated qualitatively regarding costs and time needed.

The obstacle categories are illustrated in Figure 3. These can be differentiated into external and internal obstacle categories. External obstacles include all activities that are not directly related to the manufacturer, such as activities of a *Supplier* or *Service provider*. The internal obstacle categories include activities and the corresponding personnel expenses which are directly related to the manufacturer. Times and costs per internal activity are defined to be adaptable. Four internal categories were identified: *Infrastructure*, *Processes*, *Logistics equipment*, *Personnel*. *Infrastructure* includes all activities associated with the in-house logistics areas (providing area, super market, trailer yard, etc.). Due to a supply concept switch those areas may be affected and thus require adaptions or the creation of new areas. The category *Processes* includes activities that are necessary to guarantee a working supply process, i.e. defining the information flow and call-offs, IT system adaptions, etc. The category *Logistics equipment* consists of all activities enabling the inbound and in-house transport at the quality standard needed. This can begin from the development of new charge carriers over the procurement of new logistics equipment to the re-arrangement of internally available logistics equipment (such as stackers, tow trains, etc.). The last category *Personnel* stands for all activities concerning internal logistics employees. Informing these employees and trainings on the new supply concept are key aspects of this category.

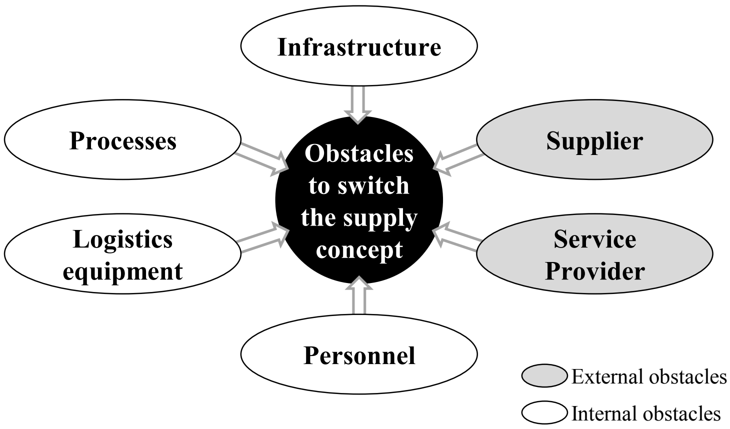

Figure 3 – Obstacle categories to switch the supply concept

The detailed activities occurring within each obstacle category depend on the planned switch and the related supply concepts. Obviously, a switch from in-stock delivery to JIT calls for more adaptions than a switch from JIS to JIT, because the underlying process and its control are more similar for JIS and JIT supply. However, the diversity of the switches does not only depend on the affected supply concepts, but also on specific framework and environmental conditions. It makes a difference, for instance, if the supplier already delivers other parts in JIS when switching to JIS. Consequently, there are no major interferences in the IT system of the supplier necessary as JIS is already running for other parts. Another example relates to the category infrastructure: If a supermarket is needed for the new supply concept, it will make a difference whether the supermarket already exists or whether it has to be installed first.

Consequently, it is essential to focus on a certain switch with known circumstances, in order to specify the obstacle categories by detailed activities. In the following an exemplary switch from in-stock delivery to JIS supply is stated. The supplier is not able to deliver in JIS so far, but the manufacturer is already receiving other material from different suppliers in JIS. A service provider is not involved in the process change – this obstacle category is neglected respectively. The detailed activities for this switch as well as the qualitative assessment of time and costs needed for each activity are derived by the means of expert interviews of an international commercial vehicle manufacturer. The results are presented in Table 2.

The measurement of cost and time is carried out by a nominal scale (low, medium, high). Cost intensity is only applicable for those activities that require an investment. Time intensity means the time it takes to finish an activity. Certainly, time intensity can also be expressed by costs when taking labor costs as a basis. However, the critical dimension of these activities is the required time, which is therefore displayed in Table 2. The sum of time and costs needed for a switch is named changeover costs in the following of this paper. The table shows that the most time intensive activities are the IT adjustments, the development and procurement of charge carriers and relevant tools, and supplier related activities. IT adjustments are highly time intense for the case of the commercial vehicle manufacturer, because the call-off orders for in-stock delivery are send via a different system than the call-offs for JIS. For other manufacturers IT adjustments may be less time intense. The development and procurement of charge carriers for JIS, however, is always time intense, when special JIS charge carriers are needed. Both time intense activities, development and procurement of charge carriers as well as the activities related to the supplier, are additionally highly cost intense. The lowest time intensity includes the briefing and training of the employees and the logistics audits of the supplier's plant.

Table 2 –Activities to switch from in-stock to JIS – A case of a commercial vehicle manufacturer

Obstacle Category	**Activities**	**Cost intensity**	**Time intensity**
Process	IT adjustments		High
Process	Parameter determination (e.g. batch sizes, container sizes, etc.)		Medium
Process	Supervision before and after supply concept roll-out		Medium
Infrastructure	Creation of necessary space/areas for the new supply concept		Medium
Personnel	Briefing and training of the process related employees (e.g. incoming goods, procurement, assembly, etc.)		Low
Logistics Equipment	Development and procurement of charge carriers and relevant tools	High	High
Logistics Equipment	Procurement of tools for providing material (e.g. tugger trains, manipulator, etc.)	Medium	Medium
Supplier	Sum of all costs occurring at the supplier's side	High	High
Supplier	Logistics audit of the supplier, to check the supplier's capabilities to apply the new supply concept		Low

Cases of switching decisions and solving methods

As mentioned before different influences and developments can trigger the need for switching the supply concept. Depending on these future developments, a switch to another supply concept may occur frequently or only rarely. Therefore, it is not only crucial to make a one-time decision, but to integrate the view of uncertain future developments into the decision problem. The considered decision problem can be divided and structured into four cases as illustrated in Figure 4. For a better comprehensibility the figure only shows switches from in-stock delivery to JIS and vice versa. These switches are replaceable for all possible supply concept switches. Furthermore, switching from in-stock to JIS may generate a different amount of changeover costs than switching the other way around (see the previous chapter for further explanations). For reasons of clarity these differences are not illustrated in Figure 4.

The first case describes the basic case, having a one-time decision for switching from in-stock delivery to JIS. This switch requires a single investment in terms of changeover costs just before applying the switch. In the second case, a switch always occurs with a corresponding reverse switch. This cases refers to the situation when a certain development is foreseeable, e.g. a high number of existing orders for a few weeks or months. Therefore, the switch to JIS lasts only for a certain time-period according to the known development. The third case includes the uncertainty at which point in time the switch is conducted. Thereby the switch from in-stock delivery to JIS and vice versa can be executed whenever necessary and reasonable. All three cases are focusing the profitability of a switch and answer the following questions: Is a switch profitable? After how many periods does a switch pay? The forth case stands for flexible switches: In this case, a prior investment is done to lower later changeover costs for unplanned switches. Due to lower changeover costs the profitability to switch the supply concept is higher than with the initial changeover costs. Therefore, a switch becomes more possible. In contrast to the other cases, the last case focuses on improving the switching possibilities and answers the question: Does an investment pay to less expensive changeover costs later? This case becomes important when a supply concept switch is refrained. A switching omission leads to opportunity costs for the manufacturer – i.e. lost savings, because the alternative supply concept is assumed to be more cost-efficient. A higher flexibility may prevent from refraining the switch. Note, that the cases only address switches to possible supply concepts. Concepts that are not used so far (e.g. JIS milk run in Table 1) first must be planned and enabled. This generates installation costs, which are not equated with changeover costs.

All four cases can be applied when seeking for a switching decision. Each case is suitable for certain circumstances. For material with a highly unforeseeable future development, the flexibility to switch the supply concept immediately seems favorable and the corresponding investment should be assessed. However, for material that is occasionally subject to changes, a one-time switch or a switch and reverse switch might be more suitable. When applying all four cases, the different solutions can be interpreted as sensitivity analyses.

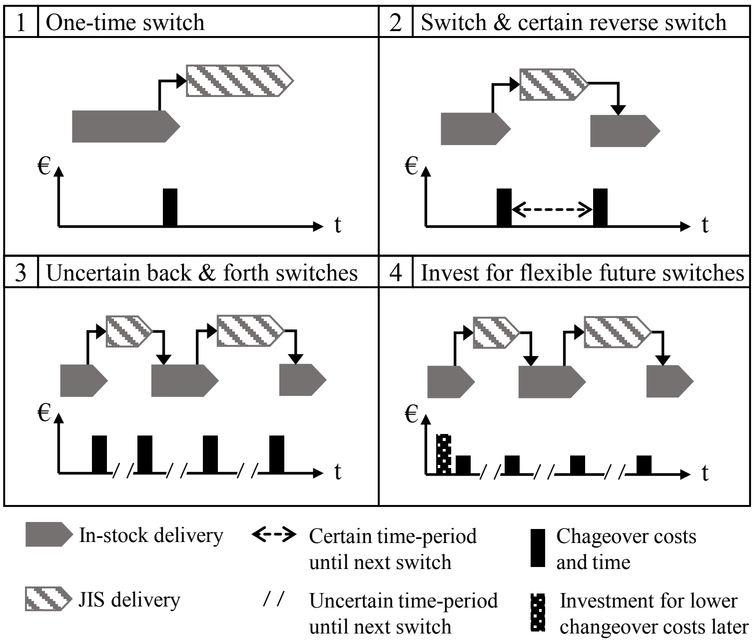

Figure 4 – Cases of switching decisions

The follow-up question to these case distinctions is: How can a decision be made for each case taking into account the case-characteristic differences? For each case, there are changeover costs occurring for a single switch – i.e. the necessary investments and labor expenses to execute all necessary activities regarding the switch. Furthermore, it was assumed that a switch takes place when the new concept is more cost efficient than the initial supply concept. That is, each switch releases potential cost savings calculated by the difference of the costs occurring for the initial and the new supply concept. Consequently, each switch includes an investment (changeover costs) followed by expected return flows (potential savings). The stated decision problem can thus be regarded as an investment decision in a predictive environment (cases 1 and 2) and an uncertain environment (cases 3 and 4).

A typical method to solve investment decisions is the *net present value* (NPV) method. This method includes all arising cash flows in chronological order by discounting all cash flows to a certain point in time. I.e. the present value of the expected cash flows of a project is subtracted by the project investment (Abele *et al.*, 2006; Lee and Lee, 2007). It is the most common method of all dynamic investment techniques (Weskamp *et al.*, 2015). However, the NPV method does not consider uncertainty and flexibility sufficiently, although these are main characteristics of an investment process (Weskamp *et al.*, 2015). The NPV method always underestimates more flexible concepts. Thereby, it rather discourages from future investments (Abele *et al.*, 2006). Hence, this method seems only appropriate for case 1 and 2, since these cases consider decisions in certain or at least more foreseeable environments. The result of this method indicates, after which period the switch pays off due to the savings of the new supply concept.

A possible method to capture the challenge of uncertainty and flexibility is the application of *real options*. The field of studies regarding real options is broad – Dixit and Pindyck (1994) and Trigeorgis (2004) are two of many standard works. Generally, an option is the right to realize an action in the future – in which the term right does not refer to an obligation (Amram and Kulatilaka, 2003). Real options are similar to financial options. But instead of modelling the option for buying or selling financial commodities, real options are used to model investment opportunities (Nembhard *et al.*, 2003). According to Trigeorgis (2004) seven types of real options can be differentiated. One type is the *option to switch*, which can be referred to the decision problem presented in this paper. This option type allows to choose between different investment alternatives or the initial investment itself. This type of option is also applicable after the investment process has been started (Weskamp *et al.*, 2015). As real options are a common tool to model decisions under uncertainty, it seems appropriate for case 3 and 4. The future switches are interpreted as a series of options. The value of each option includes the corresponding changeover costs and the savings of the new supply concept. These determined values are compared to the initial investment to decide whether this investment is worth it.

Flexible switching

As flexibility is a widespread term in many research fields, this chapter focuses on explaining the meaning of flexibility and on ways to increase it in the context of the inbound logistics. A comprehensive definition overview of flexibility and related terms, such as changeability, transformability and agility, in manufacturing systems is presented by Wiendahl *et al.* (2007). The derived definitions are transferable to inbound logistics as this process is closely related to production processes. Flexibility is referred to as the tactical ability to switch the production system by changing logistics and manufacturing processes with only little time and effort (Wiendahl *et al.*, 2007). This is applicable to the inbound process: The inbound process is flexible, when the used inbound concept can be switched with a low amount of time and effort to a specified alternative. The amount of time and effort are represented by the changeover costs explained above. The higher the changeover costs the less flexible the inbound process is when deciding to switch. To increase a low flexibility degree, the inbound process needs to be transformed. I.e. a transformation of the switching procedure or the inbound process itself, facilitates a supply concept switch and thus increases flexibility.

The main question for practioners will be less the way of assessing flexibility, but rather the actions that need to be taken to increase flexibility and thus to prevent from refraining supply concept switches. Refraining a switch leads to opportunity costs and should therefore be impeded. For this reason, additional logistics expert interviews with employees of the commercial vehicle manufacturer were conducted. The objective is to identify possible actions, which enable case 4 by adapting the inbound process and thus lowering the overall changeover costs. The interviews built up on Table 2 and focus on the obstacles, which incorporate the most cost and time intense activities. However, external obstacle categories can hardly or only little be influenced by the manufacturer. To give some examples: The time it takes to enable the internal infrastructure of the supplier for the new supply concept is difficult to reduce, because it is the supplier's responsibility. The costs a service provider raises for planning the launch of a new supply concept can possibly be decreased, but the room for negotiation is probably small.

Three major actions can be derived to reduce the obstacles from switching the supply concept: *Improvement of IT adjustments*, *improvement of coordination with relevant interface departments*, and *contractual arrangements*. The *improvement of IT adjustments* is obviously an activity that is time intense for both manufacturer and supplier. An improvement can be a systemic solution for the call-off orders that is identical for all supply concepts – currently different systems are used. The costs to introduce such a system depend on the capabilities of the systems that are used so far. The *coordination with relevant interface departments* should be improved in order to fasten the entire switching process. If the process is done manually, it probably takes longer than with an automated and standardized solution. I.e. a systemic workflow that informs employees and assigns tasks to them. However, such a workflow tool probably requires high expenses. The last major action needed to enable higher flexibility addresses *contractual arrangements*. Suppliers have to agree to flexibility, to be able to prepare the own systems for flexible switches. The contracts with forwarders probably need to be revised regarding flexible switches. All three actions can be seen as the initial investment of case 4 to reduce changeover costs for future switches. An assessment with real option can show, whether these actions pay off.

Conclusion

The considered decision problem examines whether to switch the current supply concept to another more cost-efficient supply concept in the automotive inbound logistics. As changes occur continuously over time, the improvement of flexibility to switch supply concepts more easily becomes increasingly important. The paper at hand provides a comprehensive framework for decision-making for switching the supply concept. General obstacles when switching a supply concept are defined. A practical example for necessary activities when switching from in-stock delivery to JIS is given, based on expert interviews from a commercial vehicle manufacturer. The decision-making is clustered into four cases, distinguished by the degree of uncertainty and prediction of future developments. The switching decisions for the two predictive cases are suggested to be solved by NPV. For the cases under uncertainty the method of real options is proposed as a suitable decision-making method. All cases examine whether a supply concept switch is profitable. The last case additionally explores whether an investment should be made to lower later changeover costs and to avoid possible opportunity costs in the future.

One main open issue is to apply the two identified methods for decision making (NPV and real option) in practice. Several input data are needed for a practical case: Reasonable time periods, expected cash flows for the savings of the alternative supply concept, and changeover costs. When applying the presented framework to practical examples, sensitivity analysis should be done to validate the suitability of the chosen methods.

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