Profitability of Industrial Product Service Systems (IPS²) – Estimating Price Floor and Price Ceiling of Innovative Problem Solutions

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Abstract
Companies from industrialised nations are faced with the threat of competition from low-cost countries. We suggest Industrial Product Service Systems (IPS²) as a possible answer. But as the development and production can be quite expensive for the supplier, the question arises how the net benefits of an IPS² for the supplier can be determined to ensure that the IPS² is profitable. We establish a framework for the calculation of both the supplier's revenues and costs of an IPS². Requirements induced by possible subsequent changes of the IPS² are emphasized. We propose a combination of the Net Present Value Approach and the Real Options Approach as a means of determining the quantified revenues and a combination of Direct Costing, Time-Driven Activity-Based Costing and the Real Options Approach for the calculation of the costs of an IPS² for a supplier over its life cycle.

Keywords:
Industrial Product Service Systems; Net Present Value Approach; Real Options Approach; Time Driven Activity-Based Costing, Learning Effects, Price Ceiling

1 COMPETITIVE THREATS AND CHALLENGES FOR MARKETERS

Companies from established industrialised 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 them obsolete. 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 (IPS²) as a possible solution. IPS² are product-service mixes tailored to fit individual customers' needs. IPS² are stamped by an integrated and mutually determining process of planning, developing, provisioning, and using of goods and services [2]. It is important to note, that in an IPS² context services are no longer merely viewed as an add-on to products, but rather as am equal part of an integrated solution.

In this paper we specifically focus on determining the customer value of an IPS²; i.e. the benefit of an IPS² for the supplier. This is done by estimating both the supplier's revenues and costs that incur when offering an IPS². Our method is sufficient to account for the specific characteristics of an IPS² which are changes of the IPS² over its life cycle and the combination of products and services.

The remainder of this paper is organised as follows: Chapter 2 provides a definition of IPS² and specifies criteria which have to be fulfilled in order to ensure the success of an IPS². In chapter 3 we focus on the determination of the revenues an IPS² generates for the supplier. In chapter 4 we introduce a method to estimate the costs of an IPS². The paper concludes in chapter 5 and gives an outlook onto further fields of research.

2 CONFIGURING AN INITIAL IPS²

The goal of offering IPS² is to establish a customer-supplier relationship which cannot be easily broken up by out-suppliers. The integrated development of product-service mixes tailored to fit individual customers' needs can generate entirely new barriers to imitation, allowing a company more long-term competitive advantages [3].

When it comes to the configuration of a tailor-made problem solution for an individual customer, one inherent characteristic of IPS² 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. 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, generate additional degrees of freedom for customers and suppliers which generate a variety of potential problem solutions that could be offered to customers. In this connection the characteristics of an IPS² are not static, but can be changed over the lifecycle. This flexibility allows to adjust the characteristics of the IPS² tailored to changing environmental conditions and customer preferences, which increases the benefits of the IPS² for the customer and hence the price or revenues respectively that the supplier can gain from offering the IPS².

When calculating the Economic consequences have to be anticipated as best as possible by the supplier and taken into account when choosing which IPS² solution to offer the customer. Each IPS² has to fulfil 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 [4].

The criteria i) and ii) have to be fulfilled because otherwise the customer would choose either not to invest in an IPS² or to choose an offer from a competitor. Criteria iii) ensures that the IPS² is beneficial for the supplier as well and is decisive for the question if a specific IPS² should actually be offered to the customer. As criteria iii) can only be fulfilled if criteria i) and ii) are fulfilled, we focus on the determination of the supplier's net benefit of an IPS², which is calculated based on the suppliers revenues and costs of the IPS².

3 ESTIMATION OF SUPPLIER REVENUES

3.1 The Case of non-flexible IPS²

The revenues of an IPS² for the supplier equal the price the supplier can charge. Hence, in order to estimate the revenues we have to estimate the price the customer is willing to pay for the purchase and the use of the IPS².

To estimate the price ceiling, we have to understand how the customer makes a decision about an investment. A customer will invest in an IPS² only if its value contribution for the customer is positive. The value contribution can be calculated using the Net Present Value approach.

Let NPV_0 the NPV, P the price the supplier charges for the IPS², R_t and E_t the revenues (inpayments) and expenses (outpayments) occurring in period t, and *r* the rate of return, then the NPV can be calculated as follows:

$$NPV_0 = -P + \sum_{t=1}^{n} (R_t - E_t) \cdot (1+r)^{-t} \qquad (1)$$

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 IPS²'s use over periods 1 to *t*, less the initial payment P_0, the purchase price. 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, i.e. the discounted net income stream, also referred to as the project value *PV*, equals the purchase price:

$$P^{max} = PV = \sum_{t=1}^{n} (R_t - E_t) \cdot (1+r)^{-t} \qquad (2)$$

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, R. The differential advantage of the supplier's IPS²-solution compared with the competitor's is defined as:

$$NPV_O^S - NPV_O^C = -(P^S - P^C) + \sum_{t=1}^{n} \left[(R_t^S - R_t^C) - (E_t^S - E_t^C) \right] (1+r)^{-t} \qquad (3)$$

with superscript S designating the focal supplier and C the strongest competitor. Setting the NPV-difference to zero leads to

$$0 = -P^S + P^C + \sum_{t=1}^{n} \left[(R_t^S - E_t^S) - (R_t^C - E_t^C) \right] (1+r)^{-t}$$
$$= -P^S + P^C + PV^S - PV^C \qquad (4)$$

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

$$P^{max} = P^C + PV^S + PV^C \qquad (5)$$

To verbalize this, the focal supplier's price can be greater than the competitor's to the extent that the project value for their IPS² is greater [5], [3].

3.2 The Case of a flexible IPS²

As mentioned above, a crucial characteristic of IPS² is the flexibility of the IPS²-configuration over the life cycle, tailored to changing customer preferences. A customer is not bound to an initially chosen configuration, but can choose to flexibly adjust this configuration to changing environmental and structural conditions [6], leading to an increased IPS² price ceiling and hence to higher revenues for the supplier.

Flexibility can be taken into consideration combining the NPV-approach with the Real Options approach (ROA). The ROA takes into account flexibility by considering a multi-stage decision process with a decision in t=0 and another decision in t=1 (t=2;…; 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 [7]. A decision at t=0 is accompanied by substantial uncertainty, owing to the fact that future developments and conditions are hard to predict [8]. 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.

This degree of flexibility and its consequences for the initial IPS², which has to allow for change options and the inclusion of these into its configuration, can have a substantial impact on the profitability of IPS² 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 changeovers 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 IPS² generates on the customer side, because the customer can react to possible changes of the preference drivers, leading to increased income or reduced expenses respectively [9].

Let us illustrate the ROA using the following example: The supplier offers an IPS² to a specific customer. The customer intends to use the IPS² for a life cycle of 6 periods (years). We assume that the required intensity of maintenance depends on the production volume, so that a higher production volume leads to an increased number of required maintenances. As the customer does not have the knowhow and the technical possibilities to perform the maintenance himself, it has to be performed by the supplier. The number of maintenances and hence the maximum production volume is bound by the contract. In t_0, the customer can choose between a low frequency and a high frequency of maintenances which would enable a higher production volume. After three years, the customer has the possibility to alter the initially chosen frequency of maintenances which allows him to increase the production volume. This kind of flexibility is of advantage for the customer as he can only predict the production volume under uncertainty.

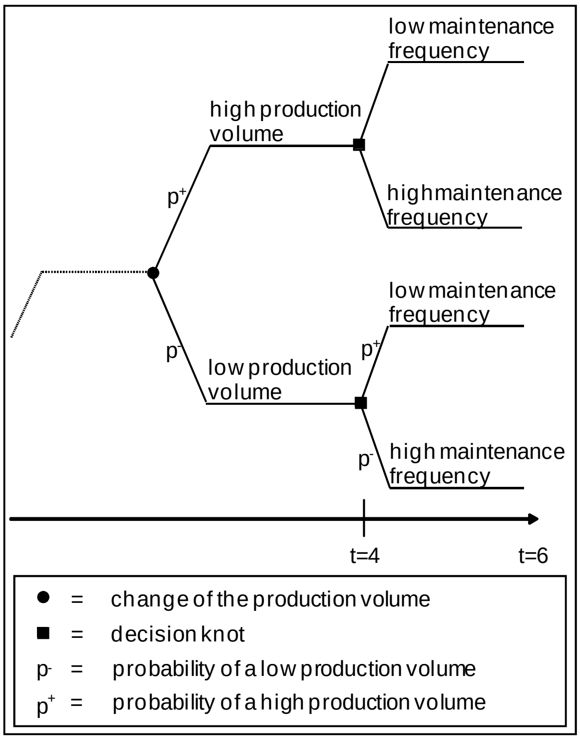

Figure 1: Dimensions of IPS²

To determine the value of flexibility, 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 Net Present Value of their IPS². 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 [10], [11]. 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 cash flows which would occur after the decision is made [12], [8].

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 [13], [12]. 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 cash flows 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.

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 IPS². The decision values of the initial configuration then equal the expected value of the IPS².

In our example, one has to start with determining the decision which the customer would make in t_4 conditional to the different production volumes which are now known by the customer. As the customer will try to maximise his NPV, he will opt for the maintenance frequency which leads to the highest decision value in t_3:

$$D_4^{opt} = max[D_4^l, D_4^h] = max[\sum_{t=4}^{6}(R_t^l - E_t^l), \sum_{t=4}^{6}(R_t^h - E_t^h)] \qquad (6)$$

For the determination of the price ceiling we first have to determine the project value. Let us assume that the demand will be low in t_0 when the investment is made. During the periods one to three, the demand is estimated to remain low with a probability of p^- and to increase with a probability of p^+. Let us further assume that the customer will first choose the contract with a low maintenance frequency and will only switch to a high maintenance frequency in case of a demand increase, as this will maximise D_4. The Project value now can be calculated as an expected value taking into consideration the optimal decisions in t_4 in case of a low production volume $D_4^{opt/-}$, in case of a high production volume $D_4^{opt/+}$ and the probabilities of the occurrence of these developments or decisions respectively:

$$PV = \sum_{t=1}^{3}(R_t^l - E_t^l)\cdot(1+r)^{-t} + p^- \cdot D_4^{opt/-} + p^+ \cdot D_4^{opt/+} \qquad (7)$$

In order to determine if the customer would really opt for a low maintenance frequency in t_0, we have to calculate this project value for an initial choice for a high maintenance frequency as well. The customer then will decide for the option leading to the higher project value.

To determine the price ceiling, we just have to put this project value into formula (2) in case of no competition or into formula (5) in case of competition. The charged price then equals to the revenue of the IPS² for the supplier.

When calculating the price ceiling of a flexible IPS² one has to bear in mind that the supplier can influence the decisions by his price setting. For example, if the supplier would not charge the price for the maintenance in form of a higher purchase price but in form of monthly rates, then the supplier can charge different prices for the different maintenance frequencies. By means of the price setting the supplier can influence the values of the decisions and thus control the decisions. Hence, in this case the decisions of the customer not only influence the price ceiling, but the price also influences the decisions of the customer.

The roll back method enables to take into consideration decisions about several characteristics of the IPS², but the number of decision values which have to be calculated increase explosively with the number of options and the number of time points in which decisions can be made, so that even modern computers would be overstrained. Hence, in case of complex decision trees it is necessary to use heuristics or simulation methods to calculate the project value.

4 ESTIMATION OF SUPPLIER COSTS

In chapter 3 we have shown how to determine the IPS² price ceiling in order to estimate potential supplier revenues. To enable a sound profitability assessment, we now focus on the costs induced by different IPS².

It is essential to correctly determine supplier costs of offering different IPS², as this enables suppliers to set a price for an IPS² which at least covers the costs induced by it [14]. From the supplier's point of view an IPS² is economically feasible only when the IPS² price ceiling is higher than the IPS² price floor.

To calculate costs directly induced by a product, traditional cost systems, such as direct costing [15], [16] can be used. Therefore, these costs do not pose a problem for the IPS² cost calculation. What is challenging, however, is the growing proportion of overhead costs.

As soon as 1985 Miller/Vollmann speak of a "Hidden Factory" which cannot be accounted for with traditional costing systems [17]. This is especially the case for services, whose costs tend to be overlooked in the bulk of product overhead costs and which often evolve to become unpredictable cost drivers.

It is therefore necessary to make use of a costing system which is capable of establishing transparency with regard to the origination of overhead costs and allocate these to the cost units fair according to the input involved.

Activity Based Costing, which assumes that a multitude of cost generating processes are needed to produce a product or service, seems to best serve this purpose. What is problematic, however, is the fact that Activity Based Costing can mainly be used for repetitive actions with very limited room for decisions [18]. Activity Based Costing is therefore primarily applicable to standardized activities. However, customer integration, which is at the heart of IPS², triggers the need for customized activities. As a consequence, the majority of the processes necessary for customized activities are no longer repetitive as is required to make use of Activity Based Costing.

What is needed is a modification of the traditional Activity Based Costing approach, to enable its application to processes with individualized cost patterns. Time-Driven Activity-Based Costing (TDABC), as introduced by Kaplan and Anderson is such a modification [19]. TDABC allocates capacities and costs to sub processes based on their target processing times and their net cost unit capacities.

The target processing time is the time needed to conduct a process once and is defined by time per output unit. This shows that time is considered to be the main cost driver. In this context it is important to note that target processing times must not be confused with average processing times as derived from traditional Activity Based Costing. Target processing times contain neither idle time nor additional time.

A cost unit's net capacity can be obtained based on the number of employees and their net working time. The net working time can be obtained based on the gross working time minus vacation, illness and unproductive times.

By multiplying target times with the output the sub process net capacity can be derived. By summing up all sub processes belonging to a cost unit the capacity utilization of a focal period can be determined.

The difference between cost unit capacity and utilized capacity is the unused capacity of a cost unit. Such a calculation can provide insight into a company's capacity utilization. In the context of IPS² this insight is crucial when it comes to deciding whether or not to build up additional capacity when accepting additional orders.

Making use of time equations is another characteristic of TDABC. A time equation is used to allocate target times to sub processes according to their input involved [20]. Consequences for cost calculations resulting from customer integration can be given explicit consideration in the time equation for each individual customer.

To do so, processing times x_1 to x_n are determined in addition to a basic time frame, which represents the processing times without the effect of customer integration.

A basic time frame for conducting a maintenance process of a standardized machine could for example be complemented by additional time if a customer acquires a machine customized to his needs which has higher maintenance requirements.

Furthermore, a customer might have highly skilled personnel, which reduces the need for maintenance through preliminary work. Such a situation could also find consideration in the time equation in form of a processing time, which would be deducted from the basic time frame.

By making use of a time equation it is therefore possible to get away from the rigid process costs of traditional process cost calculations. With TDABC process costs can be determined separately for each individual customer and each individual IPS².

To apply TDABC to IPS², however, the approach needs to be extended, as constant process costs are not to be expected over the IPS² life cycle.

In the context of cost management at an early stage, IPS² costs therefore need to be calculated under explicit consideration of a non-static development of process costs. Against this background we integrate learning effects into the TDABC system. To do so, processes need to be categorized with regard to their innovativeness. Innovativeness substantially influences which part of the experience curve forms the basis of the IPS² calculation. The concept of the experience curve states that costs per unit will decrease, if the accumulated production output increases.

Three process types can be distinguished:

1. Customized process related to one IPS² only
2. Customized process related to more than one IPS²
3. Standardized processes

The first two categories comprise all processes which need to be changed or re-developed to configure an IPS².

Processes of the first category are highly customized to meet an individual customer's needs and can therefore only be used for one specific IPS².

Processes of the second category are also being changed respectively newly developed, but are not as highly customized and can therefore also be used for other IPS².

While the learning curve starts with the IPS² configuration for both categories, the learning rate in the second category depends on the output of the IPS² for which the focal processes are required.

The third category comprises all existing processes which are used in a newly configured IPS². The learning curve of these processes therefore does not start at zero [21].

Cost development estimations of IPS² processes can be integrated into the time equation of TDABC. This means, that when calculating IPS² costs it is anticipated that processes needed in the future are subject to different costs incurred as is the case when the IPS² is developed.

Therewith, process costs can be calculated under consideration of a dynamic cost development over the whole life cycle.

Thereafter the respective number and temporal occurrence of the necessary IPS² processes needs to be estimated. After that the IPS² price floor can be determined by summing up the IPS² process costs of the separate periods and a subsequent discounting to the time at which the cost calculations are made.

As discussed in chapter 3.2, flexibility plays a major role with regard to IPS². In the following, we therefore focus on the costs associated with offering flexibility. As a means of illustration we employ a scenario. What has to be noted is that the innovative IPS² solutions discussed in this paper are reduced in complexity for our scenario. The manifold IPS² dimensions which challenge the calculation of costs and revenues for IPS² are broken down to the dimension of maintenance. We follow this way of conduct in order to better be able to elaborate on the means of calculating costs and revenues for IPS². Our scenario is as follows:

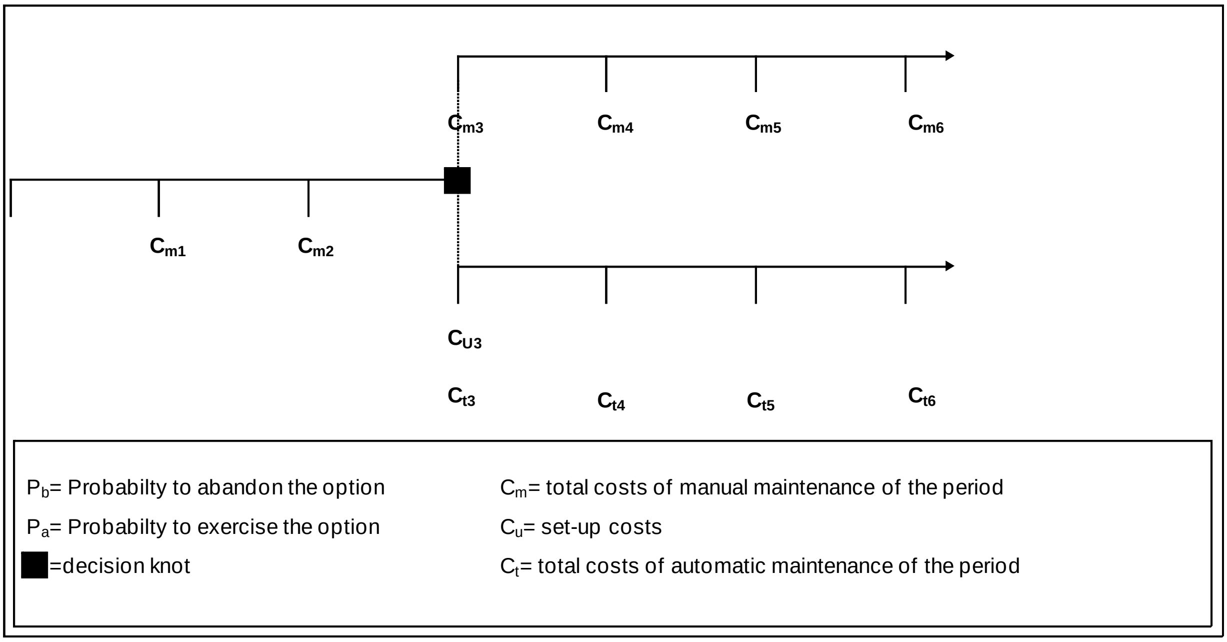

Figure 2: Total costs of the same scenario

A customer acquires an IPS² with an assumed life cycle of 6 periods. Cost considerations in this scenario are limited to a maintenance contract which is part of an IPS². Furthermore, we assume that the need for maintenance depends on the overall output. The higher the output is, the greater is the need for maintenance. Maintenance can be conducted either via manual or via automatic process execution. Automatic maintenance requires high initial outpayments, whose amortization is dependent on a high maintenance frequency, as the costs for each maintenance are higher for manual than for automatic maintenance. The number of maintenance processes to be conducted by the supplier in period 1 and 2 are fixed by contract beforehand. Owing to a low expected output, these maintenance processes are to be manually conducted to save costs.

An increasing demand and therefore an increasing output is expected for period 3, which would result in a higher maintenance frequency.

The flexible IPS² component consists of the following switching option: In period 3 the customer can decide to switch from the contractually agreed upon low maintenance frequency to a high maintenance frequency. If the customer in our scenario pays a fixed price for maintenance, which is independent of the actual maintenance frequency, the supplier will choose to switch from manual (service) to automatic (product) maintenance execution.

By using the previously described methods it is possible to determine customers' willingness to pay for such a maintenance contract. The willingness to pay represents the customers' price ceiling. To determine IPS² profitability it is now necessary to also determine the price floor.

To do so, costs which incur if customers' make use of their switching option must be calculated. The following costs can be identified for our scenario:

1. Costs for materials needed to reconfigure the machine. These are direct costs, which can be calculated with the Direct Costing approach.
2. The number of employees needed to reconfigure the machine. Costs for the configuration processes for which the employees are needed can be determined with TDABC.
3. It might also be the case that customer employees need additional training after the reconfiguration. TDABC can serve to calculate the training costs.

In a next step the probability that customers will really make use of their switching option needs to be estimated. By doing so the expected value of all costs related to maintenance along the IPS² life cycle can be determined. Figure 2 illustrates the situation at hand.

The expected overall costs for the IPS² maintenance including the switching option can be calculated as follows:

$$C_g = \sum_{t=1}^{t=2} C_{mt}\cdot(1+r)^{-t} + p_b\cdot\left(\sum_{t=3}^{t=6} C_{mt}\cdot(1+r)^{-t}\right) + p_a\cdot\left(C_u\cdot(1+r)^{-t} + \sum_{t=3}^{t=6} c_t\cdot(1+r)^{-t}\right) \quad (8)$$

Costs for manual maintenance (C_{mt}) are subject to change over the life cycle, owing to the previously described integration of learning effects into cost calculations. Costs for automatic maintenance (C_t) can be assumed to be constant. The summing up and discounting of the costs related to maintenance provide the price floor for the IPS² maintenance contract including the switching option. To calculate the overall IPS² price floor all costs incurring over the IPS² life cycle can be included in the formula.

If the IPS² price floor surpasses its price ceiling, the IPS² is economically not feasible and will therefore not be offered to customers without further adjustments and reconfigurations. Hence, it is possible to assess the expected IPS² profitability using the methods introduced in this paper. If various IPS² can serve to solve customers' problems and are economically feasible, the one with the greatest difference between price floor and price ceiling should be chosen.

5 CONCLUSION

To the many challenges companies are facing today, IPS² could constitute a solution. But only if the supplier's costs are lower than the revenues, an IPS² is really profitable, whereas a supplier should offer the IPS² which leads to the highest difference between revenues and costs. The subject of this paper was the calculation of an IPS² costs and revenues which takes into consideration the specific characteristics of an IPS², being the possibility to change an IPS² and the service parts.

One possible way of determining the revenues is a determination of the price ceiling using a combination of the net present value approach and the real options approach. The mere application of the Net Present Value thereby renders the customer value of an IPS² without any flexibility, leading to a systematic underestimation of the value which the IPS² 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 IPS². The costs are accounted by combining the direct costing, the time driven activity based costing and the real options approach.

Future research should investigate the optimal IPS²-configuration from the supplier's point of view which leads to sustainable high profits. An application of the methods introduced in this paper using a case study from industry could also be beneficial for the further establishment of IPS².

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