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## Flexibility of industrial product service systems: An assessment based on concept modelling

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**Flexibility of Industrial Product Service Systems -  
An Assessment Based on Concept Modelling**

**Arbeitsbericht Nr. 8**

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# 1 Introduction

Companies from established industrial nations are faced with a multitude of threats, caused especially by companies from developing nations such as India or China. In the past, these threats were primarily based on the common practice of imitating products of competitors from developed, industrialised nations. These imitations exacerbate the amortisation of investments in research and development and can even render it impossible. Growing capabilities and competencies of such competitors pose a further threat, since companies from developed industrial nations are unable to compete with the low labour costs of the aforementioned companies. Shorter product life cycles and insufficient leverages to protect know-how when selling highly complex technology pose further competitive challenges. Focusing on providing products does no longer suffice to create a viable economic basis for company success. Consequently, markets have experienced a shift of focus from products to market requirements and an augmentation of the importance of services. Encompassing this, significant effort is dedicated to an interwoven integration of products and services in order to generate a sustainable competitive edge and prevent out-suppliers from penetrating the customer-supplier relationship. As a consequence, bundling product and service components has become a common practice in many markets and is prevalent especially in the production technology sector. By means of bundling, suppliers want to tap unused product potential and enable product customization. Against this background of offering customized combinations of products and services, we propose Industrial Product Service Systems (IPS<sup>2</sup>) as a solution to individual customers' problems. The possibility of flexibly adopting the IPS<sup>2</sup> to changing customer needs is an inherent characteristic of this approach.

This paper aims at pointing out possibilities of evaluating this flexible adoption from an economic point of view based on a concept model. Section 2 explains flexibility with regard to IPS<sup>2</sup>. Economically relevant customer drivers for the planning of initial IPS<sup>2</sup> and an integrated modelling approach for the IPS<sup>2</sup> concept are being highlighted. Section 3 widens this static perspective by including customers' switching options regarding the IPS<sup>2</sup> configuration. We regard the opportunity of employing the chosen modelling approach to define these switching options. Based on this engineering approach, we discuss the net option value of IPS<sup>2</sup> flexibility from an economic point of view in Section 4. The paper concludes in Section 5.

## 2 Industrial Product-Service Systems (IPS<sup>2</sup>)

### 2.1 Significance of Flexibility for IPS<sup>2</sup>

IPS<sup>2</sup> are characterized by an integrated and mutually determining process of planning, developing, provisioning, and using of goods and services. They constitute a problem solution for Business-to-Business markets, customized to individual customers' needs along the IPS<sup>2</sup> life cycle. Customizing an IPS<sup>2</sup> and integrating flexibility is primarily based on the possibility of partially substituting product and service components to meet customer requirements. This crucial characteristic of IPS<sup>2</sup> takes effect along two dimensions.

*Static Perspective* - can be assumed to configure tailor-made problem solution (initial IPS<sup>2</sup>). The superior combination of products and services is determined by present customer needs ( $t_1$ ).

*Dynamic Perspective* - broadens the static perspective to warrant the adjustment of IPS<sup>2</sup> to the changing customer environment during the delivery and use phase (IPS<sup>2</sup>-flexibility) ( $t_2$ ).

The IPS<sup>2</sup> replacement option, displayed in fig. 2.1, must be considered as a special option without anticipating flexibility in an initial IPS<sup>2</sup>. Following Sanchez (1997), we define flexibility as the potential of adjusting a system to changing environmental conditions. Uncertainty related to these changes plays a very important role in this regard. Henceforth, we consider IPS<sup>2</sup>-flexibility as an extension of the static IPS<sup>2</sup> perspective by including decision options, or switching options respectively, in order to allow for an adjustment of the IPS<sup>2</sup> solution to changing environmental conditions over a given period of time. The explicit anticipation of switching options already in the initial IPS<sup>2</sup> configuration is central to this approach.

### 2.2 Value Drivers as Determinants of the Customer-Supplier Solution Space

The possibility of partially substituting product and service components enables suppliers to provide problem solutions tailor-made to satisfy individual customers' needs along the dimensions "make-or-buy" and "manual-or-automatic process execution". This tailor-made problem solution has to

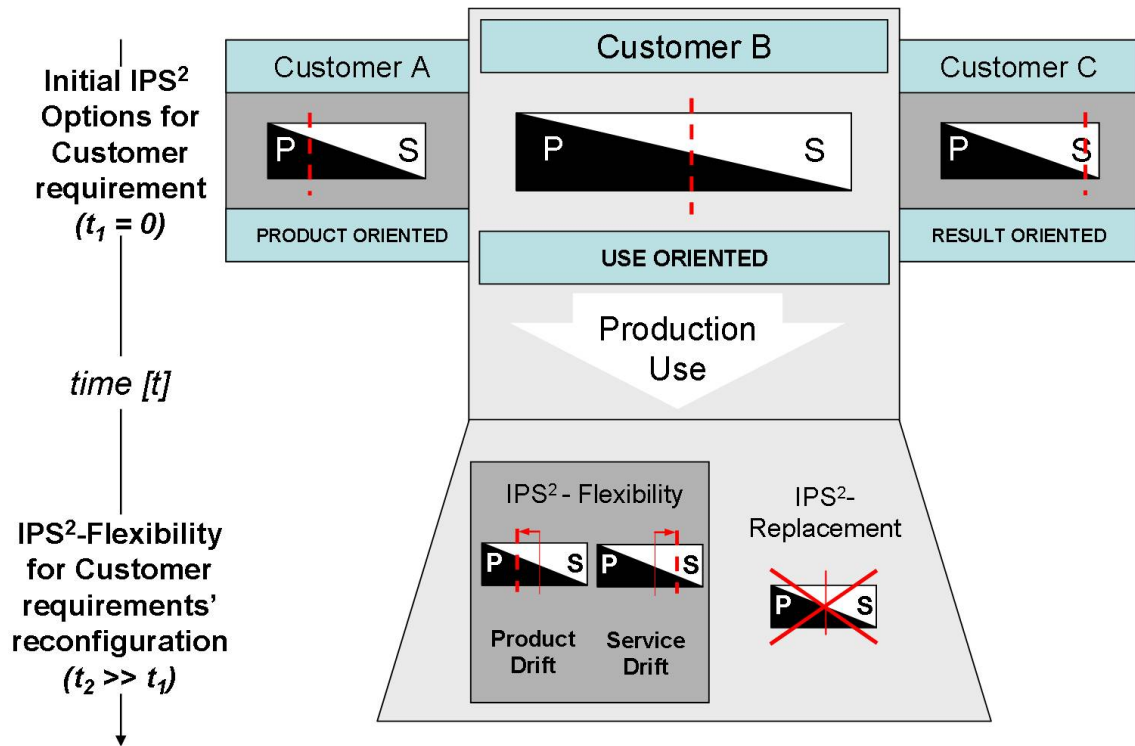


Figure 2.1: Initial IPS<sup>2</sup> options and flexibility over time

- be technologically viable,
- generate a positive customer value which is superior to the value of the best competing offer and
- ensure sustainable profitability for the supplier.

Technological limitations of possible IPS<sup>2</sup> concepts result from the current state of technology on the one hand, and from the respective supplier portfolio of potential offers on the other hand. The economic consequences of IPS<sup>2</sup> for customers depends on the strength and composition of customer value drivers. These can be either *corporate structure drivers* such as customers' know-how, number of employees and resources, or *customer process drivers* such as the complexity and significance of processes that IPS<sup>2</sup> are used in. Depending on these drivers, customers will prefer manual/automatic process execution going alongside with a make/buy decision as a solution for a certain process. However, from the wide range of theoretically possible IPS<sup>2</sup> configurations only a limited number of configurations meet suppliers' economic needs as well and could therefore be offered to customers. The combination

## 2. Industrial Product-Service Systems (IPS<sup>2</sup>)

of technological aspects as well as customers' and suppliers' economic criteria yields the IPS<sup>2</sup> *solution space*, as illustrated in fig. 2.2.

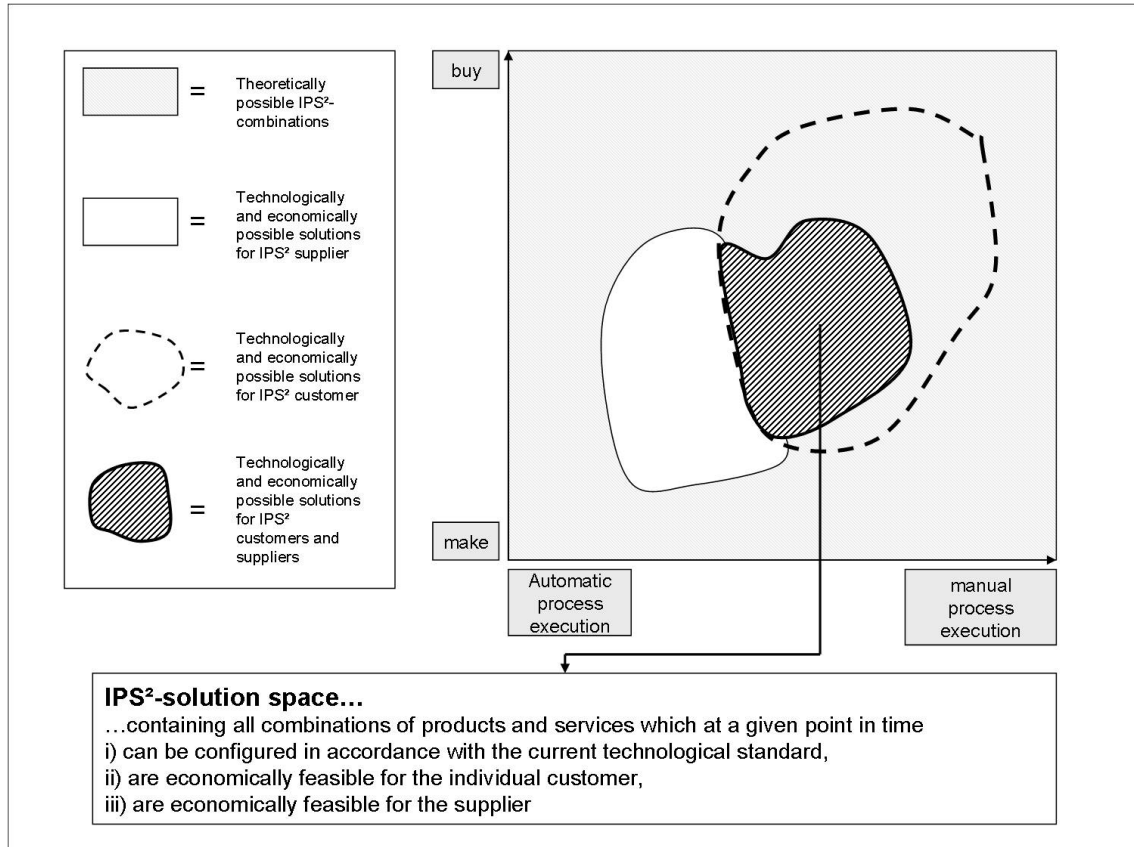


Figure 2.2: Combining the customer and supplier side to identify the IPS<sup>2</sup>-solution space

This definition of a common solution space marks the first step towards developing a performance concept tailored to individual customers. Such performance concepts are crucial parts of determining IPS<sup>2</sup> requirements. The identification of the strength of customers' value drivers does not suffice to develop an initial IPS<sup>2</sup> concept. As an essential aspect of concept development the influences of drivers' interdependencies have to be equally considered. Information about IPS<sup>2</sup> requirements serve as input to the integrated development of products and services. The interface for development constitutes a functional level of modelling, whose importance in the context of the IPS<sup>2</sup> concept model will be further specified in the following.

### 2.3 Approach for the Development of Initial IPS<sup>2</sup> Concepts

Conceptualizing IPS<sup>2</sup> is a model based process. Following the general understanding of the term (Lippold 2000) 'model', in an IPS<sup>2</sup> context, denotes a consciously constructed aim-oriented representation of an original. Describing relevant elements and interrelations on different levels of abstraction, a model serves the purpose of enabling both analysing and synthesising steps of development for the transformation of a cognitive construct into a real technical solution. Beginning with the depiction of customer requirements in a requirements model, integrated product and service development generates a variety of technical and economic partial models, whose point of integration is embedded in the IPS<sup>2</sup> concept model during the early phase of product development. This 'early phase' of product development contains all steps, from the capturing of requirements (input) to the development and modelling of assessable IPS<sup>2</sup> concepts (output) (Pahl et al. 2007). An IPS<sup>2</sup> concept of intermediate abstraction comprises all elements and their respective relationships among each other that are necessary for modelling and examining technical and economic IPS<sup>2</sup> characteristics. Such an early clarification of characteristics is advantageous, as it bears the potential of strongly influencing problem solutions at relatively low costs (Ehrlenspiel 2007).

Especially in the early phase of product development it is essential to dissolve the traditional boundaries between products and services and to combine them in an integrated concept modelling approach. By doing so the potential of concept models is being made available to IPS<sup>2</sup>-flexibility. How such a dissolution of boundaries between products and services is achieved, can be easily exemplified without delving deeply into definitions of products and services (Bullinger et al. 2006, Backhaus and Kleinaltenkamp 2001). For example: Starting with the function of "adjusting machine behaviour to changing conditions" the following customized solutions are possible:

- *manual service*: Machine and service personnel are not spatially separated. The service personnel follow handbook instructions when reacting to changes in machine behaviour.
- *teleservice*: the machine is monitored externally. Manipulations of machine behaviour are carried out by service personnel via IT support located in a control room, which is spatially separated from the machine itself.
- *automatic service equals mechatronic system*<sup>1</sup>: The machine status is monitored by sensors and evaluated via IT devices. Reactions to changes in conditions are carried out by the machine itself by means of mechatronic devices.

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<sup>1</sup>Mechatronic systems are technical products consisting of mechanic, electronic and IT components.



## 2. Industrial Product-Service Systems (IPS<sup>2</sup>)

This example shows that, as Engelhardt et. al. have defined (Engelhardt et al. 1992), pure product or service solutions do not exist, only hybrid forms are possible. In order to fulfil functions defined by customer requirements, whether these be a product or service, both resources (human, sensor, actuator, etc.) and actions (maintenance guidelines deposited in the manual, Software for processing a sensor signal etc.) are required. This new approach to integration leads to a definition of the IPS<sup>2</sup> concept model which is an extension of a modelling approach for mechatronic systems (Jansen and Welp 2005). The basic structure of an IPS<sup>2</sup> concept model as resultant from this approach is shown in fig. 2.3. It is generated by linking three modelling levels which are defined as IPS<sup>2</sup> functions, IPS<sup>2</sup> resources and IPS<sup>2</sup> actions (Welp and Sadek 2008, Welp et al. 2008).

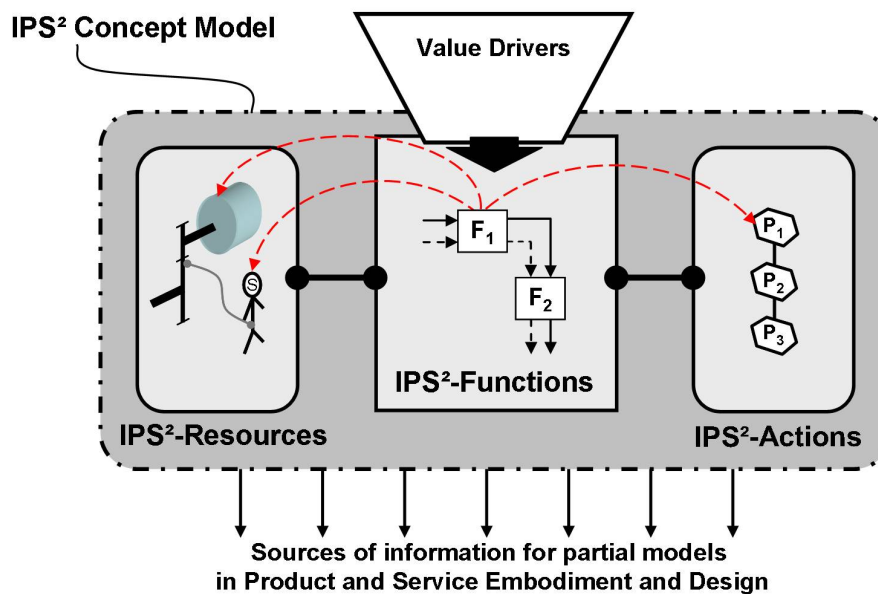


Figure 2.3: Modelling levels of the IPS<sup>2</sup> concept model

Making use of analytical and synthesizing procedures, an IPS<sup>2</sup> concept is developed, based on requirements regarding the determination of functions and the deduction of IPS<sup>2</sup> resources and actions (see fig. 2.3). Concerning initial IPS<sup>2</sup>, configurations oriented at respective customer needs are anticipated at the functional level of the IPS<sup>2</sup> concept model in an abstract fashion. Following the understanding of IPS<sup>2</sup> as a customized problem solution, degrees of freedom to realize required functions arise on the supplier side. The IPS<sup>2</sup> solution space, described in section 2.2, combined with the partial substitution of products and services generates a multitude of possible combinations of resources and actions, which by far exceeds a purely product-

## 2. Industrial Product-Service Systems (IPS<sup>2</sup>)

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induced complexity. Without specifying the variant management of IPS<sup>2</sup>, aspects of modularisation of IPS<sup>2</sup> resources and actions and the development of efficient IPS<sup>2</sup> platform strategies gain special importance from an engineer's perspective. This is the case for the dynamic and static perspective alike.

## 3 Integrating IPS<sup>2</sup> Flexibility Into the Initial IPS<sup>2</sup> Configuration

### 3.1 Identification and Anticipation of Changing IPS<sup>2</sup> Value Drivers

The life cycle oriented IPS<sup>2</sup> perspective and a period dependent consideration of the same in the delivery and use phase could lead to essential endogenous und exogenous changes of the value drivers described in section 2.2. These may be induced by changing environmental conditions (such as amendments, technological developments etc.) on the one hand, as well as by changes in customer structure (e.g. change of strategy, re-orientation in the market) on the other hand. These changes may affect the form, significance and interdependency of these value drivers, based on which the IPS<sup>2</sup>-solution space is defined and the development of the initial IPS<sup>2</sup> takes place. Possible changes of value drivers impact on inpayments and outpayments on the customer side. Consequently, a shift in advantageousness of different solutions takes place, manifesting in changes of the IPS<sup>2</sup> solution space. This is shown in fig. 3.1 by comparing solution spaces for initial IPS<sup>2</sup>, IPS<sup>2</sup> in the middle of the lifecycle and IPS<sup>2</sup> towards the end of the same. The three stages chosen merely serve the purpose of exemplification. The occurrence of driver changes is explicitly taken into consideration along the IPS<sup>2</sup> life cycle.

As mentioned before, one intrinsic characteristic of IPS<sup>2</sup> consists in maximizing the customer value over the IPS<sup>2</sup> life cycle in order to warrant the aspired close relationship between customer and supplier. This forces suppliers to anticipate changes in value drivers already during the delivery and use phase of IPS<sup>2</sup> in the early phase of product development. The main goal thereby consists in maintaining the economic advantageousness for customers and suppliers by integrating switching options into the initial IPS<sup>2</sup> concept. In this context, three main challenges arise:

- In order to be able to consider flexibility of problem solutions for individual customers, measures of adjusting the static IPS<sup>2</sup> through supplementary IPS<sup>2</sup> resources and actions have to be made available in the early phase of product development;
- Customer value and willingness to pay, induced by the additional flexibility, have to be quantified;

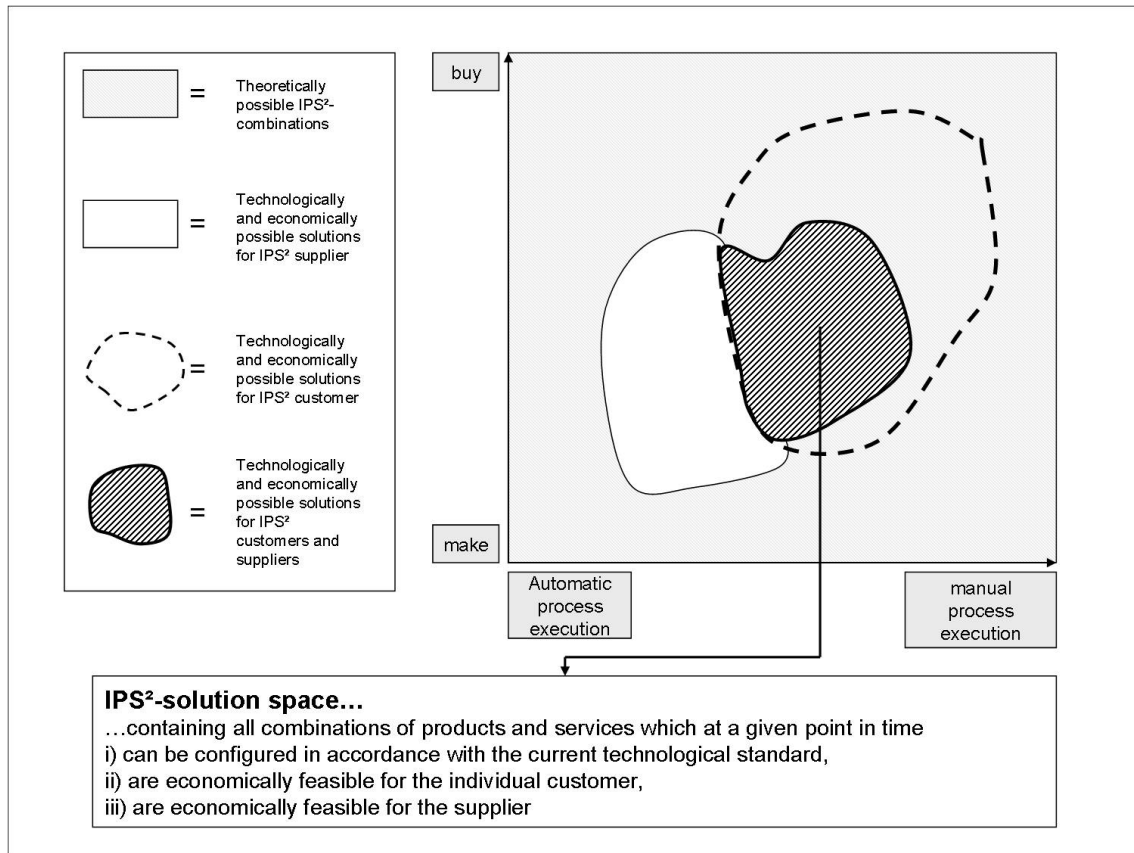


Figure 3.1: Alteration of IPS<sup>2</sup> solution space due to changes of value drivers

- Costs and revenues on the supplier side, induced by generating additional flexibility, have to be contrasted.

### 3.2 Taking IPS<sup>2</sup>-Flexibility Into Account in IPS<sup>2</sup> Concept Modelling

Delineating our understanding of flexibility throughout the IPS<sup>2</sup> life cycle against life cycle orientation in adjacent fields of study, which focus on the integration of products and services, such as "Eco-Design" (Goedkoop et al. 1999) or "Sustainability" (Tukker and Tischner 2005) helps to underline the relevance of the conceptual development phase. The focus of flexibility as it is understood in previous theories lies primarily towards the end of the product life cycle. These approaches revolve around securing product value generated through value creation and flexible utilisation of these assets e.g. in recycling product components. In contrast to this, the IPS<sup>2</sup> concept focuses on the potential of reaction, which is inherent in a problem solution during the economically important phase of IPS<sup>2</sup> generation and

### 3. Integrating IPS<sup>2</sup> Flexibility Into the Initial IPS<sup>2</sup> Configuration

utilisation. The early phase of product development is important also for the Eco-Design and Sustainability approaches. These latter approaches, however, treat it as subordinate to the phase of embodiment, in which the parameters relevant to the last phase of the product life cycle are set. The anticipation of lifecycle induced IPS<sup>2</sup> flexibility, however, requires a more strategic stance, as it has to be carried out in the early phases of product development. This aspect of IPS<sup>2</sup> flexibility is neglected by current theories of concept generation. Using the IPS<sup>2</sup> concept model it is generally possible to depict IPS<sup>2</sup> flexibility integrating products and services, as well as illustrating changes in value drivers, as can be seen in fig. 3.2. First, flexibility induced functions  $F^*$  are defined on the basis of a requirement model that is defined by the sum and characteristics of value drivers. Driver changes can either be discrete (fig. 3.2 "VD 1") or continuous (fig. 3.2 "VD 3") throughout the defined period. Moreover, these changes can have a causal relationship with constant value drivers. Both of these aspects can be explicitly taken into account in the creation of flexible performance functions (fig. 3.2 " $F_1^*$ ").

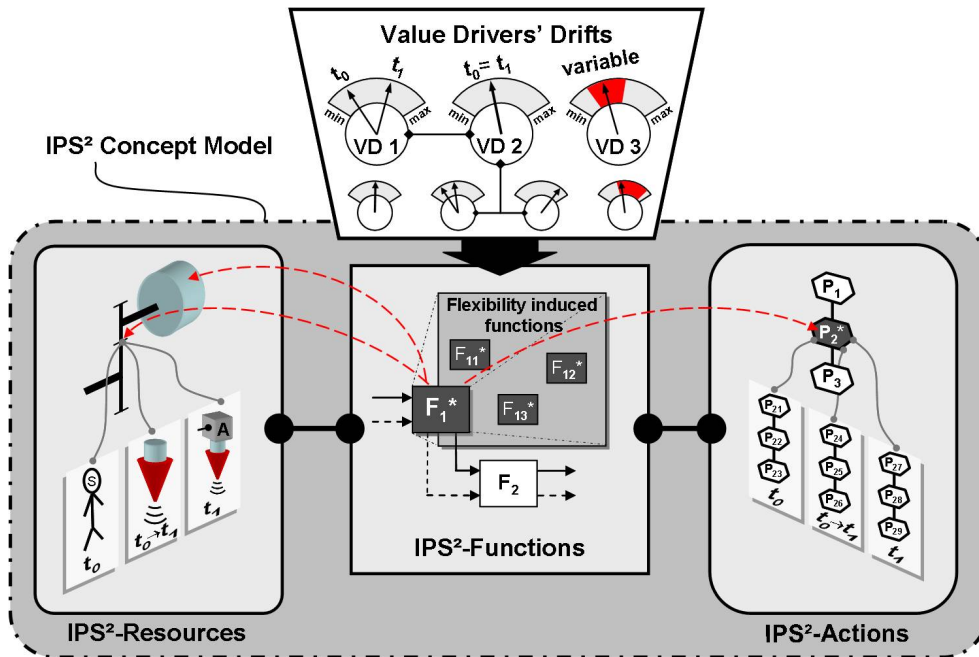


Figure 3.2: Implementing IPS<sup>2</sup>-flexibility in IPS<sup>2</sup> concept models

The variability of function characteristics is taken into consideration in the process of forming IPS<sup>2</sup>-resources and IPS<sup>2</sup>-actions. In this process, the anticipated IPS<sup>2</sup> flexibility is mirrored by time-dependent hybrid variants of problem solutions. This is exemplified in fig. 3.2 concerning the change in the degree of automation (IPS<sup>2</sup>-resources and IPS<sup>2</sup>-actions for  $t_0$ ,  $t_0 \rightarrow t_1$ ,  $t_1$ ) (Welp et al. 2008). The IPS<sup>2</sup> con-

cept model furthermore serves as an effective interface between the economic and technological perspective and is therefore supposed to support the definition and assessment of switching options.

### 3.3 Determining Real Options in IPS<sup>2</sup> Concepts

Coming from the mainly technologically oriented IPS<sup>2</sup> flexibility approach, the economic perspective on switching options has to be integrated into the IPS<sup>2</sup> concept model. We define switching options as possibilities of configuration alterations at subsequent points in time which are already included in the initial IPS<sup>2</sup> configuration. The technical concept of options is confined by the price ceiling and price floor. Customers' price ceiling equals their willingness to pay for the respective IPS<sup>2</sup> and the price floor equals suppliers' costs (Rese et al. 2007).

The combination of

- the conception of technical-economic options,
- the determination of the price ceiling and
- the determination of the price floor,

entails the following information-related dilemma: In order to conceptualize real options and switching options it is crucial to dispose of sufficient information about the previously discussed restricted economic factors. However, determining the price ceiling and price floor using the real option approach requires detailed information about the options which are to be assessed. Owing to this mutual determination of the technical and economic level of information, an integrated, iterative approach has to be applied in this context, which consists in the IPS<sup>2</sup> concept model. On the one hand this concept model serves as a source of information for the technological conception of real options. On the other hand, it serves as a "mirror" to contrast the economic perspective of IPS<sup>2</sup> from the supplier and customer point of view. Fig. 3.3 illustrates the process of acquiring a sufficient information level for the determination of real options, driven by technological and economic aspects alike.

Resulting from individual customers' value driver configurations (1) the initial information level for development is concentrated in the form of functions (2), which already anticipate the IPS<sup>2</sup>-flexibility. The determination of IPS<sup>2</sup> functions serves to identify the initial price ceiling (a). The process of further linking the customer perspective to the technical IPS<sup>2</sup> concept is conducted in step (b), by connecting customers' willingness to pay and the IPS<sup>2</sup> function structure. Building on this, IPS<sup>2</sup> resources and actions are being deducted (3). When employing resource oriented process costing, this deduction can form the basis for determining the initial

### 3. Integrating IPS<sup>2</sup> Flexibility Into the Initial IPS<sup>2</sup> Configuration

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price floor from the supplier perspective. Contrasting price ceiling and price floor combined with the elimination of information deficits (d) marks the previously mentioned economic restrictions, under which the further development of IPS<sup>2</sup> resources and activities is being effected (4). This iterative process, which aims at optimizing the price floor and price ceiling, will only be terminated if previously set criteria for termination have been met. These can either consist in reaching a certain quality of results, or in crossing a temporal threshold.

### 3. Integrating IPS<sup>2</sup> Flexibility Into the Initial IPS<sup>2</sup> Configuration

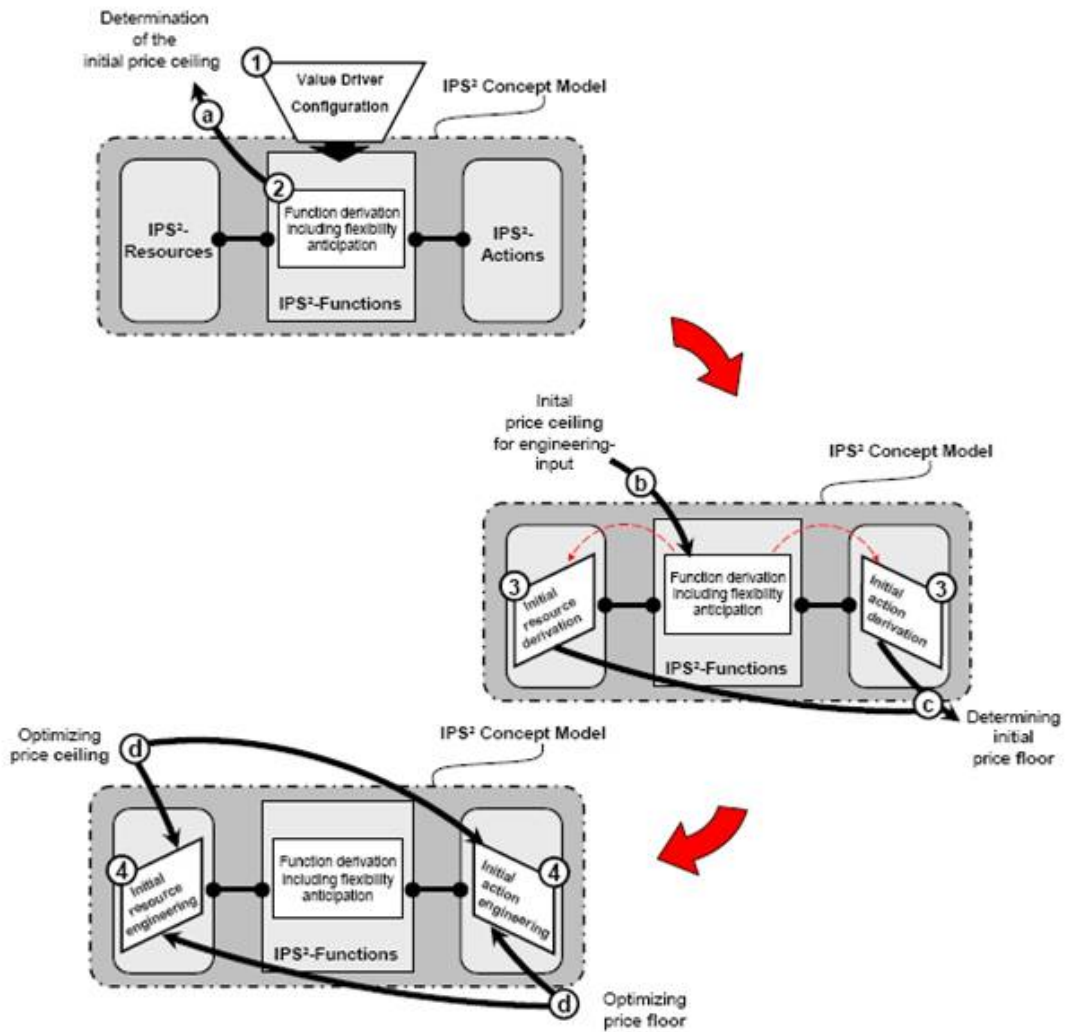


Figure 3.3: Determination of real options driven by technological and economic factors



## 4 Assessing Flexible IPS<sup>2</sup> from the Supplier and Customer Perspective

### 4.1 The Real Options Approach to Assess Flexibility

IPS<sup>2</sup> flexibility triggers consequences for suppliers' revenues (price ceiling) and costs (price floor). Assessing the flexibility of a business model can be done using the real option approach. The basis for this approach is the work of Marshak and Nelson (1962), who took flexibility into consideration by setting a 2-stage decision process, with a decision in  $t_0$  and another decision in  $t_1$ . In  $t_0$  the decider is able to choose from a set of possible alternatives, on the basis of all information regarding uncertain future environmental conditions which is available at that point in time. In  $t_1$  actual environmental conditions are known and the decider can reconsider the decision made in  $t_0$  (Miller and Waller 2003). The flexibility of a product now depends on the amount of decision options at  $t_1$ . The greater this choice set is, the higher the flexibility, which means that maximizing flexibility would consist in the maximization of alternatives. Costs for customers and suppliers, however, confine this degree of flexibility. In the following, we exemplify the real option approach expounded above. When it comes to servicing a machine, a customer could be offered the options teleservice, fully automated service or mechatronical system, as described in section 2.2. The customer decision for one of these options strongly depends on the frequency with which the service will have to be performed. If the frequency is low (state) customers will show a tendency towards teleservice because higher initial payments for an automated service would not be sensible from an economic point of view. If the aforementioned frequency is high, however, choosing an automated service is economically sensible, because services could be performed much more cost efficiently, which would compensate for the additional initial payments. To include flexibility, customers and suppliers have to decide whether a possibility of altering the type of service execution should be included in the initial configuration ( $a_1$ ) or whether customers should be bound to the initial configuration without alteration alternatives ( $a_2$ ) (see fig. 4.1).

Depending on the aspired production output of the IPS<sup>2</sup> the frequency of servicing the IPS<sup>2</sup> can increase with a probability of  $z_1$ , or decrease with a probability of  $z_2$ . While possible developments of servicing frequency are known, they only occur with a certain probability, which cause uncertainty on the customer side. Based

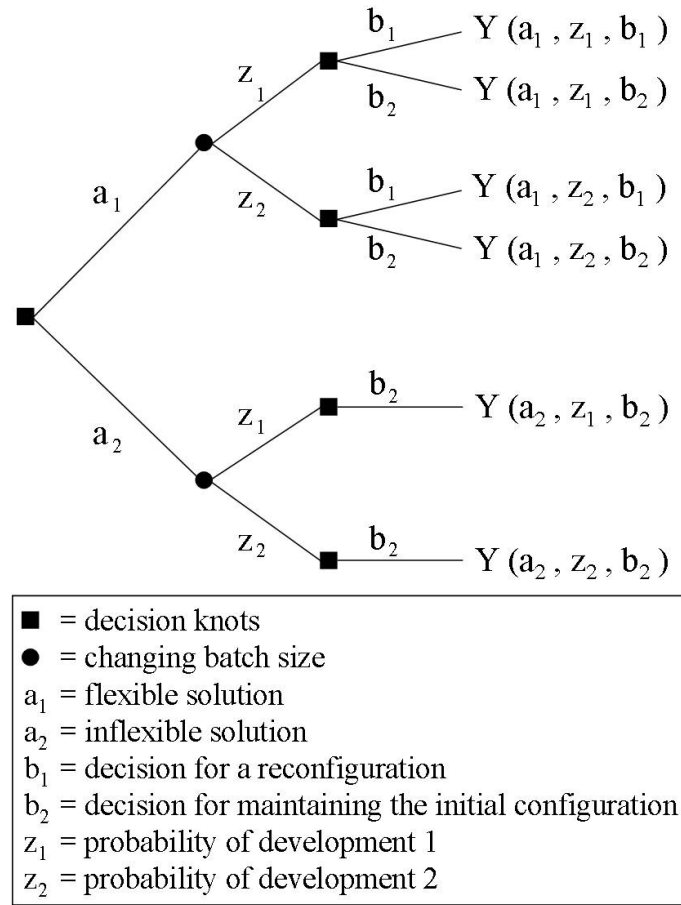


Figure 4.1: Real options decision tree

on available information about present and future conditions of servicing frequency, customers have to decide which of the servicing options to execute at the beginning of the investment. After one period they know the actual process frequency. We assume a customer decision for teleservice as part of the initial IPS<sup>2</sup> configuration. In case of IPS<sup>2</sup> flexibility customers can choose to reconfigure the IPS<sup>2</sup>, to carry out an automatic maintenance process, as a reaction to an increase in process frequency ( $b_1$ ), or maintain the previously chosen IPS<sup>2</sup> configuration ( $b_2$ ). Customers will choose the option which generates the highest value in terms of expected inpayment surpluses. In case of nonexistent flexibility ( $a_2$ ) the customer does not have the opportunity of reacting to changes in process frequency, but has to maintain the previously chosen IPS<sup>2</sup> configuration ( $b_2$ ), even if a reconfiguration would have been advantageous.

Depending on the price ceiling and price floor connected with offering this switching option the supplier now has to decide at which additional price to offer this flex-

ibility. This price can be considered a supplier leverage, by which customers can be directed towards choosing future configuration changes ( $a_1$ ) or deciding for an initial configuration, which is set over the IPS<sup>2</sup> life cycle. Suppliers will only direct customers towards the latter, if the additional price which customers would have to pay for the flexibility exceeds the value of this flexibility.

### 4.2 Determining the Price Ceiling

The price ceiling is exactly that price, which matches the customers' maximum willingness to invest in the IPS<sup>2</sup>. This means that customers

- decide to invest in one of the solutions available to them and
- prefer the IPS<sup>2</sup> over comparable competing offers.

This is only the case, if the overall value of an IPS<sup>2</sup> is positive and higher than that of competing offers, which customers take into consideration for their investment (evoked set). This overall value consists of the project value that is the investment value without the price charged by the supplier, and the costs of acquiring the IPS<sup>2</sup>, which equal the aforementioned price. If, from a customer perspective, no comparable alternatives exist, an overall value of zero is sufficient, formally put as:

$$-P + PV \geq 0,$$

with:  $P$ : price of IPS<sup>2</sup>

$PV$ : project value of IPS<sup>2</sup>.

Setting the overall value = 0 and solving this equation to  $P$ , yields the price ceiling as:

$$P^{\max} = PV$$

This means that, via the price, the supplier is able to skim the total project value, or customer value respectively. It is common practice to determine this project value using the net present value (NPV) approach. The project value equals the NPV without considering the price initially charged by the supplier.

$$PV_0 = \sum_{t=1}^n (I_t - O_t) \cdot (1 + \text{wacc})^{-t}$$

with:  $PV_0$ : project value in  $t_0$ ,

$I_t$ : inpayments in period  $t$ ,

$O_t$ : outpayments in period  $t$ ,

wacc: weighed average costs of capital of the customer.

The weighted average costs of capital quantify the rents that the investors as well as the outside creditors of the project expect (Farber et al. 2006, Husmann et al. 2006). Under competition, the overall IPS<sup>2</sup> value has to be superior to the best competing offer, formally put as:

$$-P + PV > -P^C + PV^C$$

with:  $PV^C$ : project value of the best competing offer,  
 $P^C$ : price of the best competing offer.

The differential advantage (Oxenfeldt 1979 of the IPS<sup>2</sup> in comparison to the best competing offer is defined as (Rese 2007):

$$(-P + PV) - (-P^C + PV^C)$$

Setting this equation to 0 and solving it to  $P$ , yields the price ceiling as:

$$P^{\max} = P^C + PV - PV^C$$

Thus, the IPS<sup>2</sup> price can exceed the price of the best competing offer to the amount that the IPS<sup>2</sup> project value exceeds the project value for the customer (Rese 2007). This triggers the question of how to determine the project value under consideration of real options. The initial step consists in determining the decision which a customer will make depending on different states and points in time. This determination is conducted using the rollback method (Magee 1964, Copeland and Tufano 2004), which is based on the assumption that for every decision customers will choose the option which maximizes the expected project value. This means that for each situation which could occur in  $t_1$  customers will try to maximize the expected sum of the future discounted inpayment surplus, which is connected with the respective decision:

$$D(b_j^{\text{opt}}) = \max[D(b_1), D(b_2)]$$

with:  $D(b_j)$ : decision value of option  $b_j$   
 $b_j^{\text{opt}}$ : optimal decision in period 1.

In the following, only decisions which are optimal in  $t_1$  are taken into consideration. The next step is to determine the optimal decision in the one before last period. In our example this is the decision regarding the initial IPS<sup>2</sup> configuration. The discounted inpayment surpluses connected with the decisions originating from possible

future states  $z$ , are multiplied with the probability of occurrence of these states and then summed up.

$$D(a_1) = p(z_1) \cdot Y(a_1, z_1) + p(z_2) \cdot Y(a_1, z_2)$$

with:  $D(a_1)$ : decision value of decision  $a_1$ ,  
 $p(z_j)$ : probability of occurrence of state  $z_j$   
 $V(a_1, z_j)$ : value of state  $z_j$  under configuration  $a_1$ ,

with  $Y(a_i, z_j)$  being a sum of the discounted inpayment surpluses until making the next decision and the optimal decision value  $D^{\text{opt}}$  originating from the respective states. The IPS<sup>2</sup> project value equals the decision value of the chosen initial IPS<sup>2</sup> configuration.

$$PV = \max[D(a_1), D(a_2)]$$

The willingness to pay regarding the option chosen by the customer with or without flexibility can now be determined using the above mentioned formula. In order for suppliers to decide whether or not to offer their customers the respective flexibility, the degree to which flexibility enhances the willingness to pay has to be determined. Differences for the willingness to pay with and without flexibility can be put as:

$$\begin{aligned} \Delta P &= P^{\max}(a_1) - P^{\max}(a_2) = P^C + PV(a_1) - PV^C - P^C - PV(a_2) + PV^C \\ &= D(a_1) - D(a_2) \end{aligned}$$

Building on the determination of customers' willingness to pay (option value), suppliers' costs induced by offering flexibility (net option value) will be discussed in the following.

### 4.3 Strategic Management Accounting for IPS<sup>2</sup>

Pricing delivers information about requirements and chances in a given market (price ceiling). Contrary to this, costing serves as a means of determining whether decisions made in the market are viable (price floor). Only a comparison of price ceiling and price floor resulting from IPS<sup>2</sup>-flexibility can give answers to the question of whether and to which extent flexibility should really be offered to the customer. Furthermore, costing serves to clarify in how far flexibility should already be considered in the initial IPS<sup>2</sup> configuration. The first mentioned aspect deals with the basic decision of investing in flexibility, while the latter aspect regards the timing of investment. Resulting from the special characteristics of IPS<sup>2</sup>, requirements for cost accounting, as a planning instrument in the concept phase, need to be deducted. These requirements provide a basis for the investment decision regarding flexibility.

In the following section the concepts identified for the establishment of flexibility are discussed in the context of the previously developed methodology of evaluation. We do not illustrate and discuss cost allocation in detail. On the one hand, the basis for allocation is already predetermined by the concept model and its differentiation in IPS<sup>2</sup> resources and actions. Hence, the use of resource oriented activity based costing (Eversheim and Kümpfer 1996) seems appropriate. On the other hand, the discussion of cost accounting for strategic decisions appears to be necessary for two reasons:<sup>1</sup>

Firstly, cost accounting is supposed to provide information for solving decision problems in the IPS<sup>2</sup> concept model and therewith in the early phase of development. Future cost structures have to be adjusted to market conditions to ensure an advantageous investment. Traditional cost accounting systems, however, assume given firm structures resulting in the management of costs primarily in the production phase. Secondly, IPS<sup>2</sup> life cycle oriented characteristics necessitate a strategic planning of costs. Traditional costing techniques do not account for these characteristics, as they periodically determine costs for short term problems of planning. A prominent tool which takes effect already during product planning and development is target costing. Owing to its long term focus and market orientation it seems to be well-suited for IPS<sup>2</sup>.<sup>2</sup> In the following we evaluate the applicability of these target costing characteristics to the IPS<sup>2</sup> conception.

Due to its long term focus, target costing enables the life cycle oriented optimization of the relationship between revenues and costs. This life cycle oriented perspective entails a payment oriented view on costs (outpayments) and revenues (inpayments). Assessing an IPS<sup>2</sup> concept therefore needs to be based on the NPV of inpayments and outpayments. This approach offers the advantage of exposing underlying decision and payment interdependencies through the IPS<sup>2</sup> life cycle analysis. This is especially important with regard to interactions of products and downstream services and the payments connected to them. Managing the incurrence of costs (outpayments) over the entire IPS<sup>2</sup> life cycle is therefore indispensable: Decisions such as whether the supplier aims at gaining profit mainly through servicing, or to which extent to invest into reliability of the product have to be made already during IPS<sup>2</sup> conception.

The second characteristic of target costing, its market orientation in form of static subtraction methodology, has to be regarded critically concerning its contribution to

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<sup>1</sup>See Ewert and Wagenhofer (2003), S. 272ff. for strategic-oriented cost accounting. Also see Jahnke and Chwolka (1998) for another, game theoretic interpretation of strategic cost accounting.

<sup>2</sup>Ewert and Ernst (1999) consider effort coordination as a third dimension connected to asymmetric information structure. We do not consider this dimension as we do not focus on asymmetric information.

long-term cost management (Ewert and Ernst 1999). Dynamic relationships rather exist between input and output, or costs and revenues respectively. The information related dilemma discussed in section 3.3 describes the emerging complex of problems regarding concept modelling. As value drivers, which have to be considered for the initial development, are incomplete, different concept alternatives not only induce different costs, but also different levels of willingness to pay. The iterative approach including customer evaluations of various concept alternatives solves this problem and identifies the alternative with the highest NPV. This implies an investment theoretic conception of costing, whose central planning task consists in forecasting (concept) alternatives' effects on payments. Thus, the traditional periodic consideration of costs is being replaced by an analysis of effects (Küpper 1985).

### 4.4 The Net Option Value of IPS<sup>2</sup>-Flexibility

Selling IPS<sup>2</sup>-flexibility generates an additional customer value  $\Delta P$ , as described in section 4.2. This value stems from the options' characteristics of reducing possible losses resulting from unfavorable environmental developments in comparison to an initial, static perspective. On the other hand, selling options, and thereby IPS<sup>2</sup>-flexibility, can be considered as selling an insurance policy. IPS<sup>2</sup> suppliers enter a contract which obliges them to offer an adjusted IPS<sup>2</sup> in the future under conditions which are set today. As opposing to the asymmetric structure of outpayments connected with an option, the potential payoff which a future contract generates is symmetric with regard to the value development of the subject matter of contract. Hence, by selling options, the supplier assumes responsibility for the consequences of unfavourable environmental conditions. This implies a superior potential of managing the system immanent risk on the supplier side in comparison to the risk management of the customer, as risk transfer would otherwise not constitute an additional benefit for the business relationship. In this case costs connected to offering IPS<sup>2</sup> flexibility would equal or exceed customers' willingness to pay. Risk reduction on the other hand implies a lower risk premium, causing a cost advantage for the IPS<sup>2</sup> supplier compared to the customer.

In other words, suppliers are able to build up (strategic) flexibility at much lower costs than customers. According to Sanchez (1997), building up strategic flexibility requires access to flexible resources and the potential of flexibly coordinating these resources for alternative purposes. This means that the supplier cost advantage over customers is mainly based on the disposability of flexible resources. Reverting to Ghemawat and del Sol (1998), flexibility of resources has to be further differentiated into firm flexible and usage flexible resources, which renders a continuum of alternative concepts to build up different flexibility potential. In this context it is crucial to note that each concept irreversibly defines the operating strategy regard-

ing given customer options up front. As a consequence, the net option value (NOV) of a concept should be determined using the NPV approach:

$$\text{NOV} = \Delta P - \sum_{t=0}^T \frac{E(CO_t)}{(1+k)^t},$$

where  $E(CO_t)$  is the expected cash outpayment for flexibility in period  $t$  and  $k$  the risk adjusted discount rate. If the NPV is greater than zero, an investment in flexibility is advantageous. The supplier is thus faced with having to choose the concept alternative which promises to yield the maximum payment surplus under uncertain environmental conditions, with uncertainty impacting on outpayments. Possible alternatives in the concept phase regarding a given requirement for flexibility (options sold to the customer) can, in accordance with section 2, be characterised as

- integrating flexibility into the initial IPS<sup>2</sup> configuration and
- offering IPS<sup>2</sup> replacements.

When offering an IPS<sup>2</sup> replacement, IPS<sup>2</sup> suppliers make use of the advantage of company flexible resources, which enable suppliers to employ the initial IPS<sup>2</sup> for different customers and thereby increase its durability and spread the risk over various contractual relations. In the example introduced in subsection 4.1, an IPS<sup>2</sup> replacement would initially result in a specific customer solution in form of tele-service. If desired by the customer it would have to be replaced completely by a mechatronical system and could be used for the next customer. Alternatively, the initial IPS<sup>2</sup> could be equipped with a technological device to facilitate and speed up the reconfiguration to an automatic service execution. This reconfiguration is supported by implementing a modular construction, which allows for manifold design options (Baldwin and Clark 2000). The advantage of an IPS<sup>2</sup> replacement consists in the possibility of delaying the outpayments triggered by the replacement until the customer chooses to execute his switching option. If a customer really does choose to execute the switching option, however, the IPS<sup>2</sup> replacement is accompanied by high costs of adjustment, since an entirely new solution has to be provided to the customer. This can result in higher overall costs on the supplier side as opposed to offering IPS<sup>2</sup> flexibility. Note that merely delaying the undertaking of an investment does not necessarily confer additional flexibility on a project. This is only the case if a supplier can choose not to execute the investment if environmental conditions are unfavourable (Trigeorgis 1996), which does not hold for the focal situation. Considering flexibility in the initial IPS<sup>2</sup> configuration can, on the other hand, result in a reduction of future costs of adjustment. This approach does not rely as heavily on environmental conditions and therewith on customer decisions. If a customer exercises his option, costs for a "simple" adjustment will be lower than for replacing



the IPS<sup>2</sup>. However, the integration of flexibility has to be paid for by higher initial outpayments, which at the point of the customer decision have the character of sunk costs that cannot be regained if the option is not being put into effect. The most profitable solution is therefore determined by a trade-off between resource flexibility and initial outpayments.

Summing up, alternatives differ regarding specificity und flexible usability as well as reversibility and the temporal occurrence of investment outpayments, which impact on the optimal point of investment. Furthermore, not only temporally vertical interdependencies of outpayments are relevant, but, in case of IPS<sup>2</sup> replacement, also temporally horizontal interdependencies between different projects. Emanating from the IPS<sup>2</sup> replacement, suppliers take into consideration the flexibility potential of an initial IPS<sup>2</sup> configuration, which maximizes the profitability in comparison to the replacement. If the probability with which a customer chooses an option is known, surpluses of inpayments and the expected value of these surpluses for the respective flexibility potential can be determined. When abstracting from aspects of sustainability and risk aversion, the IPS<sup>2</sup> supplier chooses the alternative with the highest expected value.

## 5 Conclusion

To the challenges companies are faced with today, IPS<sup>2</sup> could constitute a solution. These can be adapted to customer needs along the IPS<sup>2</sup> life cycle. To execute this adoption the technological and economic perspectives have to be integrated. We propose a concept model consisting of IPS<sup>2</sup> actions, resources and functions as a means of integrating these perspectives. Switching options, which constitute the source of flexibility for the customer, can be derived from the concept model. Furthermore, the dilemma of mutual determination of technical and economic aspects can be solved, using an iterative concept modelling approach. This iterative approach enables the adjustment of future cost structures to market conditions. However, efficiently and effectively providing flexibility to customers critically depends on the suppliers' capabilities of acquiring flexible resources. Consequently, the differentiation in firm and usage flexible resources determines the continuum of possible concepts. Based on the economic evaluation of these concepts, suppliers choose to either offer an IPS<sup>2</sup> replacement or to consider flexibility in the initial IPS<sup>2</sup> configuration. To evaluate the profitability of IPS<sup>2</sup> flexibility a net option value has to be determined. Deducting the NPV of suppliers' costs from customers' option value renders this net option value. We illustrate a combination of the NPV approach and the real option approach to determine customers' option value.

It would be of special interest for further research to apply the combination of NPV approach and real option approach proposed in this paper to a company in Business-to-Business markets. By doing so, supplementary insight into potentials and difficulties of this approach could be gained empirically. Moreover, as pointed out in this contribution, only firm specific resources are of strategic relevance and can help to achieve competitive advantages. Further investigating these firm specific resources, especially in the context of IPS<sup>2</sup>, could therefore also be a promising field of study.

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