CIRP Journal of Manufacturing Science and Technology 1 (2009) 279–286

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

journal homepage: www.elsevier.com/locate/cirpj

The dynamics of Industrial Product Service Systems (IPS2) – using the Net Present Value Approach and Real Options Approach to improve life cycle management

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A R T I C L E I N F O

Article history:
Available online 17 June 2009

Keywords:
Industrial Product Service Systems
Net Present Value Approach
Real Options Approach

A B S T R A C T

Companies from industrialized nations have faced with the threat of competition from low-cost countries. We suggest Industrial Product Service Systems (IPS^2) as a possible answer. Our article has two main aims. We establish a framework for designing an initial IPS^2 which meets current customer and market requirements. Building on this, we broaden our focus to include requirements induced by subsequent changes. We propose a combination of the Net Present Value Approach and the Real Options Approach as a means of determining the quantified value of an IPS^2 for an individual customer over its life cycle.

1. Competitive threats and challenges for marketers

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, industrialized nations. These imitations exacerbate the amortization of investments in research and development and can even render them impossible. Growing capabilities and competencies of such competitors from developing nations pose a further threat, since companies from developed industrial nations are unable to compete with the low labour costs of the aforementioned companies. Highly dynamic markets pose the additional challenge of having to generate sustainable competitive advantages under changing conditions. Focusing on providing products does not suffice to create a viable economic basis for company success [1]. 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. Against this background of changing environmental conditions we suggest Industrial Product Service Systems (IPS^2) as a possible solution.

In this article we specifically focus on determining the customer value of an IPS^2, from a life cycle management point of view. Section 2 provides a definition of IPS^2, with a specific focus on the initial IPS^2 configuration and introduces a method to measure the actual value which such an initial IPS^2 generates for an individual customer. In Section 3 we broaden this focus and include the possibility of a dynamic adoption of IPS^2 to changing customer needs along the life cycle. We discuss a combination of the Net Present Value Approach and the Real Option Approach as a means to determine the customer value for such dynamic IPS^2 in Section 4. The article concludes in Section 5 and gives an outlook onto further fields of research.

2. Configuring an Initial IPS^2

2.1. The importance of industrial service and providing customized solutions

The traditional focus on products, which primarily associates growth with developing innovative products and views services only as an add-on, does no longer serve to achieve sustainable competitive advantages [2,3]. In the automobile industry, for example, about 60% of the turnover is generated after the vehicle is sold [4]. The price for highly complex industrial products has an even lower proportion of overall costs [5]. A second problematic aspect of focusing merely on products is pointed out by [6]. Without a real understanding of how its customers use a company's offerings and without true customer-focused innovations, companies face irrelevance and extinction. As a consequence, companies like IBM, UPS, Ericsson and GE have turned into successful suppliers of so-called "Customized Solutions" [4]. These are initiated by analysing the customer problem and trying to solve it through the identification of adequate combinations of products and services [7]. However, it has to be noted that there are still

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1755-5817/$ – see front matter © 2009 CIRP.
doi:10.1016/j.cirpj.2009.05.001

problems with selling industrial services as part of solutions to customer problems [4].

2.2. Features and characteristics

Companies are interested in maximizing their customers' long-term happiness, which is displayed in customer satisfaction [8]. Following this line of thought, the goal of offering IPS^2 is to establish a customer–supplier relationship which cannot be easily broken up by out-suppliers. IPS^2 are stamped by an integrated and mutually determining process of planning, developing, provisioning and using of goods and services [9]. This integrated development of product–service mixes tailored to fit individual customers' needs serves different purposes. First, IPS^2 possess all features of customized solutions and are, therefore, fit to create sustainable competitive advantages, as discussed in Section 2.1. Secondly, IPS^2 can serve to increase customers' willingness to pay for industrial services, as these are inherent part of a solution for which the customer develops an overall willingness-to-pay. The previously mentioned problems associated with selling industrial services are, therefore, likely to be attenuated and might in some cases even disappear. Thirdly, IPS^2 can generate entirely new barriers to imitation, again allowing a company more long-term competitive advantages [10].

When it comes to the configuration of a tailor-made problem solution for an individual customer, one inherent characteristic of IPS^2 is of utmost importance: the possibility of partially substituting product-based and services-based components. This allows for various possible ways of executing customer processes, service-based or product-based. We label these technological possibilities as different mixtures of manual and automatic execution of processes.

What has to be made clear, however, is that we do neither consider manual process execution as a substitute for a service nor automatic process execution as a substitute for a product. We follow the line of argumentation that it is the focussing on customer processes which is important, rather than distinguishing between and offering a product or service [11–13]. For example, manual and automatic process execution may, in some cases, from a traditional perspective both be considered a service. Referring to the substitutability of products and services as an important characteristic of IPS^2 this basically means that when offering problem solutions suppliers must choose between different ways of conducting part-processes of an IPS^2 solution. Whether these would be considered services or products is of minor importance.

Furthermore, a second dimension has to be considered. This dimension describes the customer decision towards make or buy of processes. This two-dimensionality, the variability of technology on the one, and the decision of internal or external production on the other hand, generates additional degrees of freedom for customers and suppliers. These render a variety of potential problem solutions which could be offered to customers, with different economic consequences both on the supplier and the customer side.

Economic consequences have to be anticipated as best as possible by the supplier and taken into account when choosing which IPS^2 solution to offer the customer. Each IPS^2 has to fulfill three basic economic criteria: (i) it has to generate a positive value contribution for the individual customer, (ii) this value has to be higher than that of the best competitor's offer and (iii) the value creation on the supplier side has to be positive as well [14]. When considering the value an IPS^2 generates for customers, environmental issues and sustainability aspects have to be included in the calculation to establish a viable basis for IPS^2 development. It is essential to note that only those aspects are of importance, which either positively or negatively impact on customers' costs or revenues. Aspects which have to be considered in IPS^2 development due to laws and regulations are an exception from this rule.

To which extent an IPS^2 fulfills the criteria mentioned depends on the strength of various preference drivers for an individual customer. 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^2 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. From the supplier perspective it is crucial to ensure that, from the wide range of possible configurations, exactly that IPS^2 is chosen which generates sufficient customer value to exceed the expenses it entails.

2.3. Determining the value for the customer and the supplier

In business markets, value can be seen as "the worth in monetary terms of the economic/commercial, technical, service and social benefits a customer firm receives in exchange for the price it pays for a market offering" [15]. According to this definition the value contains monetary as well as social components. But in an environment which is characterized by high competitive pressure, customers primarily decide on monetary and not social benefits.

This is because customers which regard only monetary benefits can gain competitive advantages over companies which also take into consideration social aspects, so that the latter may be put out of business [16]. To assess the value contribution of the IPS^2, we propose the net present value (NPV) approach. The NPV is an approach to calculate the value contribution of an investment. A company will only invest, if the NPV or the value contribution respectively is positive. If the customer has more than one alternative, the customer will decide for the alternative with the highest NPV.

According to the NPV, the value of an investment depends on the expenses and the revenues it generates for the customer. While expenses on the customer side can be classified as out payments, the positive value of an IPS^2 for the customer is characterized by the in payments it generates. But a positive difference between the revenues and expenses alone is not sufficient for a positive value generation. This is because the investor also has the option to place the capital in the financial market in order to generate rents. Only if the investment generates higher rents than can be achieved when buying securities, stocks and bonds with a comparable risk, is an investment really profitable. This is why the expenses and revenues have to be discounted by the weighted average costs of capital (wacc) which equal the rent which can achieved when placing the money in the capital market [17].

The NPV of an investment is defined from a customer's perspective as

$$\mathrm{NPV}_0 = -I_0 + \sum_{t=1}^{n} (R_t - E_t) \cdot (1 + \mathrm{wacc})^{-t} \quad (1)$$

with NPV_0, net present value in $t = 0$; I_0, investment in $t = 0$; R_t, revenue (in payments) in t; E_t, expenses (out payments) in t; wacc, weighted average costs of capital of the customer.

This means that the NPV_0 at time 0 (time of contract) is equal to the discounted value of the net income stream (income R minus expenses E) from the IPS^2's use over periods 1 to t, less the initial payment I_0, the purchase price. A positive NPV means that the investment can generate higher rents than can be achieved in the capital market, so that the investment is beneficial. The wacc is dynamic and has to be forecasted for each period, because the conditions of the financial markets and the structure of the customer may change over time.

The NPV approach can also be used to estimate the price ceiling of the IPS². For the sake of simplicity, it is initially assumed that the supplier has no competitors and the customer decides whether to invest or not to invest in the supplier's problem solution. The price ceiling is where the NPV equals zero, that is the discounted net income stream equals the purchase price:

$$0 = -I_0 + \sum_{t=1}^{n}(R_t - E_t)(1 + \text{wacc})^{-t} \quad (2)$$

If competitors exist, the theoretical upper price limit is determined by the strongest competitor. Let P^S be the price of the focal supplier and P^C be the price of the competitor. The differential advantage of the supplier's IPS²-solution compared with the competitor's is defined as:

$$\text{NPV}_0^S - \text{NPV}_0^C = -(P^S - P^C) + \sum_{t=1}^{n}[(R_t^S - R_t^C) - (E_t^S - E_t^C)] \cdot (1 + \text{wacc})^{-t} \quad (3)$$

with R_t^S Revenues per period t caused by IPS² supplier's offer; E_t^S Expenses per period t caused by IPS² supplier's offer; R_t^C Revenues per period t caused by competitor's offer; E_t^C Expenses per period t caused by competitor's offer

Setting the capital value difference to zero leads to

$$0 = -P^S + P^C + \sum_{t=1}^{n}[(R_t^S - E_t^S) - (R_t^C - E_t^C)] \cdot (1 + \text{wacc})^{-t} \quad (4)$$

and solving for P^S gives the price at which the customer considers both suppliers equal:

$$P_{\max}^S = P^C + \sum_{t=1}^{n}(\text{CF}_t^S - \text{CF}_t^C) \cdot (1 + \text{wacc})^{-t} \quad (5)$$

with $\text{CF}_t = (R_t - E_t)$.

To verbalize this, the focal supplier's price can be greater than the competitors' to the extent that the discounted net income stream for their IPS² is greater [10,18].

In some cases no revenues can be ascribed to the investment. In this case, the costs incurred over the life of the investment have to be compared with the costs incurred by the competitor's solution:

$$\text{NPV}_0^S - \text{NPV}_0^C = -I_0^S - I_0^C + \sum_{t=1}^{n}[(E_t^C - E_t^S)] \cdot (1 + \text{wacc})^{-t} = 0 \quad (6)$$

leading to a price ceiling of

$$P^{\max} = I_0^C + \sum_{t=1}^{n}[(E_t^C - E_t^S)] \cdot (1 + \text{wacc})^{-t} \quad (7)$$

This means that the focal supplier's price can be greater than the competitor's to the extent of the discounted value of the cost savings of the IPS² compared to the competitors solution. It becomes apparent that this is nothing more than the total cost of ownership approach with a dynamic component.

When the customer's value and the price ceiling of the IPS² are known, the supplier can assess if the customer will choose the supplier's offer and which price can be charged.

3. Life cycle management of dynamic IPS²

3.1. The role of flexibility

Life cycle management is a crucial aspect of successfully establishing a customer supplier relationship through IPS². This is due to the fact that over the life cycle of an IPS², the customer preference drivers, which constitute the basis for the configuration of a tailor-made problem solution, are subject to change. This can either be induced by changes in the focal customer's environment (legal conditions, technological advances, etc.) or changes in the customer structure (goals, strategy, etc.). These changes can heavily influence the value which an IPS² generates for an individual customer and thereby its advantageousness.

As a crucial characteristic of IPS² life cycle management, possible changes of customer drivers are to be taken into account in the early phase of the IPS² configuration process. This means,

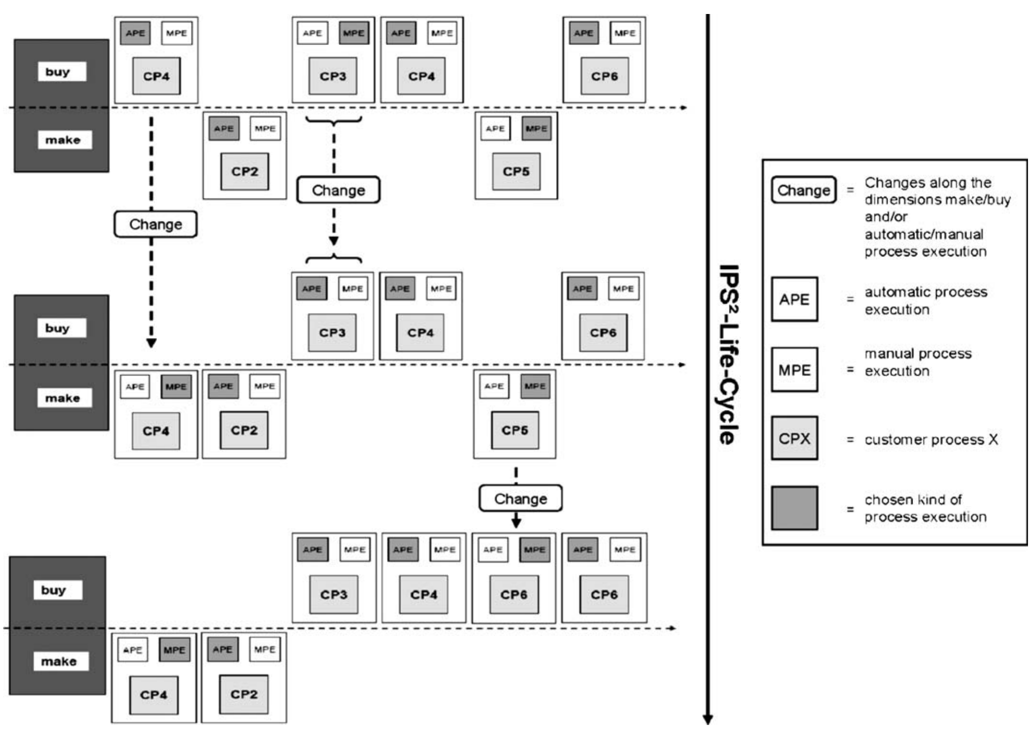

Fig. 1. IPS² life cycle flexibility.

that possible alterations of the IPS^2 over time, along the dimensions make/buy and manual/automatic process execution, also have to be taken into consideration when configuring an initial IPS^2 for individual customers, as the optimal initial configuration of a flexible investment may deviate from the optimal configuration of an inflexible one [19]. Fig. 1 illustrates changes in the initial IPS^2 configuration over the life cycle.

These alterations over time reduce individual customers' risk connected with purchasing an initial IPS^2 brings along with it. Customers are not contractually or technically bound to a certain IPS^2 configuration over the entire life cycle, but can choose to flexibly adopt this configuration to changing conditions [20]. In order for suppliers to know which kind of flexibility to offer their respective customers, they not only have to gather information to try and predict possible future changes in customer drivers, for example owing to a new strategic orientation of the customer. It is also of great importance to estimate the value that different kinds of flexibility have for individual customers. Only by doing so, suppliers are able to identify IPS^2 configurations which meet the requirements of the three basic economic criteria over the course of the IPS^2 life cycle. While we consider the NPV approach a viable method of identifying the in payments and out payments for an initial IPS^2, changes occurring over the life cycle require an adoption of this method. We propose a combination of NPV and the Real Options Approach, which we explain in the following.

3.2. The Real Options Approach

The Real Options Approach (ROA) takes into account flexibility by considering a multistage decision process with a decision in $t = 0$ and another decision in $t = 1$ ($t = 2, \ldots, n$). The decider can choose from a set of possible alternatives in $t = 0$, based on all information about future developments and conditions available at that point in time [21]. A decision at $t = 0$ is accompanied by substantial uncertainty, owing to the fact that future developments and conditions are hard to predict [22]. This is not the case for a similar decision in $t = 1$, however. The aforementioned developments are already under way, triggering a substantial reduction of the decision maker's uncertainty. Fig. 2 exemplifies these basic characteristics of the ROA, displaying points of future changes and decision at which companies can react to these changes.

The degree of flexibility that an IPS^2 contains along the dimensions make/buy and manual/automatic process execution depends on the number of possible decisions in $t = 1$. This means that the more often customers can choose to change their initial IPS^2 configuration at given points along the life cycle (e.g. from an automatic to a manual process execution and/or from a buy to a make decision) the more flexible the IPS^2 actually is. Decisions are made to adjust the configurations to changing conditions of the preference drivers. In the figure, possible decisions are marked by decision point. In each decision the customer has the possibility to opt for one of the possible configurations (configuration 1 and configuration 2 in Fig. 2). Changes of the conditions of the preference drivers are plotted as paths leading to new decision points in which the decision is made, given the current condition and the prospected future conditions and decisions.

This degree of flexibility and its consequences for the initial IPS^2, which has to allow for change options and the inclusion of these into its configuration, can have a substantial impact on the profitability of IPS^2 for both the customer and the supplier. On the one hand, it is to be expected that expenses on the supplier side rise with growing flexibility, as the preparation of possible change-overs requires the hold-out of the capability to perform the different options. On the other hand, flexibility results in an increase of the value which an IPS^2 generates on the customer side, because the customer can react to the possible changes of the preference drivers, leading to increased incomes or reduced expenses respectively [23]. In order to be able to quantify this value, we discuss a combination of the NPV and the ROA in the following.

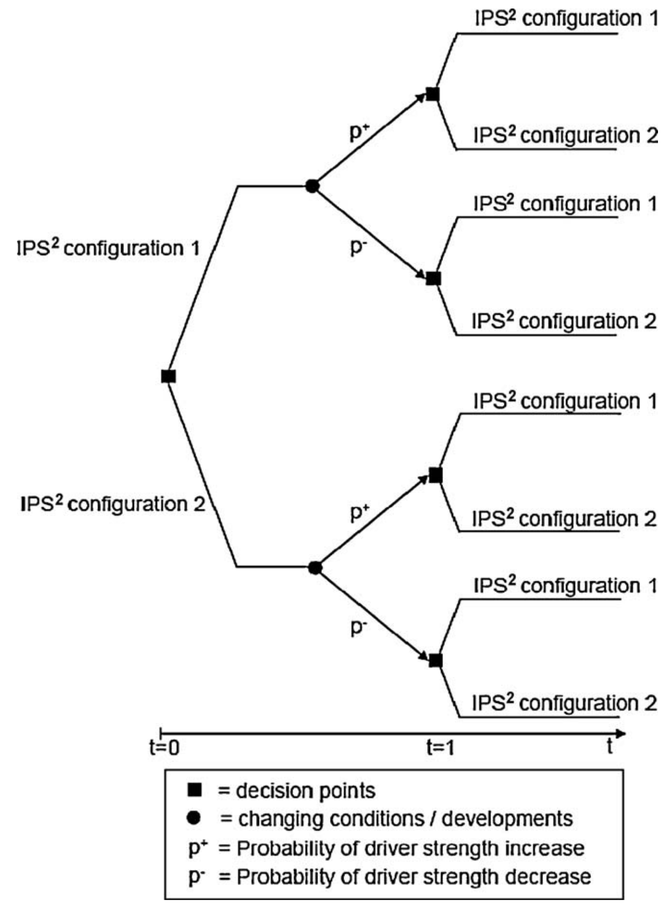

Fig. 2. Real options decision tree.

3.3. Combining NPV and ROA

One has to start with determining the decisions which a client would make under the different environmental conditions. The result is a sequence of optimal decisions which customers will make to maximize the expected NPV of their IPS^2. For the determination of the optimal decisions for the customer the rollback method can be applied. This method has been introduced by Magee and is based on the optimization principle of dynamic programming [24,25]. The initial step of the rollback method is to determine the expected value of the latest possible decisions in the different states. The value of each decision depends on the prospected sum of the positive discounted cashflows which would occur after the decision is made [22,26].

We refer to this value as the decision value. At each possible decision point the customer will choose the option which leads to the highest decision value [26,27]. Only these optimal decisions are regarded further in the analysis.

Subsequently, the values of the second-latest decisions are calculated. This is done by summing up the prospected positive discounted cashflows which occur until the next decision, and adding the values of the optimal subsequent decisions, whereas those decision values have to be multiplied with the probabilities of the states in which the decisions will be made.

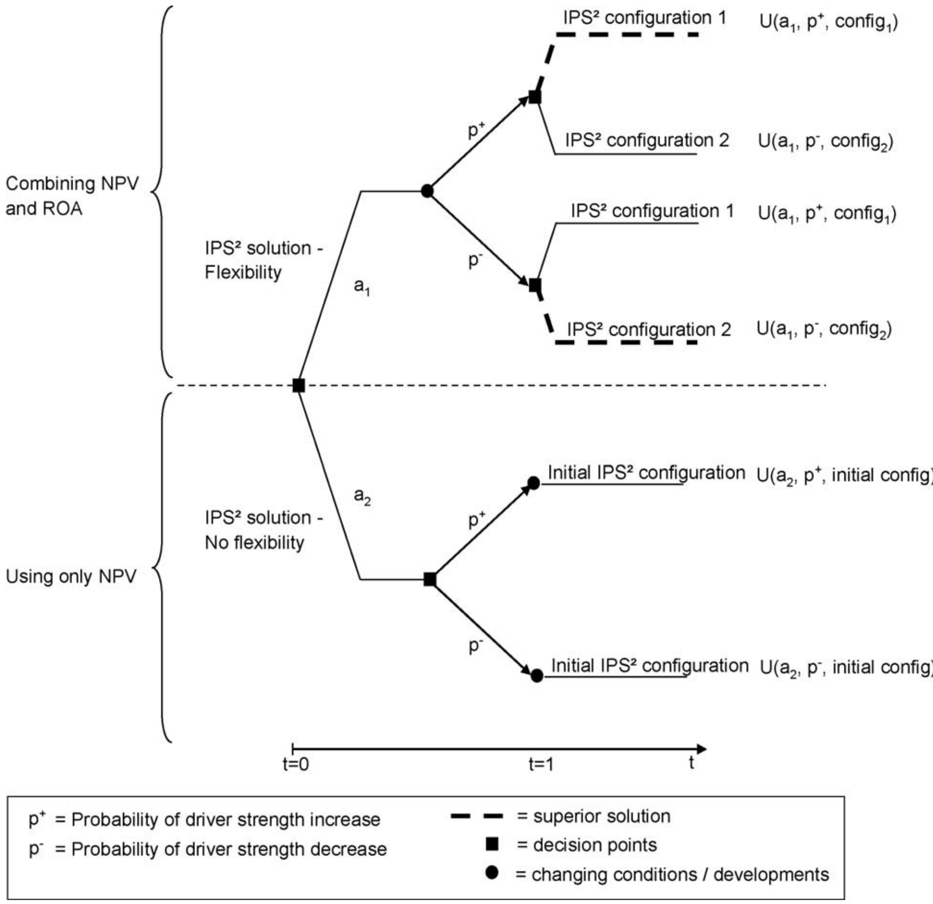

Fig. 3. Determination IPS^2 flexibility value.

A successive continuation of this procedure up to the first-made decision during the investment leads to the decision values of the possible initial specification of the IPS^2. The decision values of the initial configuration than equal the expected value of the IPS^2. Thus, by employing the rollback-method suppliers can determine the value which a certain degree of flexibility has for individual customers and configure the IPS^2 accordingly.

Fig. 3 illustrates the combination of NPV and ROA. It also outlines the demarcation of such a flexible IPS^2 configuration, as opposed to one where flexibility through change options is not included in the initial IPS^2 design. The value of a flexible IPS^2 solution can be put as:

$$U(a_1) = p^+ \times U(a_1, \text{config}_1, p^+) + p^- \times U(a_1, \text{config}_2, p^-) \quad (8)$$

The value of an IPS^2 solution with no flexibility can be put as:

$$U(a_2) = p^+ \times U(a_2, \text{initial config}, p^+) + p^- \times U(a_2, \text{initial config}, p^-) \quad (9)$$

Given possible changes in driver strength we can assume the superiority of one of two possible decisions at a given decision point $t = n$. The value of IPS^2 flexibility granted by change options along the dimensions make/buy and automatic/manual process execution can then be put as:

$$O(a_1) = U(a_1) - U(a_2) \quad (10)$$

The difference between solutions with and without flexibility is that for the latter only one path will be chosen and set right from the beginning, as marked in Fig. 1. For a flexible IPS^2 configuration no clear path can be set right from the start. Although there will always exist a superior solution at a certain decision point, the road to these points is not predetermined.

If the customer faces risks, flexibility is always beneficial for him. But the IPS^2 supplier should only offer flexibility as long as the additional price he can charge for the flexibility is higher than his additional costs, because otherwise offering flexibility would not be profitable for the supplier.

4. Case study

4.1. Case description

In order to demonstrate the applicability of the real options-approach, we will submit our concept to a first test on a real case. This test is based on the extrusion technology. In this case, a producer of twin-screw extruders wants to estimate the willingness to pay for a custom moulder who wants to process recipes of different thermoplastic materials.

The customer is focused on producing small-customized formulations which have to be delivered in increasingly smaller batch sizes. After each produced batch, the extruder has to be cleaned and refitted to the new charge. This process can take up to two hours so that the extruder can run only a short time a day if the batch sizes are small. This means that the refitting time of an extruder is an essential factor for its profitability. As a consequence, a new extruder was developed with two processing units that can be exchanged in a very short time using a mechanism to easily change the processing unit. During the cleaning of the one processing unit, the other one can be used for processing. Through this the downtime caused by the cleaning and refitting shortens up to one-fourth of the usual downtime. The question arises if the customer is willing to pay enough money to cover the extra costs of the supplier for the new technology. On the other side, due to the two processing units the production costs for the new extruder are significantly higher than those of a standard plant, and not all clients are willing to pay the higher costs in full. On this account, clients still can choose between a standard extruder and the new extruder with two processing units.

It is quite obvious that the relevant driver for the customer preferences for one of these two possible options is the batch size, because it determines the frequency of refitting and thus the meaning of downtimes. The smaller the batch size is, the greater is the preference for the extruder with two processing units and vice versa. As the batch size may vary over the lifetime of the extruder, this preference may change as well. For example, if a customer first chooses the standard extruder, he may want to change to an extruder with two processing units when the batch size decreases. Generally, each customer would benefit from the reduced downtime and the flexibility to reconfigure the extruder. But his decision is constraint by the price he has to pay for the reduced refitting time and the flexibility. Only if the additional value of the reduced refitting time or the flexibility is higher than the additional price the customer has to pay, the customer will chose these options. As the prices are variable from the supplier's perspective, he is now able to control the choices of the customer with his price setting in order to maximize the profit of the supplier. But this is only possible if the supplier knows the price ceiling for both the standard extruder and the extruder with the reduced refitting time as well as the price ceiling for reconfigurations. In the following we will describe how the supplier can estimate the inventory price ceilings of the two extruder types as well as the reconfiguration price ceilings, and how he can control the customer's choices.

The data used to estimate the price ceiling have been provided by the focal supplier who has used the data to calculate the customers' NPV for different batch sizes and formulas. Whereas some of the necessary data like energy consumption, maintenance costs or working hours which are necessary to run the extruder, other data like batch sizes, formulas processed, material costs and others have to be supplied by the customer.

The customer wants to use the extruder for 6 years. After that time the extruder is sold, yielding the selling price as additional revenues at the end of the sixth year. The customer can chose between those two configurations at t_0 when he invests in the plant. Furthermore, it is assumed that the customer has the possibility to reconfigure the extruder. This option is especially interesting for the customer if he first decides for the standard extruder and experiences falling batch sizes, so that a reconfiguration to decreased refitting times yields higher positive cash flows due to an increased production time. If the customer first opts for an extruder with a decreased refitting time, the possibility to reconfigure will be meaningless, as this option cannot lead to a higher project value compared to the alternative configuration and it does not save any costs to the client or the supplier. For the sake of simplicity, we assume that the client will decide about a reconfiguration after half of the lifetime at the end of the third year, affecting the cash flow streams from the beginning of the forth year. The batch size in t_0 is 250 kg per batch. The development of the batch size as the relevant preference driver can be estimated, for example using statistical methods on past data or interrogations of masterbatch customers. In the present case, it is assumed that after each year the batch size as the main preference driver for this options either increases with a probability of $p^+ = 0.3$ to a plus of 25 kg or decreases with a probability of $p^- = 0.7$ to a minus of 25 kg as compared to the previous period. These possible developments and decisions are illustrated in Fig. 3. In this model there are 512 possible combinations of paths of batch size developments and configurations. The customer's wacc is 8%.

4.2. Key results

According to the back-roll method, the valuation of the project starts with determining the optimal decisions in t_3. At this point of time, we have four possible states of batch sizes which can vary between 175 and 325 kg in steps of 50 kg. The optimal decision has to be estimated for each of the four states, taking into account the possible developments of the batch size after the decision is made. As there are two possible developments from year to year and 3 years of remaining machine life, there are $2^3 = 8$ possible paths of batch size development after each decision. To calculate the decision value of a specific decision in a specific state, the sum of the discounted positive cash flows which will incur conditional to the decision are calculated for each of the possible development paths and multiplied by the probability with which the development path will really occur. Summing up this expectation values for all of the eight possible developments yields the decision value. For example, if the batch size in t_3 equals 275 kg, and the batch size decreases in t_4 and t_5 and increases in t_6, a decision for the extruder with two processing units yields 660.884,13 € as the sum of the discounted cash flows. The probability that this path occurs equals $0.7 \times 0.7 \times 0.3 = 0.147$, so that the path value weighted with the path probability in case of this decision and development equals 97.149,97 €. The sum of these entire expected path values amounts to 731.709,46 € and corresponds to the decision value.

A reconfiguration is only possible with the help of the supplier, as only he has the necessary parts. If the supplier does not charge a reconfiguration price, the customer will opt for the configuration with the reduced refitting time in any case. Only the configuration price can cause the customer to choose the standard solution. The reconfiguration price ceilings are calculated according to formula 5a). The decision values of the different options in t_3 and the reconfiguration prices are listed in Table 1.

If the customer first opts for an extruder with reduced refitting times, than the price ceilings for a reconfiguration to a standard extruder are negative. This means that only if the supplier pays that amount of money to the customer, for example for taking back the second processing unit, the customer will have that reconfigurations performed. By setting a reconfiguration price below or above those price ceilings, the supplier can now control the options the customer will chose. If a reconfiguration price is charged, the price has to be considered as a discounted outpayment which influences the optimal decision.

To calculate the decision values of the two configurations in t_0, let us assume that no reconfiguration prices are charged. Again the sum of the discounted positive cash flows which are linked to the specific configuration are calculated for all of the eight possible

Table 1
Decision values and price reconfiguration price ceilings in t_3.

Batch size in t_3 (state) (kg)	Decision value	
	Standard	Reduced refitting time
325	405.334,39 €	947.591,38 €
275	225.646,49 €	731.709,46 €
225	28.033,83 €	485.042,48 €
175	−190.329,80 €	200.482,48 €
	Reconfiguration price ceilings	
	Price ceiling for a reconfiguration to a reduced refitting time	Price ceiling for a reconfiguration to a standard extruder
325	683.087,64 €	−683.087,64 €
275	637.493,59 €	−637.493,59 €
225	575.699,28 €	−575.699,28 €
175	492.310,92 €	−492.310,92 €

development paths until t_3 and multiplied with the probabilities of these paths. Summing up this entire expected path values and adding the values of the optimal decisions in t_3 multiplied with the probability of the states in which these decisions are made, yields the decision value of a specific configuration in t_0. For example, if the customer would opt for an extruder with two processing units in t_0 and if the batch size increases in t_1 and decreases in t_2 and t_3, the sum of the discounted positive cash flows equals 870.468,45 €. Multiplied with the probability of this development $0.3 \times 0.7 \times 0.07 = 0.147$ gives the weighted path value as 870.468,45 € × 0.147 = 127.958,86 €. The sum of all weighted path values amounts to 739.974,35 €. The values of the optimal decisions in t_3 multiplied by the probability of their occurrence sum up to 446.547,28 €, whereas the probabilities can be calculated as the sum of the path probabilities of all development paths leading to the specific state. The decision value for opting for the extruder with two processing units then gives the decision value as 739.974,35 € + 446.547,28 € = 1.186.521,63 €.

In order to calculate the project values of an extruder without flexibility, one has to calculate the sum of the positive discounted cash flows for all possible developments until t_6. Multiplying this path values with the path probabilities and summing up this values then gives the project value for an inflexible extruder, regarding only uncertain batch size development, but no reconfigurations. The project values of the different initial configurations and flexibilities under the assumption that reconfigurations are free are shown in Table 2.

If the supplier charges reconfiguration prices in t_3 equal to the price ceiling, then the project values of the flexible solution (left column) equal the ones of the inflexible solution (right column).

An analysis of extruders from competitors showed that there are no alternative extruders which have a positive NPV. Due to the low batch sizes, there is too much downtime so that the production is too low to earn the inventory price and the processing costs. Hence, no competitors have to be regarded in the further analysis. But if competitors would exist, this would not affect the relation between the price ceilings of the different configurations, but all inventory price ceilings would decrease in an equal amount. This decrease corresponds to the difference between the strongest competitor's project value and its price ceiling. If the supplier would only offer one configuration and flexibility, the price ceiling of that offer would correspond to its project value. But as the supplier offers two different initial configurations and flexibilities, there are nevertheless more alternatives the customer has, whereas the price ceiling of one of these alternatives depends on the prices of the other alternatives. The supplier now can influence the customer's decision on these initial alternatives by setting adequate prices. The customer will choose an alternative if it leads to the highest NPV of these offers. If the supplier would only offer an extruder with a reduced refitting time, the price ceiling would equal the project value of 1.186.521,63 €. In case of offering more options about the initial configuration and flexibility, the price ceiling of one offer is dependent on the price which the supplier charges for the other offers, as the different offers have to be regarded as competitive alternatives. For example, if the supplier prices all offers at prices equal to their project value, each of these offers would have a NPV of zero, and the customer would be indifferent. If the price of the alternative the customer is supposed to choose is marginally lower than the project value, then the customer would opt for this alternative if all other offers would be priced at the project value. Or, if the supplier would charge one of the other offers at a price which is 100.000 € lower than its project value, which means that the NPV of this offer is 100.000 €, then the price of the offer under consideration has to be marginally lower than 100.000 € as its project value, so that the NPV exceeds 100.000 €. In few words, if the supplier wants the customer to opt for a specific initial configuration and flexibility, the difference between the project value and the price of that offer has to be the largest.

If the supplier wants to use reconfiguration prices to control the customer's decision in t_3, the relationship between the reconfiguration price and the inventory price ceiling has to be taken into account. If the supplier would set all possible reconfiguration prices above the reconfiguration price ceilings, the project value would equal the values of an inflexible extruder. If all or some of the reconfiguration prices would be set between zero and the price ceilings, the project value would lie between the project values with and without flexibility. For example, if the supplier would charge 500.000 € for a reconfiguration from a standard extruder to an extruder with a reduced refitting time for all states, the customer would only perform the reconfiguration in case of a batch size of 175 kg in t_3. The project value of a standard extruder with flexibility would amount to 141.953,70 €. The project value of the decision for an extruder with a reduced refitting time would not be affected. If now the supplier would charge the extruder with a reduced refitting time at 1.186.521,63 € and the standard extruder with flexibility at a price lower than 141.953,70 €, the customer would first chose the standard extruder, and in case of a batch size of 175 kg in t_3 he would perform the reconfiguration. In all other states, the customer would maintain the old configuration.

Table 2
Project values of different initial configurations and flexibilities.

Initial configuration	Flexibility	No flexibility
Standard extruder	579.241,43 €	139.666,86 €
Reduced refitting time	1.186.521,63 €	1.186.521,63 €

5. Conclusion

To the many challenges companies are faced with today, IPS^2 could constitute a solution. In this context it is crucial to determine the value an IPS^2 has for respective customers in order to understand which IPS^2 configuration the customer will pursue. This value is dependent on customer drivers and their respective strength. As these drivers are subject to change, companies have to assume a life cycle oriented perspective and try to flexibly adopt their IPS^2 configurations to future challenges and requirements. Before doing so, however, suppliers have to identify the respective customer value an IPS^2 generates. The identification of this value poses the object of scrutiny in this article.

One possible way of determining the customer value consists in combining the NPV and the Real Options Approach. The mere application of the NPV thereby renders the customer value of an IPS^2 without any flexibility, leading to a systematic underestimation of the value which the IPS^2 creates for the customer. Only the combination of the NPV-approach with the Real-Options-Approach enables a reliable estimation of the true value of the IPS^2.

Future research should investigate further into the issue of estimating IPS^2 value, with a special focus on a comparison of economic aspects on the supplier side, especially on costs of flexibility for the supplier

Acknowledgement

We thank the German Association of Research for funding this study within the SFB/TR29 project.

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