Development accompanying calculation - How to calculate IPS² costs during the early development phase?

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Abstract

Recently, many companies of the capital goods industry are moving away from simply offering individual products to providing innovative customized solutions, so called Industrial Product-Service Systems (IPS²). This article introduces a system which enables the calculation of an IPS² in the early phase of development. This system is based on specific IPS² characteristics and information which is provided in the different phases of development. We therefore deduce the requirements for the development accompanying calculation which are caused by the transformation from a product supplier to a supplier of IPS². Subsequently, we make use of a systematic illustration of these requirements to examine to what extent traditional instruments of construction accompanying calculation are able to meet these requirements and to reveal weaknesses of these instruments. We then provide solution alternatives, which lead to the design of a calculation system for IPS².

Keywords

IPS², Development accompanying calculation, Time-Driven Activity-Based Costing, Target Costing

1 INTRODUCTION

Recently, many companies of the capital goods industry are moving away from simply offering individual products to providing innovative customized solutions. While a few years ago the core competences of such enterprises were centered on the development and production of machines and plants, today's highly dynamic markets ask for a radical change of mind. Due to the globally accelerated spread of information an approximation of competitors' core performances has taken place. In this regard, it becomes very difficult for a company to differentiate itself from others which leads to a severe price erosion with decreasing profit margins. On this background enterprises try to successfully rival on the global market by designing highly complex products. This on the other hand is accompanied by a shortfall of customers' knowledge regarding the use, maintenance and disposal of such commodities. Thereby, the primary technological advantage which is, compared with standardized products, used to justify the accordant additional charges, is being ruined. [1]

Based on the previously described problems companies are forced to expand their product-centric business models by offering after sales services. In this regard, short-term strategies which are mostly used in the context of such after sales businesses turn out to be unrulable cost drivers. Furthermore, these widespread unplanned offerings mostly emerge as a so called "service jungle" which is in the end neither transparent for the provider nor for the customer. [2] In this regard, they also often fail to meet their customers' requirements. To that effect, in the long term enterprises have to emerge as providers of so called **Industrial Product-Service Systems (IPS²)**. Such innovative customized integrated solutions similarly consist of products and services which have been simultaneously developed and are being offered on business-to-business markets. [1]

It is the aim of this contribution to point out the development accompanying calculation of industrial product service systems as the crucial part of a proactive cost management. Deduced from the requirements which go alongside with the transformation towards an IPS² supplier this contribution highlights solutions of a development accompanying calculation which are then integrated into the system of a **proactive cost management** of IPS².

2 BASIC PRINCIPLES OF A DEVELOPMENT ACCOMPANYING CALCULATION

The possibility of influencing costs is highest in the early stage of development. At this stage 70% to 80% of the overall company costs are being determined. The fact that constructing engineers make their decisions during the development stage without taking into consideration economic aspects therefore has to be seen as critical. This can be exemplified by focusing on the decision regarding the system architecture of a product, which is to be made during the development process. The core product's technical alternatives which are needed to warrant the functions dictated by customer needs are mostly being selected based on experience or gut feeling of the constructing engineer. [3] Selection of technical alternatives based on such an approach are being made without including economic considerations and cannot be used as a basis for further decisions. The purely technologically oriented development approach needs to be extended by an economic perspective.

The **Development accompanying calculation** aims at solving this problem. The constructing engineer is being provided with information which allows the estimation of cost consequences of the actions taken during every phase of the development process. However, the different directions of calculation and development are problematic in this regard. Calculation follows a bottom-up approach in which overall product costs are being determined starting with single components and assemblies. Development follows a top-down approach as illustrated in Figure 1.

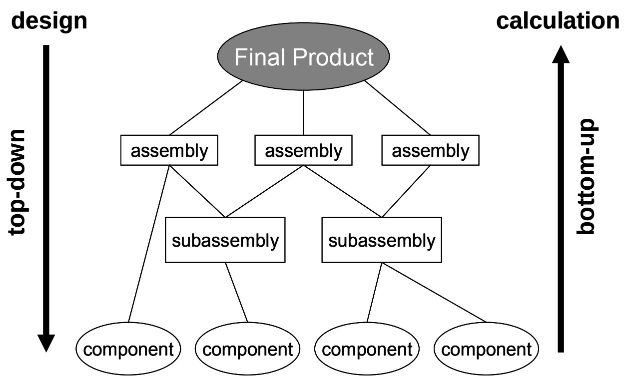

Figure 1: Direction of calculation and design. [4]

Following this approach calculation can only start after the development is completed. At this point of time, however, factors which trigger company costs have already been determined. Therefore only a reactive cost management can be used. As this contradicts the demand for a proactive cost management, the development accompanying calculation provides methods which are adjusted to the information level of the different development phases.

The following phases can be distinguished:

- the planning phase
- the conception phase
- the draft phase
- the project engineering phase.

In the planning phase only the requirements which have to be met by the IPS² are being described. The conception phase focuses on the functions which need to be fulfilled by the IPS². Solution concepts, but no product drafts are being created. Products drafts are being developed in the draft phase. The project engineering phase is characterized by the highest level of detail, the final form and dimension as well as the construction data are being determined. [4]

2.1 Planning Phase of an IPS²

In the context of IPS² the development accompanying calculation adopts a special role. Customized problem solutions require quick and precise cost estimation already in the planning phase. The precision of the calculation in this phase is decisive for the economic success of an IPS² and therewith for the economic success of an IPS² provider. Missing knowledge about or missing precision regarding costs which will incur in the future can lead to the following effects: On the one hand prices set by the IPS² supplier might be too high, leading to failing business negotiations on the other hand suppliers might not be able to cover future costs incurring during the processing of orders. To solve this problems the instrument target costing, as part of the proactive cost management of IPS², needs to be applied parallel to the development accompanying calculation.

Target costing serves to circumvent prices rejected by the customer, by not developing the IPS² with the maximum technological capacity, but instead developing a configuration which focuses on the parameters costs, characteristics and quality and is accepted by the customer. [5] Target costing provides an answer to the question “at which level can the IPS² price be set”. The development accompanying calculation answers the question “at which level will the IPS² price be set”.

Target Costing consists of four steps: [6]

1. Determination of overall target costs
2. Target cost splitting
3. Target cost attainment
4. Target cost controlling

Only the first step occurs in the IPS² planning phase. To carry out the subsequent steps information is necessary, which cannot be provided at this early stage of development. The determination of overall target costs (Step 1) depends on the object focused upon.

Beside the market into company approach, the approaches out of company, into and out of company, out of competitor and out of standard costs can be applied. However, only the market into company approach determines overall target costs out of the relevant market respectively out of the specific customers in the case of IPS². The other approaches mentioned derive target costs either completely or in parts from the technologies and experiences of the supplier company and the competitors. To reduce the threat of a target price which is not accepted by the customer these approaches should therefore not be used for IPS².

The result of the first step of target costing is the target price of an IPS². Subtracting a target profit for the supplier from this price leads to the overall IPS² costs which are accepted by the customer, so-called allowable costs. [7] The cost ceiling of an IPS² is therewith already calculated during development. Crossing this cost ceiling results in failing economic viability.

The calculation of the IPS² costs during the planning phase is problematic due to the low degree of detail of the IPS² which is to be configured. A bottom-up approach cannot be chosen as neither solution concepts nor parts and components to be used have yet been determined. Calculation therefore needs to be focused on the level of the end product. The costs of the IPS² which is to be developed are hereby derived from the costs of similar IPS² of the supplier. The costs of similar systems can be extracted from a cost data base, in which the system architecture as well as the requirements are displayed and in which cost data are available broken down to the level of components. [4] The assessment of economic success of IPS² to be developed depends on the precision of this data. Therefore the choice of the cost accounting methods which are to be used by a company is very important.

Another factor with great importance for assessing the economic feasibility is the IPS² business model chosen by the customer. Three different types of business models can be distinguished, **function oriented**, **availability oriented and result oriented business models**. [8]

- The objective of a function oriented business model is to secure the functioning of a good over an agreed upon period of time. Hence, the core business is gradually extended by product accompanying services to the degree that a cooperation between supplier and customer is requested.
- When the supplier takes over availability guarantees (e.g. maintenance and optimization services) it is the first time that he has a personal responsibility concerning the technical production risks of the customers and is thus directly integrated in the business processes (availability-oriented business model).
- If the supplier is completely responsible for the production result, we talk of a result-oriented business model.

Depending on the chosen business model a gradual shift of cost risks from customer to supplier takes place. While in the function oriented business model customers initiate the conduction of services, this is the direct responsibility of the supplier in the result oriented business model. Costs incurring in this phase of an IPS², including all services conducted, need to be covered by the customer in the function oriented business model and by the supplier in the result oriented business model. This has consequences for the system architecture and the methods of cost estimation which are used in the planning phase.

Consequences for the system architecture:

While minimizing life cycle costs should be the aim of constructing engineers, the purchase price is still the most important aspect in the machine and construction site sector, although this approach is myopic and often not economically feasible. [9] In this context the trade-off between initial costs and follow-up costs is crucial. Minimizing life cycle costs is mostly accompanied by an increase in initial costs (development costs, costs of production, etc.) which are being compensated by a disproportionate decrease of follow-up costs (costs of operation, maintenance costs, energy costs, costs of disposal, etc.).

Consequences result especially for the function oriented business model, because customers are at first primarily interested in buying the physical component of an IPS².

An IPS², based on minimal life-cycle costs, leads to a price increase due to high start-up costs in this first, short-term relation between customer and supplier. It is a result of the fact that, in this business relation, only the customers profit from the cost savings in the operation and disposal phase. Empirical surveys proved, however, that only a minor part of potential customers uses the Total Cost of Ownership method, which helps to unveil the advantage of increasing acquisition costs. [10] [11] [12] [13] Therefore, IPS² suppliers should thoroughly consider the strategies which are to be followed within the function-oriented business models. On the one hand, it is possible to present calculations concerning increasing life cycle expenses to the customer in order to reveal the advantages of the higher purchase price; on the other hand, the target of the development can be a minimal purchase price. The last-mentioned strategy cannot be recommended to IPS² suppliers, as the current price war in the capital goods industry is one of the major reasons to become a supplier of Industrial Product Service Systems.

Effects on quotation costing:

Apart from the described effects on the system architecture of an IPS², the selection of the business model will also effect quotation costing. In case of the **function-oriented business model**, the calculation of the primary costs of the IPS² is sufficient, as the material components of the IPS² and the services required by the customers in the operational phase are priced individually. It is necessary to include further types of costs, when taking over a part of the cost risks (**availability-oriented business model**) respectively the full cost risks (**result-oriented business model**) by the IPS² supplier in the pre-development phases. In case of the availability-oriented business model, it needs to be clarified, from the supplier's point of view, which services need to be available at which point and to what extent, in order to fulfill the availability agreed. Finally, in a result-oriented business model, the complete life cycle costs of an IPS² need to be determined as the supplier is responsible for the operation of the machines. This relation between selected business model and extension of the business relation between customer and supplier needs to be considered explicitly when using the methods of target costing and the development accompanying calculation.

Finally the result of the planning phase is a target price which is derived from the customer's willingness to pay for an IPS² which serves as a cost ceiling during development. By using development accompanying calculation a matching of target costs and costs emerging on the level of the whole product is possible already in the planning phase of an IPS².

2.2 Conception and draft Phase of an IPS²

In the conception phase, the IPS² is described with the help of functions, in order to prevent a fixation on components (products) and processes (service). Functions fulfill requirements, which are performed and considered as important by the customers. [14] Within the context of a proactive cost management it is not sufficient to contrast the overall target costs, determined in the planning phase of an IPS², with the incidental costs. A specific cost influence requires a higher level of detail. Target costs need to be specified in the level of the products component, respectively processes. The distribution of the overall target costs on functions and corresponding components, respectively processes is made in the second step of Target Costing, target cost distribution (see Figure 2). Different approaches of target cost distribution have been dispread in literature. [7] The Functional Area Method is used for complex innovative products, it is based on the assumption that an IPS² can be represented by a combination of functions, which are fulfilled by technical components or processes. [15] Basis for the Functional Area Method is the conjoint-analysis, whose goal is to specify the functions which need to be

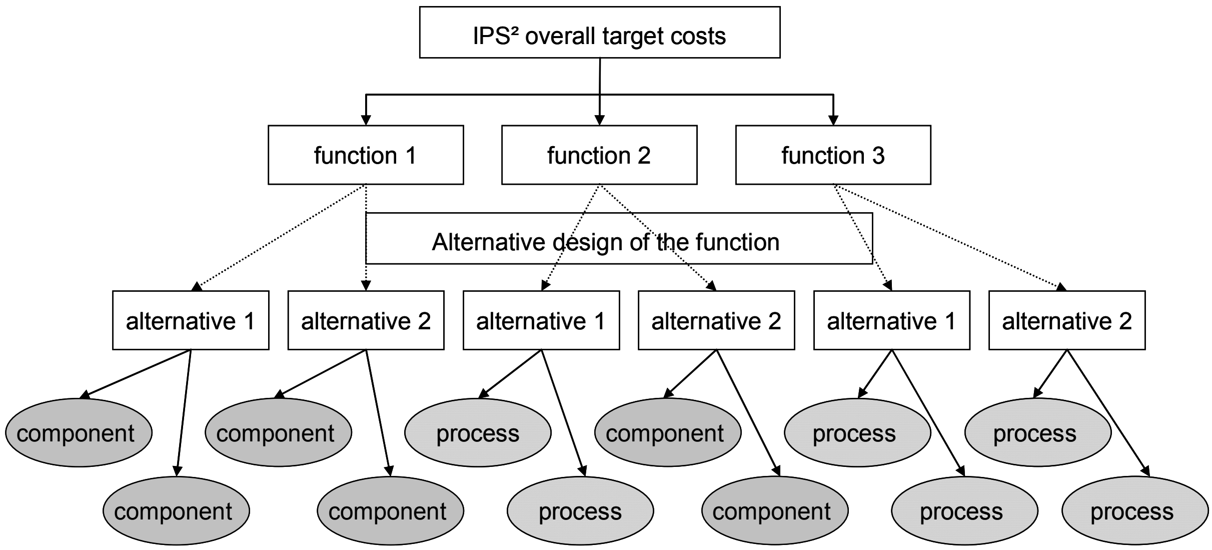

Figure 2: IPS² system architecture

fulfilled by an IPS² (from a customer's point of view) and, at the same time, to show the valuation the customer gives to these functions. Based on the latter, the share of benefits of the components, respectively processes, which are required to fulfill the functions, in the overall benefit will be specified. This share of benefits can be interpreted at the same time as an upper cost limit of the function. [16]

The second step of target costing cannot be applied during the conception phase. The necessary details will only be supplied in the following draft phase. In this phase, a so-called rough draft of the IPS² will be developed; the result being a list of all technically possible alternatives of functional compliance. In the case of IPS²s, this rough draft will also show the substitution of products and services. There is the option that either components (products) or processes (services) can be used to fulfill several of the functions (compare Figure 2).

Result of the target cost distribution is, apart from the listing of required components, respectively processes to fulfill the function, an upper cost limit of individual functions. In the third step of target costing, target cost attainment, so-called drifting costs need to be specified and contrasted with the target costs. Drifting costs are predicted costs for the IPS² creation based on the existing technology and process standards of the company.

A rough draft of an IPS² is used to specify the incidental costs of a company up to process, respectively component level. The systems used for cost calculation will be explained in chapter 3 in more detail.

The alternatives to fulfill the functions have been determined from a mere technical point of view and are now subject to an economic evaluation. The proceedings, which have been criticized in chapter 2, namely the selection of alternatives for function fulfillment, which are based on the experience of the developer, have thus been extended by an economic point of view.

Cost information has been provided, which is, apart from strategic aspects, particularly relevant in, e.g. make-or-buy decisions. Based on this cost information, a statement can be made if certain components or processes are to be produced, respectively provided or if they are to be sourced out. [16] [4]

The costs of the function are specified by adding up the components, respectively processes which are part of an alternative of function fulfillment. In the following confrontation of these drifting costs and target costs, there are three cases which require different types of action:

- **Target costs = drifting costs**: In this case the customer's requirements are fulfilled in an optimal way. The costs caused by the components, respectively processes correspond exactly to the weight of this component, respectively process for the fulfillment of the IPS² function
- **Target costs > drifting costs:** The customer assigns a higher value to the function, than the costs it causes. In this case it needs to be examined if the processes, respectively components used fulfill the customer's actual requirements**.**
- **Target costs < drifting costs:** The costs exceed the value attributed by the customer. Costs need to be reduced.

At the end of the design phase all information is available in order to choose a variety of the components and processes used in the function realization, both from a technical and economic point of view. This information can be used to support the decision when selecting the system architecture of an IPS².

It needs to be pointed out that a mere cost observation as a decision criterion for the alternative selection and thus the decision about the system architecture of an IPS² is not sufficient. With the transition to a long-term business relation, as in the availability- and result-oriented business model, a certain degree of flexibility will be required in order to be able to react to future environmental influences in an appropriate way. This flexibility needs to be designed already in the development of an IPS², by adjusting the system accordingly. In this context, cost information can only be used to support the decision.

Based on the results of the draft phase, the final design and dimension of the IPS² can be made in the project engineering phase. In this phase, every component and its alternatives will be formulated technically and evaluated economically so that the best alternative can be selected [4].

The combined use of target costing and the development accompanying calculation enable, in the early phases of the IPS² development already, the support of engineering methods and complements the merely technically point of view by an economic perspective. The strict pursuit of a customer orientation over the complete design process and the constant comparison with the future costs of an IPS² enable an early evaluation of profitability. At the same time, approaches for cost influences will be shown at an early stage already, thus supporting a proactive cost management as illustrated in Figure 3.

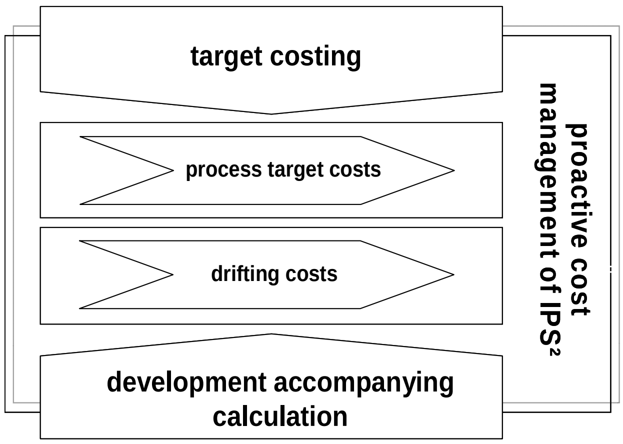

Figure 2: IPS² Cost Management. [17]

3 COST ACCOUNTING FOR IPS²

As mentioned in the previous chapters, cost calculation of IPS²s is very important within the development accompanying calculation. Without a **cost accounting system**,

which provides detailed information concerning the costs of the companies, an economic foundation for the transfer to an innovative business model it is not possible.

It is particularly the fact that IPS² suppliers do not only offer products, but services too, which is a challenge to the **traditional cost accounting systems** which are used in mechanical engineering. Due to a lack of organizational units for the service provision, the costs are usually allocated indifferently to cost centers. [18] In the case that services are recorded separately, there is also a problem with traditional cost accounting systems. Service costs can usually not be added to individual performance and are therefore overhead costs, and are allocated via surcharges to calculation objects. The problems arising from this fact will be described in detail later in this article.

The use of traditional cost accounting systems can also be criticized within the frame of a development accompanying calculation. A special emphasis needs to be placed on the decision in the design phase of the IPS² concerning the alternative selection for the function fulfillment (compare chapter 2). When the focus is on the direct material costs, as common in traditional systems, a wrong signal is sent to the developer. It is a result of the allocation of overhead costs via a direct-material burden rate. Developers are going to choose alternatives with particularly low material costs, in order to reduce the overheads costs allocated to the components. Therefore, traditional cost calculation systems favor alternatives with a large number of reasonably-priced components. Here, complexity costs in form of overhead costs will not be allocated to the components individually, but to the individual material costs via overhead rates. [19] A way out is Activity-Based-Costing (ABC). In this system overhead costs are not allocated via overhead rates but are allocated process-oriented. The following section is supposed to represent the ABC system by means of the service processes occurring in an IPS² and show the amount of extensions which need to be added.

3.1 Costing of IPS² service processes

Service characteristics pose a major challenge, when it comes to calculating the costs of an IPS². In this regard, the integration of a customer or rather his external factors as well as the intangibility or rather the fact that services cannot be produced in advance, can be considered to be most fundamental. [20] In order to be able to perform such processes, service providers have to 'establish' capacities (e.g. personnel) which cannot be reduced at short notice. Hence, due to the fact that in most cases such capacities cannot be assigned to one single process, but rather to a multitude of different service offerings, overheads emerge. Traditional cost accounting systems allocate such indirect costs generally via a direct material burden rate. In case of services, where such indirect costs are dominant, these rates lose their validity. That is attended by the fact, that in the past, mainly products rather than services have been used as calculation object. Thus, against this background, a direct costing of service processes is not possible.

3.2 Time-Driven Activity-Based Costing (TDABC)

In view of the previously described problem, *Cooper* and *Kaplan* developed a method called **'Activity Based Costing' (ABC)**. [21] In opposition to traditional cost accounting instruments, due to its complex exposure to overhead costs, such a costing technique can be particularly valuable, when it comes to calculating an IPS²'s service processes.

However, by virtue of the increased share of fixed indirect costs in the context of services, the ABC approach cannot be adapted without specific modifications. In order to determine the emerging costs of an activity or rather process, the respective resource costs are being calculated. After that, they are being divided by the estimated or actual sum of cost drivers. In this regard, the notion 'cost driver' describes a reference parameter which particularly influences the amount of costs. However, in case of fixed overheads it is to criticize that the respective cost rates vary, depending on the amount of cost drivers.

The following example shall help to explain the previous argument. Resources, worth of $112.500, have been assigned to a specific process (e.g. maintenance) during a period t_1. Furthermore, cost drivers (e.g. number of performed maintenances) emerged in the amount of 800. This in turn leads to a process cost rate of $140,63.

In opposition to period t_1, in period t_2, cost drivers occurred in the amount of 700. Such a reduction is caused e.g. by the loss of customers. Against this background, due to the fact that the respective resources (e.g. personnel) cannot be rapidly reduced, the process cost rate varies. Hence, although the same amount of resources has been used as in period t_1, during period t_2 the process cost rate rises to $160,71 (cf. Table 1). In this context, the difference of $20,08 cannot be traced back to a loss of efficiency, e.g. regarding the personnel's performance etc. In fact, this rather indicates the costs which are caused by unused capacities. [22]

Period	Activity	Assigned costs	Activity Quantity	Cost Driver Rate
t1	maintenance	$112.500	800	$140,63
t2	maintenance	$112.500	700	$160,71

Table 1: Exemplary calculation of a maintenance costs by using the ABC approach

As a result, a company's degree of capacity utilization decides about the amount of the respective process cost rate. In order to avoid such unsteadiness, **Time-Driven Activity-Based Costing (TDABC)** has to be used. In general, this approach can be understood as an advancement of Activity-Based Costing. In case of the TDABC, the time needed to perform a certain process one-time, is being multiplied by the respective costs per time unit. Hence, this approach only needs the following two parameters in order to calculate the emerging costs:

1. costs per time unit in order to provide the respective resource capacities, and
2. time necessary to render a specific process one-time. [23]

Such a calculation can be subdivided into the following steps.

(1) First of all, in order to calculate the costs per time unit, one has to identify the amount of resources (e.g. personnel, tools etc.), necessary to perform a certain process. In a second step, one has to determine the respective resource's maximum capacity. In case of personal, it is assumed that 80% of the theoretic maximum capacity can be used. If it is about a machine, one calculates with 85 % of the theoretic maximum capacity. With regard to human resources, this is based, e.g. on work breaks, schooling or illness. In case of technical resources (machine), interruptions, just like repair or maintenance, lead to such a reduction of the theoretic maximum capacity. In a last step, the respective process's resource costs have to be divided by the calculated maximum capacity. As a result, one achieves the respective costs per time unit. In the following, these explanations will be clarified with the help of the previously described example. It is assumed that a company employs 15 people that are all equally qualified to render a specific service, e.g. maintenance. Each employee theoretically works 40 hours per week. This results in a maximum capacity of 32 hours per week or rather 128 hours per month (period). So to speak, in case of 15 people, this leads to a maximum capacity of 1.920 hours or rather 115.200 minutes per period. Hence, if it is additionally assumed that resources in the amount of $112.500 have been assigned to that particular process, costs to the tune of $0,98 per minute occur for the capacity's provision.

(2) Besides identifying the costs per time unit, the time necessary to render the process once also has to be determined. In most cases, this is based on direct observations. With regard to our example, we assume that a process time of 120 minutes has been assigned to each maintenance provision. Thus, by multiplying the costs per time unit by the respective one-off execution time, this results in a cost rate of $117,60 for performing the respective process once. As a result, such a cost rate has been calculated independently of the cost drivers' amount. Hence, the variability which has been criticized in the context of the ABC approach can be avoided. Therefore, in view of our example, the process cost rate of $117,60 per period t_1 and period t_2 correctly reflects the real amount of resources needed to perform the respective maintenance one-time. Table 2 illustrates these coherences.

Period	Activity	Activity Quantity	Unit Time	Total Time used	Total Time Supplied
			In minutes		
t1	main-tenance	800	120	96.000	115.200
t2	main-tenance	700	120	84.000	115.200

Period	Assigned Costs	Cost-Driver Rate	Cost of unused Capacity
t1	$112.500	$117,19	$18.750
t2	$112.500	$117,19	$30.469

Table 2: Exemplary calculation of a maintenance's costs by using the TDABC approach

In this regard, the costs of an action in the amount of $140,63 (period t_1) and $160,72 (period t_2) which had been calculated with aid of the ABC approach include idle time costs.

However, in the context of the traditional Activity-Based Costing such costs cannot be identified separately. Only by using the proposed TDABC approach, such idle time costs become obvious.

With the help of the TDABC approach, the cost information provision of the decision which needs to be made in the design respectively offer phase of the IPS², concerning the choice of the various ways to fulfill the functions can be guaranteed. With the identification of a resource use caused by a particular process, there is an additional guarantee that the cost approaches will not be distorted by the company's periodic capacity utilization.

4 CONCLUSION

70% to 80% of the overall company costs are being determined during the development of a product. Therefore, it has to be seen as critical that constructing engineers often make decisions without any economic information. In this paper we showed that the development accompanying calculation and target costing as parts of a proactive cost management for IPS² are able to complement the merely technically point of view by an economic perspective.

Based on the level of information of the different development phases of an IPS² we examined the applicability of development accompanying calculation and target costing. Furthermore, we identified IPS² specific requirements. As a result we can state that a matching of IPS² costs and the costs which customers are willing to cover can be done on various levels of detail in the different development phases. In an early phase of development a cost calculation of the IPS² which is to be developed has to be based on similar, already existing, IPS² which the supplier offers. In this phase costs can only be estimated for the overall IPS². In subsequent phases costs can be estimated for components and processes, due to further detailing of the IPS² system architecture. In this regard, the kind of cost accounting system used plays a major role. Traditional cost accounting systems are not suitable for the development accompanying calculation of IPS². In this systems product costs were systematically distorted through the focusing on direct material costs and allocating overheads via a direct-material burden rate. Therefore we presented the activity-based-costing as system to eliminate this problem. However, services, which form an additional part of IPS², demand an enhancement of ABC. TDABC has been introduced as such an enhancement; its advantages have been emphasized by means of a example.

Target costing and development accompanying calculation have been pointed out as methods of a proactive cost management which allows a systematic match of incurring and allowable costs already during the development phase.

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