# Service Engineering as an Approach to Designing Industrial Product Service Systems

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**Abstract**

Unique customer solutions which integrate products and services into a high value offering have the potential to successfully differentiate from competition even prices are dictating product markets. However, companies face tremendous challenges to develop customer solutions. Service engineering is considered to be the scientific discipline which supports the design task of intangible offerings and thus a foundation for solution design. We enhance the existing body of research in service engineering by proposing to apply the systematic approach of service engineering for solution design. An architecture for services design is introduced as an initial starting point to designing service based solutions.

**Keywords**:

Industrial Product Service Systems, Solution Systems, Customer Value, Design Framework, Service Engineering, Service Engineering Architecture

## 1 INTRODUCTION

Providing business related services more and more means to solve a customer problem and deliver an individualized solution that is able to substitute a customer internal process or function rather then just to deliver a single service in a single transaction. For example, the automotive industry requires pre-production services (such as design services and research and development), production-related services (such as maintenance and IT services), after-production services (transport and distribution services) and financial services and finally other business services such as accounting or legal services.

In business to business settings of producing companies, these services are usually bundled into an integrated offering which is configured by different tangibles such as capital goods, spare parts and intangibles such as repair services, remote services, joint project management and others [15].

It has been well realized that this integration of high quality services, business related services in particular, is crucial for the competitiveness of existing and future economies. Thus, producing companies increasingly link products, parts, after sales services and valued added services such as training, business consulting and engineering services into a integrated solution system to successfully differentiate from worldwide competition [12]. The underlying strategy in industrial markets is to substitute the subsequent and single offerings by integrated value adding solutions which lead to lasting relationships to closely link providers and customers. These often are characterized by collaborative engineering efforts and even link providers and customers on an emotional level. Belz has first introduced the term solution system to describe the integrative character of the solution delivered [2]. Companies in the future have to develop and establish solution systems to generate superior value to the customer [14]. The corresponding concept is illustrated in the following picture.

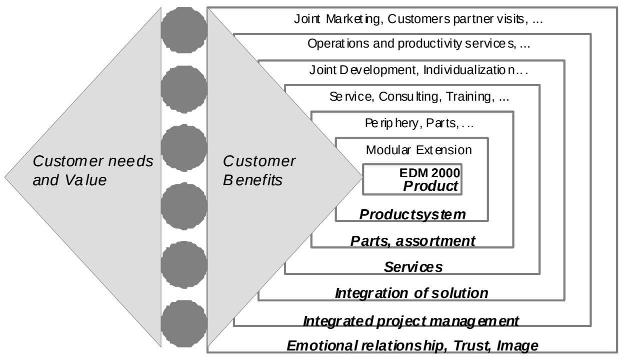


Figure 1: Solution system to deliver value to the customer (Source: [2], [14]).

The transformation towards a solution provider however has tremendous impact on the whole company. It is not only important to formulate the appropriate strategy including for successful differentiation, it is the integration of all relevant company activities which has to be achieved: strategy, product definition, marketing concept and the solution design process itself have to aligned and inherently linked. In addition, all organisational structures and the company culture and employee behaviour have to be changed towards a more customer and solution orientated characteristics. E.g. there is a need for decentralised structures which concentrate the relevant competencies where they are needed near the customer. Figure 2 illustrates the integration needs and direction as mentioned for four important company activities: differentiation strategy, solution concept and configuration, solution marketing and communication and finally the solution design activity. The integration as illustrated means that all of these activities have to be changed simultaneously towards a solution, customer needs supporting and value driven orientation. This simultaneous shift is the prerequisite to successfully implement a solution orientation within a producing company. An unbalanced change in organisational transformation processes will cause tension and finally the fail of the initiative [3].

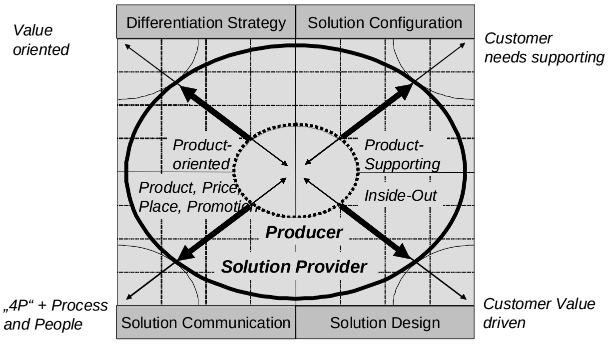


Figure 2: Required integration and orientation of company activities for successful transformation.

We here concentrate on the methodological foundation of the solution design process. Designing solution systems as illustrated in Figure 1 is a challenging task. There are challenges to facilitate the rich interactions and cohesion between the different services or solutions and the customers. There are challenges to ensure flexibility and reconfigurability of services and solutions in processes and structures [8]. Unfortunately, managers of service organizations are facing tremendous difficulties in meeting these challenges. The high degree of integration and synchronization needed in services and solutions causes complexity which is not understood. Neither within the structure of service based solutions nor in implementing new service processes [9].

There is first a need for a comprehensive understanding of the nature of solution systems and second a need for systematic design processes. Otherwise, it will not be possible to properly handle the complexity in today’s and future service based solutions and relationships.

## 2 CUSTOMER VALUE PERSPECTIVE ON INTEGRATIVE SOLUTIONS

Value is an important concept in the management literature. The term value is used in several very different contexts. From the perspective of managing an organization, creating and delivering superior customer value to high-value customers is considered to be an important means in order to increase the value of an organization [18].

From a different point of view, the term customer value takes the perspective of an organization’s customers. This perspective considers what customers want and what they believe that they get from buying and using an organizations product or service offering. This perspective is central to the resource based view of strategic management, which considers value to the customer to be the dominate prerequisite to produce a sustainable competitive advantage based on the companies resources and competencies. Only if resources and competencies are used to deliver a solution which is valuable to the customer, these resources and competences can be considered to be of significant relevance for a companies competitive position.

The customer value perspective is coherent with the perspective applied in this paper and existing definitions integrative offerings of products and services such as the IPS² concept (IPS² Industrial Product Service Systems). In this context, an IPS² are understood as integrated product and service offering that delivers values in different a use and application contexts [see also 13].

Value is the underlying concept of solution systems as illustrated in Figure 1. There exists a brought variety of divers definitions of the term customer value. Customer value can be defined as follows:

“Customer value is a customer’s perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer’s goals and purposes in use situation” [18].

This definition emphasizes the customer perspective of value. It incorporates both desired and perceived value and emphasizes that value originates from customers’ perceptions, preferences, and evaluation. It also links together products or services with use situations and related consequences.

Customer value can be classified in several ways [18]. One possible classification suggests to specify types of value regarding to their contexts within a customer’s evaluation process and distinguishes product value, value in use, possession value, and overall value [18]. Value in use, for example, reflects the use of a product or service in order to achieve a certain goal or set of goals. Hassle free supplier relationships or a proactive services are examples for value in use. Possession value reflects the inherent meaning of the product or service to the customer. For example, value to an industrial customer may be resulting from the rate of return or cost reduction earned on the purchase of a new piece of equipment or on the use of an industrial service. If the cost reduction or revenue enhancements generated by the product or service purchase justify the price, value has been created. This purchase process can be objectively valued. In the case of value in use, this process is subjective, but benefits and costs are still compared so that in industrial settings value for the customer often means the difference between the benefits customers realize from using a product and the costs they incur in finding, acquiring and using it. If the benefits exceed the costs, then a customer will at least consider purchasing a product or service. To increase the understanding of the term customer value the model of three hierarchical levels of value as illustrated in Figure 3 serves as a useful explanation [see also 18].

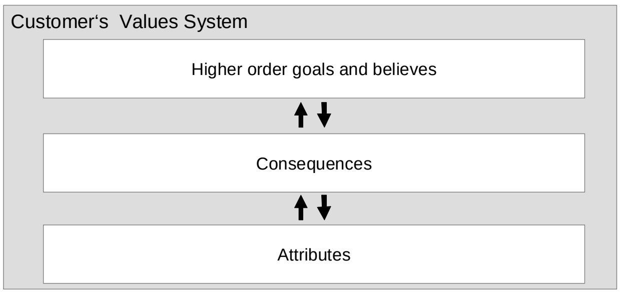


Figure 3: Customer values hierarchy (based on [18]).

The customer value hierarchy as depicted suggests that customers experience value at different levels when they expect a desired value and when they perceive value as well. This hierarchical structuring is important to systematically designing solution systems as illustrated in Figure 1: The structuring i.e. allows to specify requirements for the different elements (tangible or intangible elements) of the solution system in a hierarchical manner and thus allows the application of systematic design approaches as illustrated in this paper.

## 3 SERVICE ENGINEERING ARCHITECTURE AS A FRAMEWORK FOR SYSTEMATIC SOLUTION DESIGN

Handling complexity in solution design requires for frameworks and methods which help to systematize and structure complex tasks into pieces which can be overseen and handled properly. In the following, service engineering is considered to be the scientific discipline and a foundation to solution design. An architecture for services design is introduced here as an initial starting point to designing service based solutions. This architecture as illustrated comprises steps for successful design and development of Services and has been introduced by Gill in 2003 [7].

The term Service Engineering becomes more and more prominent in the scientific literature as the discipline covering the development and design of new services Service Engineering can be further defined as the engineering discipline which covers the systematic design of services. Service Engineering covers the following perspectives [10].

The architecture of service engineering as illustrated in the following picture structures the overall service engineering task while linking tasks with the methods and tools required performing the tasks [7].

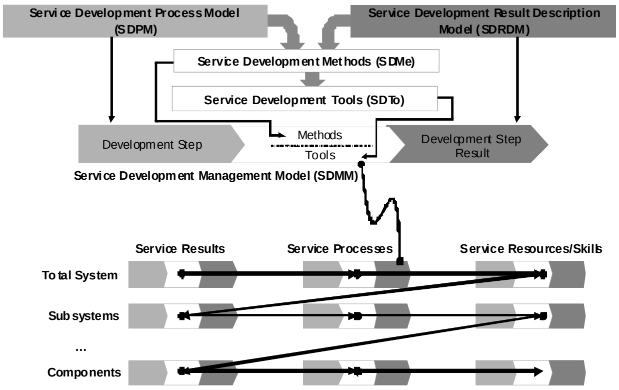


Figure 4: Architecture for service engineering: essential components (Source: [7]).

The architecture as shown in Figure 4 consists of five essential components for designing and developing business related services:

The Service Development Process Model (SDPM) comprises development steps that are necessary to determine requirements and to form the functions and processes that fulfil these requirements. This model also contains steps to identify the skills and resources that are essential to perform these processes professionally. The steps included in the SDPM will be described in detail in the following sections.

The architecture component Service Development Methods (SDMe) comprises methods that enable a systematic approach to the development targets. Which methods are suited to support the design and development will also be shown in depth in the subsequent sections.

The architecture component Service Development Tools (SDTo) contains only tools that directly support distinct methods. In the understanding of this architecture, the tools of the SDTo operationalize the methods of the SDMe.

The Service Development Result Description Model (SDRDM) documents the specific outcome of design and development steps as well as of the service work itself. Thereby, this model builds a common understanding among the design and development team members at the same time. The SDRDM combines functional and graphical aspects of the representation of development results.

The Service Development Management Model (SDMM) integrates the four other components. The SDMM connects the development steps of the SDPM with the methods and tools of the SDMe and SDTo respectively in order to achieve the development result represented in the SDRDM.

To keep the complexity of a development project as low as possible, it is not useful to construct the service in detail from the start. Instead, the development can be stated in such a way, that first the requirements for the service system are implemented in a general concept. Afterwards, the general concept can be divided into components. The determined characteristics of the general concept result in requirements for those components.

Each component can then be considered independently. This procedure of specifying concepts into partial concepts and their subsequent configuration can be continued at all levels of detail in the same way. An appropriate method to detail a service system is the Function Tree Analysis under consideration of Suh's axiomatic design. Suh states that one can only detail a function tree with the embodying concept in mind [1], [13].

Based on the essential characteristics of professional services the architecture itself is divided into three partial models with regard to the characteristic elements of services: results, processes and resources. The partial models are intimately connected in the sense of means-end relationships. Since results are generated by a set of processes, which still has to be specified, a determined service result implies requirements for the service processes. Hence, service processes are means, which generate predetermined results. The processes in turn necessitate resources for their implementation. For this reason processes and resources represent a means end relationship. Therefore, a complete service concept always contains a result concept, a process concept and a resources concept.

### 3.1 The result branch of the service engineering architecture

This partial model of the architecture comprises activities to incorporate the external requirements of customers as well as the internal requirements; to check their plausibility, to prioritize and to detail them. One example for steps undertaken in the result branch and the corresponding methods are illustrated in the following picture.

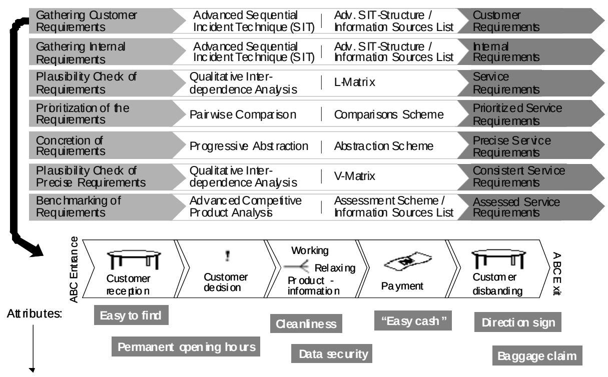


Figure 5: Result branch of the service engineering architecture.

The first step on this level for example is the investigation into the customer and company requirements, it is recommended to employ the Advanced Sequential Incident Method [11]. In this method, individual process steps are identified along the chronological course of the service creation on a level, at which customers and suppliers have direct contact. In the following development step "plausibility analysis of the service requirements", requirements from the perspective of customers and the company are brought together and analyzed with respect to their plausibility. The Qualitative Interdependence Analysis is employed to show the mutual dependence between requirements, which are regarded as coequal by analyzing the reactions of the elements to changes in one element [4]. For this purpose, the requirements for the service from the perspective of the customer are confronted and compared with those from the perspective of the company in a matrix. Criteria for the Qualitative Interdependence Analysis are “target-neutrality”, “target-harmony” and “target-conflict”. The results of this development step are consistent service requirements from the perspective of customers and the company. As a next step, the service requirements are prioritized from the customer perspective with respect to their impact on the success of the service. The Pair wise Comparison has been identified as a suitable method for this prioritization [6]. In the development step “concretion of the service requirements” the method of Progressive Abstraction is used in the architecture. With the Progressive Abstraction the requirements in terms of their benefit of use are edited, and the levels of measures are revealed which contribute to a large extent to the achieved objectives of the development.

### 3.2 The service process branch of the architecture

Starting from the service requirements, the respective tasks are identified and defined. The leading question for this task can be formulated as follows: “How can the individual service requirements be implemented?” After having found implementation methods for each requirement, the requirements are summarized hierarchically with the help of Transfer Graphs as a tool of the Affinity Method [11]. The results of using this method are hierarchically structured service tasks, which are deduced from the requirements. One example for methods in the process branch of the architecture is illustrated in the following picture.

In the next step, the service tasks have to be analyzed with respect to their type. By allocating the service tasks to the types “overall task, “primary task” and “secondary task” distinctions can be made.

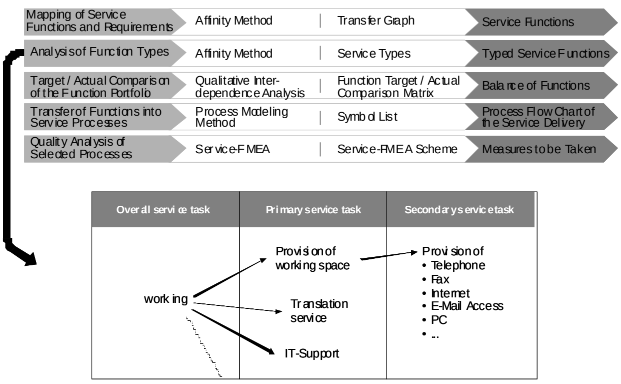


Figure 6: Process branch of the service engineering architecture.

The overall task shall be defined as to meet a maximum amount of service requirements the customer is willing to pay for. The primary task fulfils at least one service requirement and can also be priced. Although a secondary task must also fulfil at least one requirement functionally, the customer is often not willing to pay for that. In order to benefit from synergies, an alignment of service tasks, which are already implemented, and the service to be developed need to be conducted. For this purpose, the Interdependence Analysis is again a suitable method. Therefore, all primary service tasks should be evaluated by an ordinal rating scale, which distinguishes target is covered by existing task” and “target is not covered by existing task” respectively. In he following development step “transfer of service tasks into service delivery processes”, those primary service tasks, which are necessary to fulfil the customer requirements, are further detailed by a Process Modelling Method. As a supporting tool for this, the Service Blueprinting of Shostack introduced in 1984 [6] has been identified. The Service Blueprinting is a flow chart particularly for the service delivery process, which distinguishes several ways of customer interaction and visually separates them by so called lines-of-visibility. The customer section contains only processes the customer is directly involved in. The onstage processes are visible to the customers, but they do not take an active part in it. The third section of the process flow chart comprises the backstage activities that are entirely performed by the employees without any contact to the customer. With this differentiation the service delivery processes can be adjusted with respect to performance, robustness and reproducibility.

For a detailed analysis of potential risks associated with service delivery processes, the application of the Service-FMEA (Failure Mode and Effects Analysis) is implemented into the architecture. Using the Service-FMEA, first, potential failures linked to the process steps are determined and rated on a 1 - 10 scale with respect to their severity (S) and their detectability (d) [6]. For processes with direct customer interaction as ascertained in the Service Blueprinting, the detectability is irrelevant since there is no chance to prevent the customer from experiencing the failure. Afterwards, the causes of each potential failure need to be discovered and evaluated with regard to their probability of occurrence on a 1 - 10 scale as well. Subsequently, these three values of severity, occurrence and detectability, if applicable, are multiplied. The result is the so called Risk Priority Number (RPN), which identifies the greatest areas of concern and indicates what kind of corrective actions should be taken. Particularly, preventive measures can be taken, which helps to avoid cost intensive failures before they might occur.

Once the development steps for all identified primary service tasks have been undertaken, the development of the service delivery concept is complete.

### 3.3 The service skills and resources branch of the architecture

This partial model of the architecture helps to develop a concept for the essential service resources. The skills, which are necessary to perform the identified service tasks and service processes, are identified first with the help of’ the Affinity Method and hierarchically structured by means of a Transfer Graph. The result of this development step is a target skills profile, which should be understood as the sum of skills necessary for delivering the service. A part of the the skills and resource branch of the architecture is illustrated in the following picture.

Afterwards, the individual skills are analyzed regarding to their type: professional competence, social competence, personality competence and method competence can be distinguished.

Besides the allocation of the identified skills to these types, a qualitative evaluation with regard to the marks “no competence necessary”, “basic understanding necessary”, “first practical experience and advanced understanding necessary” as well as “management, practical experience and distinct understanding necessary”. In order to benefit from synergies a target/actual comparison should be conducted with the skills, which are already available throughout the company and the determined skill profile. A suitable method for this is again the Interdependence Analysis.

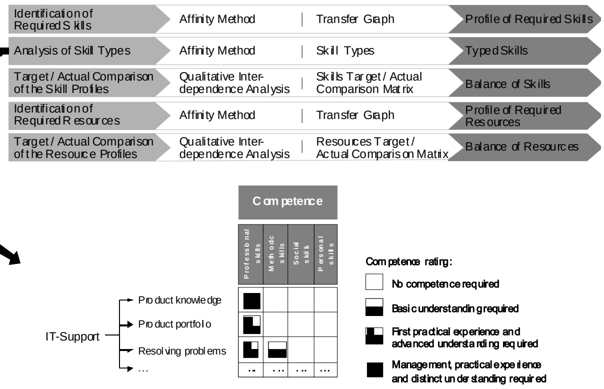


Figure 7: Resources branch of the service engineering architecture.

Subsequently, the key resources related to the skills for the Service delivery have to be identified with the help of the Affinity Method. It is important to find as many resources as possible, which embody he required skills. A Transfer Graph is again an adequate tool for the structuring.

Afterwards, a target/actual comparison is conducted between those resources that are necessary for the Service delivery, and those that are already available throughout the company. Again, an adequate method is the Interdependency Analysis with an ordinal rating scale of “target is covered by existing resources” and “target is not covered by existing resources” respectively. In case of resource coverage or a resource excess, the service which should be developed can be generated with the already available resources of the company. In case of a resource deficit, the corresponding resources have to be obtained. When the development steps for the identified competencies and resources are finished, the development of a potential service provision concept is completed.

## 4 INTEGRATIVE FRAMEWORK FOR SOLUTION ENGINEERING

Integrative industrial solutions such as delivering a comprehensive assembling line are more complex in their nature then single services and thus require an even more structured and systematic approach for their development or engineering.

Combining the hierarchical perspective of customer values, the illustrated concept of the solution system and the architecture of service engineering into an integrative framework reveals into the framework illustrated in the following picture. The framework as illustrated follows the basic design principles of structuring and systematizing.

The framework is based on the basic assumption, that goals can be broken down into consequences and consequences can be broken down into attributes within the customer’s value system. Customer defined goals, consequences and attributes define how elements in the solution system have to be specified. Based on this specification, each element of the solution system as illustrated in Figure 1 is considered to be designed within a capsulated engineering process: The spare delivery service for example is based on specific resources and processes which guaranty for a specific service level. The repair service is based on specific skills and process which are implemented to fulfil the repair task. However, this does not mean, that elements are not interrelated. The functional interdependencies between these single services are determined by their contribution to the specific customer value at the three hierarchical levels.

In the following, we illustrate how the framework and architecture as presented can be used to systematically develop solution systems. We here take an example from the capital goods industries which is a company delivering assembling system as turn key solutions and offering the operation as well.

The company designs and produces complex assembling systems, i. e. for the automotive industry. The unique capability of the company is to design the assembling systems based on a physical model or digital model of the part to assemble. The company then fully integrates the assembling systems into the customer’s production processes. The company offers leasing arrangements for their solutions and different service contracts including the operation of the assembling system at the customer’s site. Challenges the company has to overcome are illustrated in picture 8.

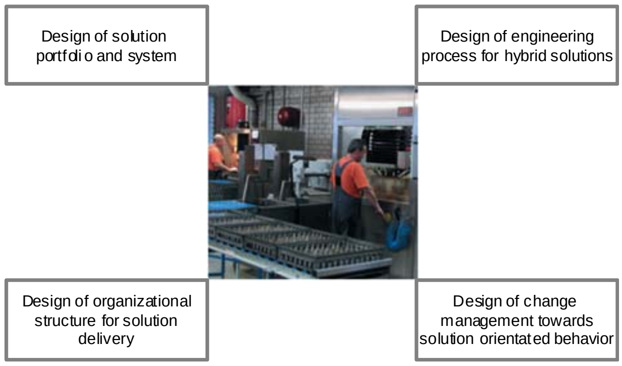


Figure 8: Potential to apply service engineering framework and architecture to introduce company transformation.

The solution delivered by the company can be best described by the term “assembling capability”. Following the hierarchical concept of customer values as introduced, the consequences for the customer in the specific use situation are that parts of the production system are controlled by the provider and thus efforts and costs can be reduced. Efforts for designing and integrating the assembly system are fully outsourced. Control authority over the assembly system is outsourced as well. Cost Reduction of internal engineering efforts and subsequent costs are anticipated goals at the customer site. The provider guaranties for reliability and hassle free operation and thus satisfies the customer requirements at the attribute level.

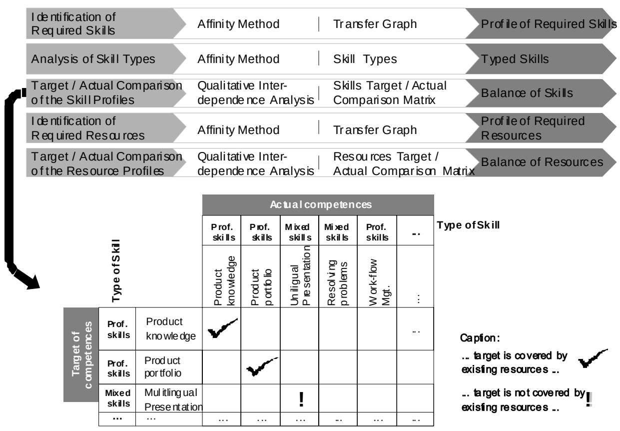


Figure 9: Architecture of service engineering to develop a resource profile for solution delivery.

One major challenge when designing a solution as described is to exactly specify the behavioural skills needed to successfully implement the solution concept into practice. Employees need very specific skills, in particular when the solution as described here is i.e. operated at the customer's site. Employees then need specific communication or language skills in order to provide a beneficial problem solution to the customer. As illustrated in the following picture, the architecture supports to systematically identify the adequate method to identify a skill profile for the service technician.

Another challenge when designing solutions such as the assembling system as described is to design the required flows of activities and communication. Solutions as illustrated often require remote service concepts which require complex interaction and communication flows between the customer's site and provider's site. At the provider's site, processes have to be handled with customer interaction or by the back-office employees.

Designing the process and communication structure requires methods and tools which allow structuring and systematic drawing. The following picture illustrates, how the architecture supports to identify the right methods and tools to designing process and communication flows.

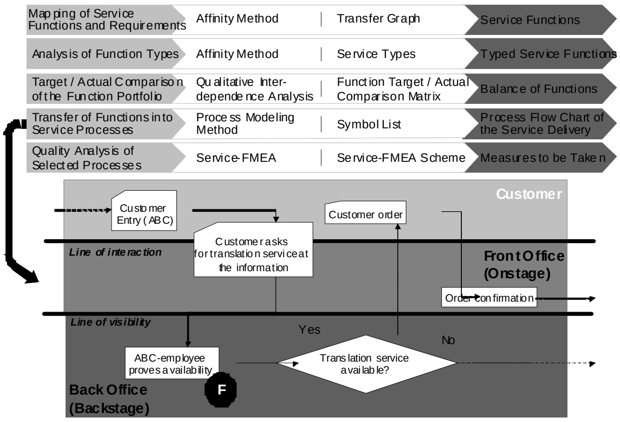


Figure 7: Application of service engineering architecture to identify methods and tools to designing process and communication flows.

Both examples for application of the service engineering framework and architecture demonstrate that both, the framework and architecture, can support the engineering of complex solution systems. The main contribution is to reduce the complexity in engineering complex solutions as the architecture supports structuring the associated planning and design steps for the single components which are put together into the overall solution after their design. In addition, the architecture contributes with the suitable methods and tools to design the single services of the overall solution system.

The architecture of service engineering as described provides a rich and comprehensive set of methods and tools to develop new solutions. The architecture is based on findings and research in the area of business related services which are provided to solve an often complex and comprehensive customer problem with an adequate service based solution. Planning and conception of new services is supported by the architecture in a structured and systematic fashion.

## 5 SUMMARY

The aim of this article is to enhance the existing scope of the discipline of service engineering and science. Service Engineering is considered to originate from engineering and design theory and the discipline of Service Engineering provides processes and an architecture for the systematic planning of new Customer solutions in an business to business context.

The architecture for service engineering introduced provides the methodological framework for successful solution design. Implementing this into practice including work and task coordination and information processing within task execution will be the next challenge. Industrial engineering will then complement the existing body of service engineering and will provide - with engineering science, marketing, and organisation design, a future set of disciplines for the multidisciplinary structure of service engineering.

## 6 ACKNOWLEDGEMENTS

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