

**DELIVERY MANAGEMENT OF INDUSTRIAL PRODUCT-SERVICE SYSTEMS –
CHALLENGES FOR A PERFORMANCE MEASUREMENT**

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ABSTRACT

In the manufacturing industry, competitors are continuously struggling to differentiate themselves from other companies in the market. Industrial product-service systems (IPS²) offer this differentiation by representing a paradigm shift from traditional product selling and service offering to providing customer value. During the use phase of IPS², the organisation and planning are executed and managed by the IPS² execution system (IPS²-ES). To ensure and improve the effectiveness and efficiency of the IPS²-ES during the use phase, a performance measurement is needed. This paper presents a motivation for a performance measurement during the delivery phase and based on this the requirements for the performance measurement are introduced. An outlook for further research will be given.

Keywords: Performance measurement, industrial product-service system (IPS²), planning

1 INTRODUCTION

For several years now, product-service systems (PSS) have been in the focus of both research and industry, as for example presented in Aurich and Clement (2010) and Mont (2002). The authors point out that PSS consist of product shares and service shares that are provided to a customer to achieve customer value. Meier *et al.* (2010) also cover the topic of integrated products and services, but they focus on industrial product-service systems (IPS²) with customers from various industry sectors, not on consumer solutions. A definition of IPS² is presented in Meier *et al.* (2010) as follows:

An Industrial Product-Service System is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system.

Research shows that the lifecycle of IPS² consists of different phases (Aurich *et al.* 2007; Meier *et al.* 2012). While Aurich *et al.* (2007) list those phases as organisational implementation, PSS planning, PSS design and PSS realisation; Rese *et al.* (2012) present a more detailed approach. They distinguish between a planning phase, development phase, implementation phase, delivery and use phase and a closure phase. This paper focuses on the delivery and use phase, in which the IPS² is used by the customer or the provider to fulfil the customer needs. To be able to deliver the IPS² to reach the contracted customer value, the provider has to work in networks, as for example suggested in Völker (2012). Although there are several contributions for supply chains in different sectors (e.g. Voudouris

et al. 2008) the network organisation for IPS² has special requirements and is briefly explained in section 2.1. For the efficient and effective delivery of the IPS², the resources that are provided by the different network partners have to be planned. Both strategic capacity planning as well as operational resource planning have to be considered (Funke 2012). These research fields are briefly described in section 2.2. Because of the complexity of these planning approaches and the need for managing the network of partners, it has been found that existing software solutions do not provide the required support for the IPS² provider (Meier and Dorka 2013). This paper introduces a new software system, named IPS² execution system, which is further described in section 2.3. Based on the state of the art in this field, this paper demonstrates the need for a performance measurement method for IPS² in chapter 3. Based on this motivation, the requirements for such a method are derived in chapter 4. The results of this work have laid the basis for further research, which is presented in an outlook at the end of this paper.

2 STATE OF THE ART

To give an introduction to the research topic, the network organisation and planning for IPS² are described in the following sections. The IPS² execution system is explained, which sets the context for the performance measurement presented in this paper. In this context, the authors provide an overview of the literature concerning performance measurement and present different views on the topic.

2.1 Network Organisation for IPS²

The delivery of IPS² is a complex task. An IPS² provider cannot necessarily provide all required resources for the delivery. Therefore, a network of partners, including the IPS² provider and the IPS² customer, is created to deliver the IPS² in cooperation (Völker 2012). The integration of the customer is above all an important task in product-service systems. Each partner in the network assigns some of his resources to be available for the delivery and by that forms a virtual organisation unit. The different virtual organisation units in the network form a virtual organisation for the delivery of IPS² (Völker 2012). While the different partners can even participate in the development of the IPS², the IPS² provider is responsible to select the partners who form the network for the delivery.

2.2 Planning for IPS²

Based on the network organisation for IPS², the resources provided by the network partners need to be planned for the delivery of the IPS² customer value (Funke 2012). Multiple delivery processes (e.g. maintenance processes, training events, repair processes, etc.) per IPS² have to be scheduled. Most delivery processes can be considered in the strategic capacity planning because their schedule is predefined in the IPS² product model. Here the required capacities for different resource types are identified. During the execution of the delivery plan it might happen that an unscheduled process has to be executed, as for example a repair process. Operational resource planning integrates the new process into the existing delivery plan using the available resources.

2.3 IPS² execution system

To support an IPS² provider in the delivery of the IPS², namely in the scheduling of delivery processes and management of the partner network, an IPS²-ES can be utilised (Völker 2012). A definition of an IPS²-ES is given in Meier et al. (2013) as follows:

An IPS² execution system is the essential software system for the IPS² operation phase that supports the IPS² provider in the provision of customer value by adaptive IPS² delivery planning, IPS² network management and an integrated performance measurement method.

According to this definition, the IPS²-ES has to provide means of adaptive IPS² delivery planning and IPS² network management. To do this, it has to leverage methods developed for IPS² and provide proper software support. Basically, the organisational entities of the IPS² network have to be represented in the software system to provide data about resources that they provide for the IPS² delivery (Meier et al. 2013a). With this information the IPS²-ES can execute strategic capacity planning and operational resource planning as introduced in the chapter above. Whenever an unplanned demand at one of the supplied IPS² arises, the IPS²-ES has to consider this demand and

change the delivery schedule to include the new demand. The IPS²-ES provides a high level of automation in the execution of its tasks. It uses self-organisation to add or remove connections to the partners' software systems and executes the planning method automatically whenever needed (Meier *et al.* 2012). Although the user of the system can intervene at any time and change the systems behaviour, the following questions remain unanswered: is the intended effect of the IPS² reached and is it reached efficiently? This means that the performance of the system is not known. Since the IPS² operates automatically and does so without requiring user input, it is not possible for the user to evaluate the performance based on his actions. A measurement of the performance, which is already mentioned in the definition of the IPS²-ES, can provide the required information to decide whether a user intervention is needed.

2.4 Performance Measurement

Performance Measurement approaches have been used for corporate management since the end of the 1980s. These approaches use new concepts and key figures (Gleich 2001) and are a further development of traditional ratio systems (Leimeister 2012). Compared to control data which refers to the past in traditional ratio systems, Performance Measurement is designed to be future- and process-oriented (Lynch and Cross 1995). This development was pushed by the interest in process orientation, customer orientation and quality improvement (Giese 2012). Hence, performance measurement has not only been applied for monitoring and measuring but also as a decision making support. Literally, Performance Measurement means the measuring of performance. There is no common definition of Performance Measurement in the specialist literature because many authors forgo a definition due to the high complexity and permanent development (Giese 2012, Leimeister 2012). However, the most definitions have in common that performance measurement should control and improve efficiency and effectiveness and the focus is on strategic issues (Giese 2012). Another reason for the no common definition of performance measurement is that performance measurement is used in different sectors such as supply chain management (e.g. Giese 2012) or services (e.g. Leimeister 2012). Richter and Steven (2009) developed a balanced scorecard as an instrument of performance measurement for IPS². The classic balanced scorecard from Kaplan and Norton (1997) considers the process, potential, customer and finance perspective. The balanced scorecard for IPS² was extended by the relationship perspective because IPS² require trustful dealings between the partners. The focus of the IPS² balanced Scorecard is rather on strategic issues. Computer science uses a similar definition. Performance is defined as a "degree to which a software system or component meets its objectives for timeliness" (Smith 2002). That means primary response time behaviour and secondary throughput and capacity of the software system (Pressmann 1992). The response time behaviour is an index for the speed of the system from the end user perspective (Smith and Williams 2001). The throughput describes the operations per time unit (Woodside 1988). The capacity of the software system is defined as the collection of resources like the speed of the processor or the bandwidth of the network. Thereby the response time is the most important performance indicator for the end user. It is irrelevant for the end user whether the capacity or throughput is the problem for a high response time (Schlimm *et al.* 2007). Overall, performance measurement is a way to measure and evaluate the effectiveness and efficiency of a system in order to draw conclusions. It is of minor importance whether a company, a department or a software system is analysed. The primary function of a performance analysis is to support managers in making decisions.

3 MOTIVATION AND NECESSITY FOR AN IPS² PERFORMANCE MEASUREMENT METHOD

Referring to the chapter above, the main aim of the IPS² performance measurement method (IPS²-PMM) is to make sure that the targeted effect of the IPS²-ES is reached. As already described in the definition of the IPS²-ES, the system is a highly automated software system that provides IPS² delivery planning and coordination of the partner network. During the delivery of IPS², the needs of customer and provider have to be provided as defined during the IPS² development phase. Customer expects that the promised customer value is reached and that s/he is satisfied with the delivery of the IPS² as a whole. The provider, on the other hand, is interested in the efficient and effective delivery, represented by the delivery plan created by the IPS²-ES. In addition to that, the provider requires the

steady support of the IPS²-ES without major problems. The execution of the different tasks and the preservation of customer satisfaction as well as provider support are aggravated by the dynamic IPS² environment. Frequent changes in the customer demands require a quick reaction and flexibility of the IPS² provider and the IPS² itself. Thus IPS² are not rigidly developed but dynamic in their design. Particularly the cooperation with the customer allows for the quick reaction to changed customer requirements. Here the trigger could be the customer as well as new requirements which arise from generated knowledge during the use phase (Völker 2012). In addition to the dynamics represented by the customised IPS², each partner in the network and the IPS² are exposed to a general change which every company is confronted with. Examples for such a general change are developments like globalisation. These challenges are called change drivers and affect the whole organisation of a company (Wiendahl *et al.* 2007). Particularly service suppliers are exposed to a high uncertainty during the service delivery (Erkoyuncu *et al.* 2011). By the connection of several companies in supply chains, changes cause problems in the whole supply chain, as can be seen in the bullwhip effect (Lee *et al.* 1997). A similar effect is expected from changes within IPS². By the high number of stakeholders in IPS² networks, the effects of the change drivers on single companies are potentiated. As companies in IPS² networks originate from various industrial sectors, change drivers from all these sectors have an influence on the IPS² networks and therefore on the IPS² themselves. Hence, the delivery planning faces major challenges. The dynamics of IPS² modify the intended effect of the IPS² during the use phase which the planning has to adapt to. In turn, the main instrument for adapting the planning in the IPS²-ES is the weighting of the planning targets. A modified adjustment of these parameters leads to different planning results. Besides the planning, the network management is a main functionality of the IPS²-ES. From a traditional view, the competition of products is decisive for market leadership. However, with IPS² and the new product understanding, the qualities of the companies in the network are important sales arguments. Thus, a robust, effective and efficient network is particularly necessary. Here, especially the communication between the IPS² and the network partner is of high importance for the software system. Only a continuous communication with up-to-date information enables a feasible planning. If incorrect data is transferred or outdated data is forwarded, the danger of creating an invalid delivery plan is significantly rising. This prevents the network partners from reliably executing the delivery plan, which has a negative impact on the robustness of the network. As the IPS²-ES is a software system, it is subject to the same challenges that other software systems face. An IT measuring system can provide support in order to ensure a stable software environment. The motivations described above lead to the necessity for a method which safeguards the intended outcome of the IPS²-ES for an effective delivery of IPS². The special requirements for such a method will be presented in the next chapter.

4 REQUIREMENTS FOR AN IPS² PERFORMANCE MEASUREMENT METHOD

As described above, performance is a way to measure and evaluate the effectiveness and efficiency of a system in order to draw conclusions. In the context of the IPS²-ES, performance can therefore be defined as the capability of the system to execute the tasks required to effectively and efficiently deliver the IPS². These tasks are described in the definition of the IPS²-ES as follows: support the IPS² provider in the provision of customer value by an adaptive IPS² delivery planning, IPS² network management and an integrated IPS²-PMM. The IPS²-PMM ensures the performance of the other two main aims: IPS² delivery planning and IPS² network management.

In these systems, the technical side of the IPS²-ES can first be considered. For the overall system performance it is important that the leveraged software services (e.g. planning service, resource availability service, etc.) are executed without errors. Whenever a service shows a high error ratio, these errors might affect the whole IPS²-ES and therefore degrades its performance. Another indicator for under-performing services is the response time behaviour. A slow response time might either be caused by a sluggish network connection or by an inefficient algorithm used for the intended functionality. In both cases, the performance of other services or the IPS²-ES as a whole might suffer from these defects. It is not always possible to tell in which time a service has to answer a request, but it is possible to compare services with similar capabilities to each other. Hence, the IPS²-ES performance measurement has to provide a mechanism that allows the user of the system to identify under-performing services. This information can be used to replace these services by services with a

similar functionality but a more appropriate performance. The adequacy of purpose of services and partners is even more important for the IPS²-ES performance than the technical performance. The most crucial service of the system is the planning tool, i.e. a proper delivery plan. As mentioned above, the delivery plan has to be created while keeping costs low, processes on schedule and utilisation optimal. For the operational resource planning, the real-time capability of the planning method is of high importance. During the time constraint for the planning only the weights for cost, punctuality and utilisation optimisation can be changed for the planning. The aim of the IPS²-PMM here is to change the weights so that the costs still offer a profitable IPS² delivery for the provider while the punctuality and utilisation can be maximised in the given planning time. This is an on-going function the PMM has to provide so that the planning weights are adapted to the currently given delivery processes, available resources and IPS² to be provided. Thus, the PMM has to optimise the quality of the scheduling and control of the IPS²-ES. Other services can also be checked against their adequacy of purpose. In the IPS²-ES, services to determine the travel time and costs for service technicians are leveraged. This may include train operators, route planning services for cars, air carriers, etc. When one of these services always comprises higher travel costs and/or longer travel times, the service provider might not be adequate for the transport of the service technicians. This can happen, for example, if an IPS² provider only delivers IPS² in his vicinity. Similarly, services for the transport of tools and spare parts can be more or less adequate for the use in the IPS²-ES of a certain provider. Hence, the PMM can help to identify less useful services. When these are removed from the system, the delivery planning method has to consider fewer options when creating delivery plans. The delivery in a partner network requires reliable partners. If any delivery process scheduled by the IPS²-ES is not carried out correctly, the original plan loses its effect and therefore the IPS²-ES performance deteriorates. This can happen if a network partner delivers incorrect spare parts or does not achieve the required aim within the execution of a delivery process. Also an unachieved first-time-fix-rate can have an influence on the performance. These aspects have a direct or indirect impact on the customer satisfaction. Hence, the PMM has to track the difference between intended and actually reached effect of the delivery plan. Using this method, the IPS² provider can identify whether partners are reliable in their part of the delivery of the IPS². Apart from the reliability of the partners, their capability to participate in the virtual organisation of the IPS² provider can be measured. The partners have to stipulate the resources they can supply and the time at which these are available. The accuracy of the data as well as keeping it up-to-date is crucial. Whenever the availability of a resource changes, the IPS²-ES has to be notified to be able to consider the new availability in the planning. This ensures that each network partner can accept a newly generated delivery plan. If the availability information is not accurate, the partners might have to reject the delivery plan due to a lack of resources, which in turn requires a new planning run of the IPS²-ES. Hence, the ratio of rejected to accepted delivery plans reflects the capability of the partner to participate in the virtual organisation. This ratio can also be useful for the partner assessment whenever a reconfiguration of the IPS² network is necessary.

5 CONCLUSION AND OUTLOOK

In this paper, the necessity of a IPS²-PMM for IPS²-ES has been presented. It is clearly shown that the effectiveness and the efficiency of the IPS²-ES cannot be determined by the user without the aid of the system itself. The two main tasks of the IPS²-ES, namely the network management and IPS² delivery planning, have to be measured technically and their adequacy of purpose of both services and partners in the network. The next step is a software implementation of the IPS²-PMM into the IPS²-ES.

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