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Article

A Method for Building Service Process Value Model Based on Process Mining

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Featured Application: The model proposed in this paper may help service providers to clearly understand value creation in the process of cross enterprise collaborative services. The methodology, combined with domain knowledge, and based on the actual operation of the service system, may help manufacturing enterprises to accelerate the process of servitization.

Abstract: With the emergence and development of servitization, more and more enterprises are turning from product focus to service focus. Service is customer-oriented, and driven by customer requirements. Value is the goal pursued by all actors in the service. In order to analyze the mechanism of multi-actor collaborative value creation in the service process, this paper proposes a method for building a service process value model, based on process mining. Driven by the raw data and an event log of service activities and processes in the real world, stored in the service system, the method uses process mining techniques and combines domain knowledge to describe the construction steps of the service process value model at the conceptual level. We focus on the specific processes and activities in the service, and mainly consider the value creation of the activity. The model proposed in this paper aims, to reflect how service actors co-create value in the actual execution of service processes, and to help service actors achieve their value goals. We use a case study inspired by an industrial case to validate our idea. Moreover, we develop a new plug-in, based on the α -algorithm for ProM, to realize the model construction in the case study.

Keywords: servitization; business process; service actors; service value; service process value model; process mining

1. Introduction

At present, in the context of industry 4.0 [1], service has become the main force of economic development, and provides power for the transformation and upgrading of enterprises. Various industries are changing from traditional business to service, which is called “servitization”. Firms attracted by the potential revenue benefits are choosing to move from supplying product only, to supplying product and services [2]. More and more manufacturing companies are transforming from a product focus to a service focus in order to provide better service for customers [3]. From the perspective of service, not only between the manufacturer and the customer is there a relationship of service and served, but also in the relationship between the supplier and the manufacturer. Therefore, the service provider and the customer are relative. For example, in the after-sales service of an air conditioner, the manufacturer provides the service for the customer who purchased the air conditioner. In the process of providing the service for the customer, a certain supplier may be

required to provide a spare part. At this time, the manufacturer is the customer of the supplier; but in the whole after-sales service process, it can be considered that this supplier is a participant of the service. Service not only focuses on the process of service providers, providing services to customers, but also on the value creation in the service process. Service providers provide services to customers through the service process, so each activity in the service process should create value, and the results of service will be affected by the value produced in the service process.

Process mining is receiving increasing attention in the past two decades. There are two main reasons: on the one hand, more and more event logs recorded in the information system provide detailed information about process history; on the other hand, the need to improve and better support business processes, in a competitive and rapidly changing environment, is becoming increasingly prominent [4]. The Process Mining Group defines it as a family of techniques in the field of process management that support the analysis of business processes, based on event logs in the information system. The idea of process mining is to discover, monitor, and improve actual business processes by extracting knowledge from event logs [5]. Some scholars have done related research in this field [5,6,7,8,9,10,11], focusing on how to discover or extract business process models from event logs, proposing corresponding algorithms, and developing corresponding tools. These process models mainly pay close attention to control flow, resources, time, and organizations. However, there is little attention given to value creation by activities in the business process.

Since value is the goal pursued by all actors, whether it is the service provider or the service demander, some scholars have discussed service value creation, or co-creation. Wang [12] proposed the concept of a product-service value creation network from the perspective of industry, and put forward four steps in the value creation process, which include value identification, value proposal, value delivery, and value evaluation. Yip [13] presented an integrated design framework for a service-centric service system, which considers the interactions between actors in the value co-creation process at a strategy level, and is integrated with techniques for executing each stage of the framework. Takahashi [14] argued that service value is affected by providers, receivers, and/or its environment, and discussed the value creation model from the viewpoint of case-based decision theory. However, these studies tend to focus on the conceptual level and industry level, with a lack of attention given to the role of customers in service, and do not pay attention to the process and activities of service performance. In reality, services to meet the requirements of customers are basically complex services, which need to be completed by multiple enterprises or actors. Simultaneously, we also realize that customer requirement is the driving force of service, and customer value determines the value of service. Therefore, service is customer-oriented, and the creation of service value is a complex process. To describe value creation clearly at an activity level may help service actors to more easily understand and achieve their value goals.

This paper focuses on value creation in the service process of multi-actor collaboration, in the cross-enterprise environment. We propose a method for building the service process value model (SPVM), which is used to describe how each actor in the service process exchanges and creates value, with activities as the carrier. In order to construct the service process value model, based on the materials and methods of services and service processes, process modeling and process mining, and service value networks, this paper defines the dimensions and granularity of value, and describes the value of activities and service process. Two ways of building a service process model based on process mining techniques are presented, and the value of the service process is annotated by combining domain knowledge. The service process value model shows the value input and output of each actor on the corresponding activities in the cross enterprise service process collaboration, and the dynamic changes in the service process in different situations to meet the needs of customers. This is helpful for enterprises to provide a better service experience for users.

The originality of this contribution is in a new method of constructing the service process value model. Differently from the traditional modeling methods, using process mining techniques can build a service process value model faster and more accurately. Due to the existence of a large number of event logs in the information system, it is possible to cover all paths of the service process. Hereby, we work on an observed, and running, model, based on data that reflects the actual execution of

processes. At the same time, considering the domain characteristics, the value information is extracted from real data and event logs, which makes the model more reliable. We improve the model to save time and money that would have been spent if working directly on the running of the service system. Moreover, to verify our idea, we developed a new plug-in for Prom to extract activity actors and value information from raw data and event logs, and support the construction of a service process value model. It shows the construction process of the model in the form of a visualization, which can help enterprises better understand the co-creation mechanism of service value, which is conducive to cross enterprise collaborative service value optimization.

The rest of this paper is structured as follows: Section 2 provides the materials and methods used to produce the proposed paper. Section 3 presents the contribution to overcoming the above-mentioned issues. Then, a case study is presented to validate the approach. Finally, some discussions about limitations and future work are proposed in Section 4, and the conclusion is given in Section 5.

2. Materials and Methods

In order to construct the service process value model, this paper takes the service activities and processes in the service system as the research object, analyzes the processes and activities in the service system based on the service related domain knowledge, and carries out the value annotation. The general idea of the paper is shown in Figure 1. The service system stores the raw data and event log of service activities and processes in the real world. We build business process models from these data and event logs, based on process mining, and then transform them into a service process model, constructing a service process value model on this basis. Considering the actual execution and path coverage of business process, we use process mining techniques to obtain a business process model. Combined with the theory of service value networks, this paper discusses the mechanism of value creation in service process. Hereby, this section describes the materials and methods of services and service processes, process modeling and process mining, and service value networks.

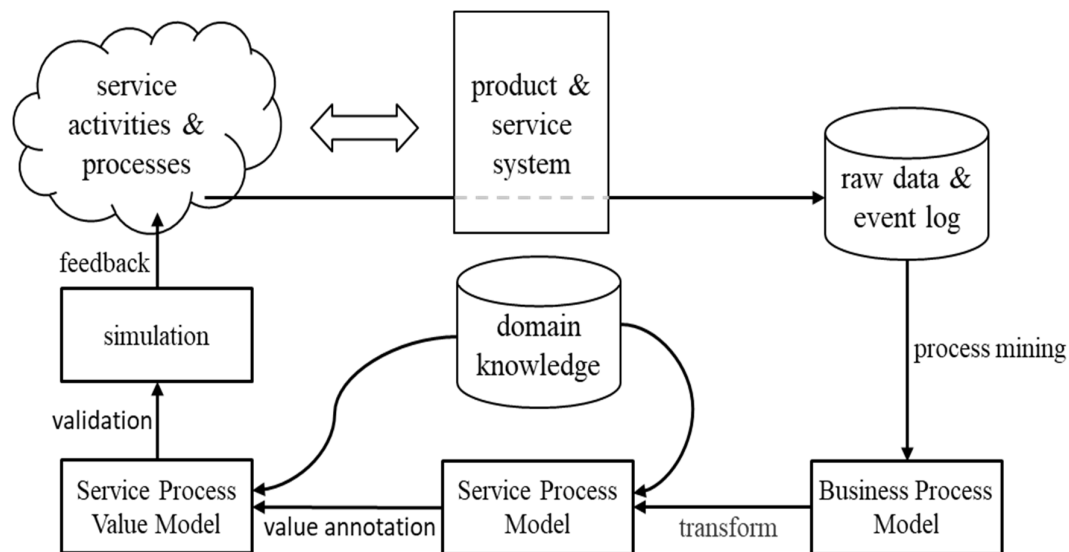


Figure 1. The general idea of the paper.

2.1. Service and Service Process

A service is defined as the application of competences for the benefit of another, meaning that service is a kind of action, performance, or promise that is exchanged for value between provider and customers [15]. Service can be divided into two granularities: primitive service and complex service. A primitive service is a candidate atomic service, with a specific service capability. A complex service is a service requested by a consumer, which is a composition of a set of primitive services [16]. To support the implementation of services for customers, there must be a corresponding service system

to compose various primitive services together. A service system is considered as a complex socio-technological system, and is defined as “a value co-production configuration of people, technology, other internal and external service systems connected by value propositions, and shared information (such as language, processes, metrics, prices, policies, and laws)” [15]. In a service system, services are interacting each other, for example, by exchanging messages. Orchestration and choreography are the main ways to realize service composition. Orchestration is concerned with the composition of services, seen from the viewpoint of single service. Choreography is concerned with the composition of services seen from a global viewpoint, focusing on the common and complementary observable behaviors [5]. Through orchestration and choreography, primitive services and complex services are integrated to create an end-to-end service process.

Service process is an integral part of service, and it is the actual procedure, mechanism, and operation flow of service provision. The service process can be viewed as a chain or constellation of activities that allow the service to function effectively [17]. In general, the execution of service processes is constrained by a service-level agreement (SLA) between service provider and customer [18], or the quality of service (QoS) requirements of customer. The SLA specifies the metrics of the customer, used to monitor and verify the contract. QoS can be regarded as a part of SLA, mainly considering the parameters related to customer requirements, such as response time, availability, security, etc. Customers may not only care about the functionality of the service, but also want to achieve some specific service quality objectives, such as the fastest response or the most reliable service [19]. The current research on service process is mainly about the reconfiguration of service process, and the management of service process. Zhai [20] presented a reconfiguration region identification algorithm and middleware components to support the service reconfiguration based on end-to-end QoS constraints. Li [21] proposed an adaptive QoS-aware service process reconfiguration approach based on supplementary services and a region-based reconfiguration algorithm, to solve the problem efficiently with low reconfiguration costs. Zappatore [18] proposed a contract template and a directed tree-graph model for SLA specification definition to manage service delivery. Nan [22] argued that service process management is a way to effectively manage publication, discovery, negotiation, deployment, and implementation of services, and presented an SLA-based service process management approach for service-oriented architecture (SOA). Yang [23] argued that the scope of process management consists of process design, process execution, process mining, and process intelligence, and a petri-nets based service process management method was introduced for workflow verification. Most of the literature focuses on the composition of services, not the service process itself.

2.2. Process Modeling and Process Mining

A process consists of interrelated activities, or sub-processes, for performing a task [24]. Process modeling is a technology of process graphical representation. It records the “process” of the task and the logic, policy, and procedure implemented by the “process” of the task. So, a process model can provide a comprehensive understanding of a process [25]. Most of the process modeling research focuses on business process modeling. Businska [26] argued that business process model has multiple dimensions, including the organizational structure model, goal model, data model, location model, and other models, and presented a knowledge state transition model as a new dimension of business process model. Aguilar-Saven [25] described the main process modelling techniques, including flow chart technique, data flow diagrams, role activity diagrams, role interaction diagrams, Gantt chart, IDEF, colored Petri-net, object-oriented methods, and workflow technique. Unified modelling language (UML) is considered as the standard object-oriented modelling language, which is not only applicable to software systems, but also to business processes and other non-software systems. Villarreal [27] described the application of model driven architecture (MDA) and UML for the modeling and specification of collaborative business processes for enabling enterprises to establish business-to-business collaborations. Van der Aalst [28] presented a new α -algorithm that extracts a process model from the workflow log. This is a new technique for process modeling called process mining.

Process mining can be regarded as the link between model-based process analysis and data-oriented analysis techniques [6]. Event logs are necessary resources for process mining, and the quality of log data determines, to some extent, the quality of the model mining results. XES (eXtensible Event Stream) was adopted in 2010 by the IEEE Task Force on Process Mining as the standard format for logging events. It is now in the process of becoming an official IEEE standard. XES is an XML-based log file format [29]. Process mining often starts with process discovery. Once there is a process model, conformance techniques can be used to compare the mined models (event logs) with the existing models. The results of the checking show the deviations between the model and log. After the conformance checking, enhancement techniques can be used to extend or improve an existing process model, using other information recorded in the same event log. The process mining algorithm is a method of studying how to discover the activities experienced by the whole process runtime through the process log, so as to establish the process model. At present, many process mining algorithms have been proposed, which come from different research projects, and represent several different research directions. Each algorithm has its own solution for solving some difficult problems in process mining. Many process mining algorithms have been proposed, including: (1) a mining algorithm based on Petri net [28], (2) a block-oriented mining algorithm [7], (3) a mining algorithm based on an activity dependency graph [8], (4) a mining algorithm based on ADONIS [9], (5) a Fuzzy mining algorithm [10], etc.

2.3. Service Value Network

With the rapid growth and application of information and communication technology, smart business networks emerged, in which emerging technologies promote cooperation and value co-creation [30]. With the emergence and development of servitization, the service value network (SVN) has become a new research focus. Blau [31] argued that service value networks are smart business networks, which provide business value through the agile and market-based composition of complex services from a steady, but open pool of complementary, as well as substitutive standardized service modules, by use of ubiquitously accessible information technology. Therefore, the new way of value generation proposed by service value networks has greatly expanded the understanding of value and value generation scenarios. SVNs encompass multi-way collaborations between different service actors, comprising service providers, enablers, consumers, and other stakeholders [16]. As a node in the service value networks, firms must recognize and act on value creation in the context of networks and integrate and transform micro-specialized competences into complex value propositions with market potential [32]. In SVNs, everything is viewed as a service, and all the actors are connected to the SVNs by providing standardized service modules. Therefore, in essence, the focus of SVNs is still the composition of service. Chu [33] presented a progressive service value network design scheme for bi-lateral service scenarios, in which a broker is introduced to composite services or resources into a whole and provide it for customers. Schulz [34] argued that a service intermediary created a service value network by offering complex services to customers and consuming services from suppliers and considered an end-to-end service level management for service value networks. Fu [35] argued that the service modularization of network members can not only comply with the collaborative requirements of the service platform, but also protect the competitiveness of the member enterprises. At the same time, it is difficult to generate value by relying on a single module. Therefore, it is necessary to fully integrate the service modules among partners to complete value creation.

A value network can also be thought of as a service eco-system, which may better capture the adaptive and evolutionary characteristics of a value network [32]. From this perspective, it is very similar to the service system mentioned in Section 2.1. In a word, the research literature on service value networks is relatively sparse, and the level of attention is generally abstract. The focus is mainly on value collaborative creation, based on service composition, and less attention is paid to the specific value creation process.

3. Results

The method we propose is based on the data and event log in the service system. In order to explain the concept and each step for building the service process value model, let us consider a telephone repair example, provided by the process mining website (www.processmining.org).

3.1. The Repair Example

A telephone repair company has a standard repair process that can fix different defects of different types of phones. The company can repair three different types of phones, namely “T1”, “T2”, and “T3”. When a customer’s telephone device fails, it will be sent to the repair company, and the repair company will register after receiving it. After registration, the telephone is sent to the problem detection (PD) department. There it is analyzed, and its defect is categorized. In total, there are 10 different categories of defects (from 1 to 10) that the phones fixed by this company can have. Once the problem is identified, the telephone is sent to the repair (R) department and a letter is sent to the customer to inform him/her about the problem. The repair department has two teams. One of the teams can fix simple defects and the other team can repair complex defects. However, some of the defect categories can be repaired by both teams. Once a repair employee finishes working on a phone, this device is sent to the quality assurance (QA) department. There it is analyzed by an employee to check if the defect was indeed fixed or not. If the defect is not repaired, the telephone is again sent to the repair department. If the telephone is indeed repaired, the case is archived, and the telephone is sent to the customer. To save on throughput time, the company only tries to fix a defect a limited number of times. If the defect is not fixed, the case is archived anyway, and a brand-new device is sent to the customer. The description of the example can be found in reference [36].

3.2. Method for Building Service Process Value Model

3.2.1. Process and Activity

Service systems use processes and activities that differ from a business process. Processes and activities cover a full range of situations that might involve highly structured workflows and flexible processes, the sequence and content of which depend on the skills, experience, and judgment of the primary actors [37]. As mentioned in Section 2.1, SLA is the guarantee of the service provider to provide service for customers. Under the constraint of the SLA, the candidate primitive services in the repository for each service can be divided into different service sets, and the service process and activities matching the requirements of the customer can be constructed quickly. Customer requirements are the driving force of a service system, and services, including processes and activities, are dynamically constructed. As shown in Figure 2, for customer service requirements with the same function and different SLAs, the provider will select different primitive services from the service repository to form different service processes and activities. Usually, a primitive service is used to complete an activity in the service process, and there is a one-to-one relationship between them. When a process contains a sub-process, the sub-process can be regarded as an activity of the parent process, and the service used to implement the sub-process may be a primitive service or complex service. Since the structure of the parent process and sub-process are consistent, we can ignore the sub-process and treat it as an activity. For example, if a customer wants to send a package to a destination, taking the postage and delivery time as SLA parameters, the delivery time will be longer if the price is lower. Then, for a low postage package, a vehicle should be used to transfer it from one station to another station until it reaches the destination; for a high postage package, for the package with high postage, air transfer should be used to reduce the delivery time. From the perspective of the customer, what he wants is a complete service, and he does not care about the service process and activities. Therefore, if the customer pays \$5, the package should arrive at the destination within 5 days; if the customer pays \$10, then the package should arrive at the destination within 3 days. From the perspective of the service provider, they need to understand the whole service process and activities, and the appropriate primitive services should be selected to complete

the corresponding activities or tasks, which may be the provider's own or outsourced to other participants. So in order to deliver the customer's package to the destination, the service provider may use a logistics company's vehicle to transport the package from one place to another until it arrives at the destination; it may also rent space on an aircraft flight to transport the package to the destination.

To meet the need of the customer, each service needs to combine different primitive services, which represent specific activities or tasks in the service process. Therefore, each service process is composed of different activities, which are executed to complete the whole service. In the service process, each activity needs to be fulfilled by at least one actor, including the customer, service provider, and other participants. By completing these activities together, the actors (co-)create value, exchange value, and meet their own value expectations.

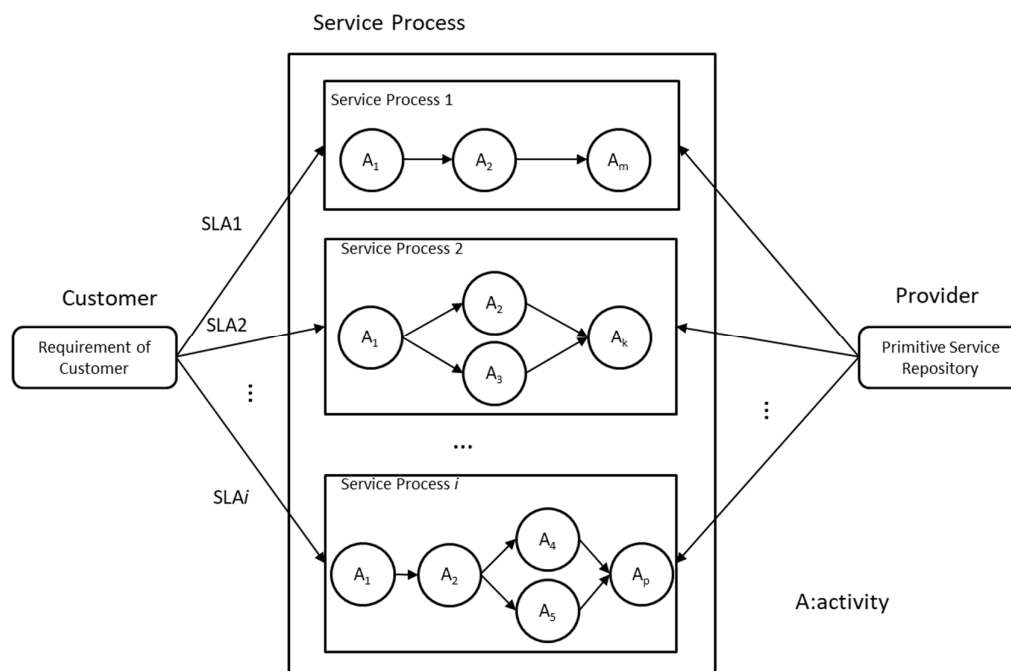


Figure 2. Process and activity.

3.2.2. Definition of Some Concepts

Based on the above description, in this paper, some concepts related to the service process value model are defined as follows:

Definition 1. Business process is a series of activities completed by people, organizations, or automated resources to achieve specific goals.

Definition 2. Service Process is a series of activities completed by people, organizations, or automated resources to provide specific services to the target customer.

The similarity between service process and business process is that there are not only strict sequence restrictions among activities, but also the contents, methods, and responsibilities of activities must be clearly arranged and defined, so that the activities in process can be transferred between different actors. An activity in a business process, and a service process, can represent a sub-process, and the process can be nested. Business process is generally used to describe the collaborative production process of products, while service process describes how to deliver services to customers, to meet their requirements. Therefore, business process is product-oriented, and service process is customer-oriented. However, with the gradual evolution of servitization, the

differentiation between products and services is increasingly blurring [38]. Lusch [32] argued that products can be seen as service distribution or provisioning mechanisms. Based on Banerjee's argument of "everything as a service" [39], we further argue that the production process of a product can be a service process, or a part of a service process, the difference lies in whether it is customer-oriented. Hereby, if the business process is customer-oriented, it can be a service process, otherwise it is part of the service process.

Therefore, for non-customer-oriented business processes, based on the MDA method mentioned in [40], we can transform a business process into a service process. When constructing a service process model, we also need to consider the impact of some characteristics of the service domain on service process. In the service domain, the service ecosystem has formed its unique service domain characteristics in its long-term development and evolution process; mainly including apriority, correlation, and similarity [41].

3.2.3. Building a Service Process Model Based on Process Mining

Through the traditional modeling method, we can build the service process model by observing the service process and activities in the service process, and by combining them with domain knowledge, manually or using modeling tools. However, the service process obtained in this way is relatively rough and may be different from the actual implementation of the service process. The observation is not accurate enough, and many hidden details may not be obtained through observation. To describe the model more accurately, we use a method based on process mining to build the service process. Normally, many raw data and event logs related to services are stored in the information system. If there are enough traces in the event log, the process and activities obtained by process mining will cover a full range of situations. As shown in the dotted box in Figure 3, there are two ways to build service process using process mining, based on raw data and event logs: one is from the business process model (BPM) to the service process model (SPM); the other is from the enriched event log to the service process model.

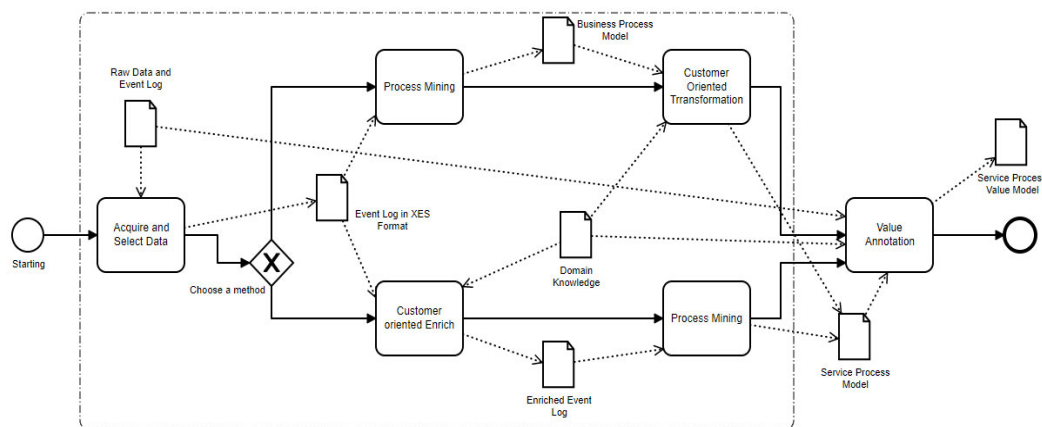


Figure 3. Modeling based on process mining.

- From BPM to SPM

The raw data and event logs stored in the information system are the basis for building models. As mentioned in Section 2.2, the event logs need to be preprocessed and saved in XES format. By using the corresponding algorithm in process mining, such as the α -algorithm, we can get the business process model (control flow model), represented by Petri net. Since a business process is not customer-oriented, we need to transform it into a service process. In this way, we first get the business process model and then transform it into a service process model. In the transformation of the models, domain knowledge and domain characteristics should be considered.

- From enriched event log to SPM

In this way, since the raw data and event logs do not contain the behavior information of customers in the event or activity, we also need to preprocess them, and supplement the customer-oriented information with domain knowledge and domain characteristics. Hereby, we get the formatted enriched event log. Then we can directly extract the service process model by mining the log. Since the model we get is already customer-oriented, it is a service process model, and it does not need to be transformed again.

In this paper, we just use process mining as a necessary tool to help in building a service process model. As for how to extract the process models from logs, this paper is not concerned. Many scholars have done a lot of research on how to extract the process model from the event logs, through process mining, which is mentioned in Section 2.2.

- From SPM to SPVM

The service process model is a transition model that prepares for the service process value model. So, after getting the service process model, we need to construct the service process value model based on it. As shown in Figure 2, combined with the additional value information captured in the raw data and event logs, and the knowledge of domain experts or human experience, the value annotation is attached to the service process and it is converted into a service process value model. In fact, value is annotated onto the activities of the service process, because value is created through activities. In addition, domain knowledge is closely related to the field of service. For example, for the maintenance of mobile phones, customers usually send the mobile phones that need to be fixed to a designated maintenance point for repair; while for air conditioning maintenance, maintenance personnel are required to provide maintenance services on site. Although they are all maintenance services, there may be great differences in domain characteristics. Therefore, domain knowledge has an important impact on the value of activities.

Hereby, the service process value is based on service process model, and it not only focuses on the cooperation relationship among actors in the activities or process, but also emphasizes the value creation of actors in the activities. Value is the core of service process value, and activity is just a means to support the realization of value. In other words, satisfying the customer's value expectation is the core of the service process value model, and service process is the basis to realize the value expectation. Our focus is on how to add value information to the activities in the service process. Next, we will describe and define the concept of value in service.

3.2.4. Value in Service

Value is the goal pursued by both sides, the service demander and service provider. Both sides create value through working together in the service process to meet their respective value expectations. Generally, different service actors have different value expectations.

- Dimension of value

Owing to different concerns, different people may define value from different perspectives. Allee [42] argued that there are two types of value, tangible and intangible value. Therefore, we further argue that value is multidimensional, and that the value creation and value expectation of each actor may only contain some of these dimensions. For example, value can be defined from the perspective of economic benefits, product acquisition, resource used, and customer experience, etc. In this paper, in order to distinguish the value creation of the different actors, in service process and activity, we use three dimensions to define service value: time and space, profit, and experience, as shown in Figure 4.

The time and space dimension refers to the requirements of service value creation in time and space, which can be realized only by meeting the requirements. It is closely related to the activities in the service process. For example, in a logistics service process, a certain amount of time is spent to transfer a package from one place to another; in a product manufacturing process, it takes a certain amount of time to turn some materials into parts. The time and space dimension reflects the time

consumption, and the change of location or status, in activities. The profit dimension refers to the benefits obtained by actors in the service activity, including economic benefits, physical products, information, etc. It is related to the service actors because each actor in the service process, including the customer, benefits from it. For example, in logistics service, the customer's package arrives at the destination, the logistics company gets the freight, and the truck driver gets the reward; in product service, the customer gets the product he wants to buy, and the manufacturer and the material supplier gain the sales income. The experience dimension refers to the intangible value or impact of the service process or service results, including knowledge, corporate reputation, social impact, customer satisfaction, experience, and skills, etc. The experience dimension is related to the effects of the service process or service result. For example, in a logistics service, as the logistics company delivered the package to the destination earlier than expected, customer satisfaction increased, and the reputation of the logistics company also improved. In addition, the cube symbolizes three dimensions of the value, and the creation of value is inseparable from the use of resources in the process of service. These resources can be people, vehicles, tools, materials, spare parts, products, data, etc. Considering the complexity of the impact of resources on value creation, this aspect will not be discussed in the paper for the time being but will be carried out in the future research work.

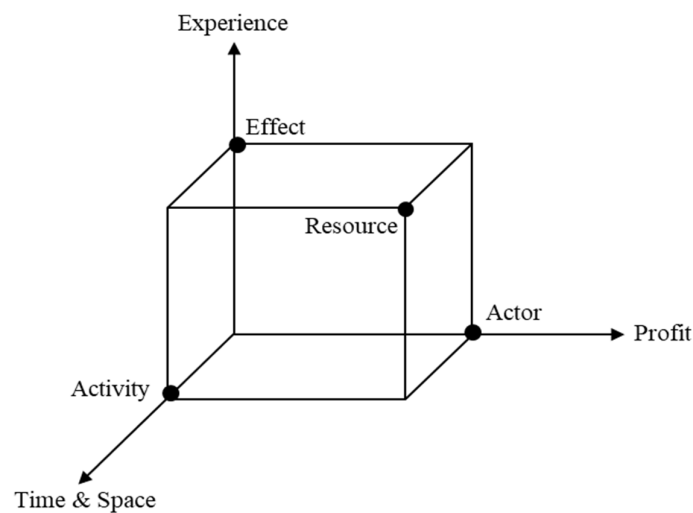


Figure 4. Dimensions of value and resource.

Based on the above description, we define value in service as follows:

$$V = (v_{ts}, v_p, v_e), \quad (1)$$

where v_{ts} is the time and space dimension of V , v_p is the profit dimension of V , and v_e is the experience dimension of V . If a dimension has no value, we use “ ” to represent it. Therefore, the format of V is a triple and some places of it might be empty. For example, if the working time of a staff member, A , is two hours in the service, his value can be expressed as $v = (2 \text{ h}, ,)$.

- Granularity of value

As we mentioned previously, services are customer-oriented. The service process is implemented around the requirements of customers. The process of the provider providing services to the customer is shown in Figure 4. The activities in the service process may be parallels, loops, etc., which will not be considered here, but only the process of the service moving closer to the customer. We can find that the value of service has a different granularity. Value in the service economy is driven and determined by the customer [43]. From the perspective of the whole service, the entire service process is customer-oriented, so it is the maximal granular value. In the service process, the activity for completing every specific task will create value, which is the minimum granularity of value. Some activities are fulfilled by the service provider itself, and some activities are outsourced

to other participants. As shown in Figure 5, six activities are outsourced to other participants, and the number of activities completed by each participant may be different. How participants complete these activities is transparent to the service provider. Service providers do not need to know how, but the participants themselves should know. These activities can be regarded as sub-processes in the service process. For example, a service provider wants to transport a package from one place to another. It can outsource the activity to a transportation company. It does not need to consider how the transportation company completes the activity. Then, we can take the value generated by activities which are completed by participants as the medium granularity value. Therefore, there are three kinds of granularity value in the service, that of large granularity value for the customer, medium granularity value for the participant, and small granularity value for the activity. Of course, the value granularity of the service provider is the same as that of the customer.

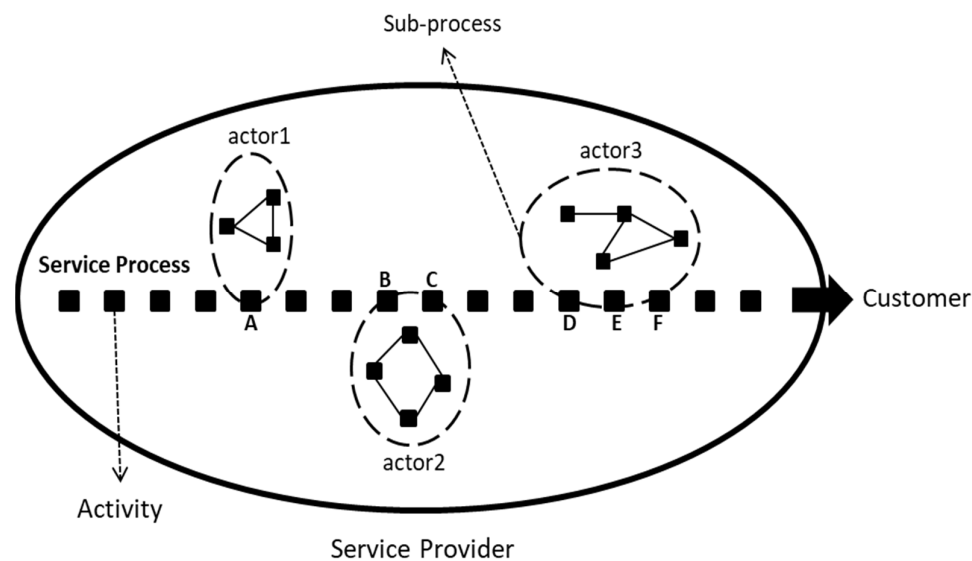


Figure 5. Granularity of value.

In the actual service process, an activity may be completed by multiple actors, and each actor completes different parts of the activity. Due to the complexity of some activities, a single actor is unable to complete them. For example, in the air conditioning installation service, two people are needed to complete the external unit installation; in the air conditioning maintenance service, when the spare parts need to be replaced, the spare parts provider and worker need to participate in the activity together. This situation will be considered later in this paper.

3.2.5. Construction of the Service Process Value Model

- Value of activity

Activity is the basic unit of the service process, which completes the specific task in the service. Activity is also the basic unit of value creation in the service. If an activity does not generate value, then it does not need to exist in the service process. As shown in Figure 6a, from the perspective of only one actor in the service, each activity has an input value and an output value. V_{in} represents the input value of the activity, and V_{out} represents the output value of the activity. In normal circumstances, the output value of an activity should be greater than the input. However, there are also exceptions, such as in the production process, the probability of waste products is inevitable, so the value generated by a certain activity is less than the input value. As mentioned in Section 3.2.1, the value of activity may be tangible, intangible, or both. Therefore, we can use the time and space, profit, and experience dimensions to express each specific value, whether it is input value or output value.

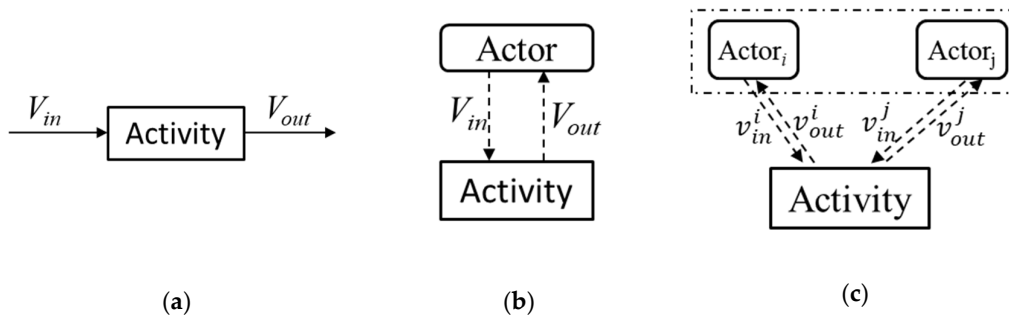


Figure 6. Value of activity. (a) Each activity has an input value and an output value; (b) each actor has an input value and an output value on the activity; (c) multiple actors work together to complete the activity.

An activity can be completed by one of, the service provider, customer, and other actors, or it can be done by multiple actors. For the same activity, its input value and output value may be not the same in different situations. That is to say, the value of V_{in} and V_{out} will be different when the performers of an activity are different. For example, if a product is sold by a manufacturer or by a retailer, the cost will be different, and the price of the sale may be different. Therefore, the value creation of activities is inseparable from the actors. In essence, it is the actor who achieves value creation in the process of performing the activity. As shown in the Figure 6b, each actor has an input value and an output value on the activity they participate in. If multiple actors participate in the same activity, each actor creates their own value through the activity. As shown in Figure 6c, $Actor_i$ and $Actor_j$ work together to complete the activity, the input and output values of $Actor_i$ are v_{in}^i and v_{out}^i , and those of $Actor_j$ are v_{in}^j and v_{out}^j . For example, there are two actors, the manufacturer and the customer, in the activity of selling products directly by a manufacturer. For the manufacturer, the input value of the activity is the product, the output value is the money paid by the customer; and for the customer, the input value is the money, the output value is the product. Of course, both actors involved in the activity need a certain amount of time to complete it. These values are the only tangible values that we can observe. Since the service provider can improve its reputation through the product quality, and the customers get the products, they also get spiritual satisfaction at the same time. Hereby, the output value of the manufacturer may also include corporate reputation, and the output value of customer should also include the satisfaction of the requirement.

- Value of service process

The service process is composed of activities in a certain order to fulfill the requirements of customer. Then, based on activity value, we can get the value of the service process. However, service systems are complex adaptive systems, and they are dynamic and open [5]. As such, the service processes are dynamic, and the activities in the service process are also dynamic. In the current market competition environment, the division of labor and cooperation is very common. Since the customer wants a complete service, the service provider needs to integrate the primitive services of other actors into a complex service to meet the needs of the customer. In other words, under the coordination of the service provider, different actors will participate in the completion of different activities, and each activity may have multiple actors competing for participation. Therefore, the customer-oriented service process needs to be completed by multiple actors. As shown in Figure 7, there are five activities in the service process. An activity in the process can be executed by different actors, and an actor can also participate in different activities. For example, in Figure 7, on activity A, there are three actors involved; the service provider or $Actor_k$ can complete the activity C, activity D, and activity E, $Actor_i$ is in competition with $Actor_j$ on activity B, and $Actor_i$ can cover activity B and activity C. We only show the three participants in the figure, and of course there are others. We just ignore them for the convenience of the figure display and introductory purposes. Since the value of

the activity will be different when the performer of the activity is different, the value of the service process also will be different. The service provider can dynamically adjust the service process, according to the customer's value expectation, to meet the requirements.

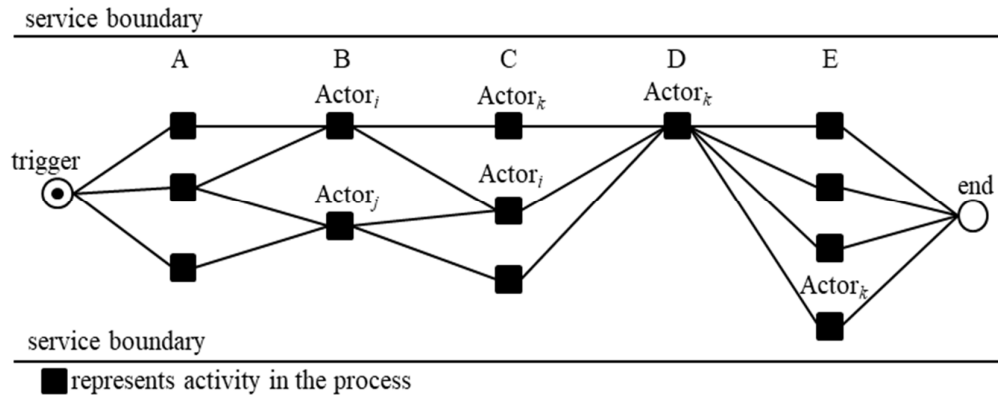


Figure 7. Service process and activity.

Another important feature of the service process can be found in Figure 7, which is that the service process is triggered by the customer and ends with the delivery of the service to the customer. This is one of the important differences between service process and business process, because the starting point of service is to meet the requirements of customers. It is also possible that the service provider needs to do some aftercare work, after the service is delivered to the customer, such as archiving the service-related information.

- Constructing the service process value model

Based on the above analysis, we can start to build the service process value model. As mentioned in Section 3.2.3, no matter which method is used to build the service process model, the related event log of the target service and process mining algorithms are the necessary foundation. For the event log, if it has been saved in XES format, we can use it directly, otherwise, we need to process it according to the standard of the XES format, so as to prepare for the subsequent work. For the process mining algorithms, there are many algorithms for process mining, which have been mentioned in the relevant literature, and we will not repeat them here. Here we mainly use the α -algorithm, or its improved algorithms, for mining. To extract the actor(s) and the corresponding value of each activity from the raw data and event log, we need to add new functions to the existing algorithm tools or develop a new tool. At the same time, we need to combine domain knowledge or user experience, such as the apriority of service, that is, experience knowledge generated in over the long-term service process. Since the service process model is the abstraction of many concrete service processes, the value of each activity here is an average value, or a value range. Furthermore, as the model obtained by process mining is described as a Petri net, activities in the service process are mapped to the transitions in it. We need to add the actor(s), the input value, and output value of the activity to the corresponding transition, as shown in Figure 6b,c. To describe the construction process of the service value model in a formal way, we define business process model, service process model, and service process value model as follows:

Definition 3. Business process model is a business petri net $N = (P, T, F)$, where

- P is a set of places;
- T is a set of transitions, representing activities;
- $F \subseteq (P \times T) \cup (T \times P)$ is the flow relation describing the arcs between places and transitions (and between transitions and places).

Definition 4. Service process model is a service petri net $SN = (P, T, F, t_s, t_e)$, where

- P, T , and F are the same as in the business petri net N ;
- $t_s \in T$, t_s is the first activity of the service process and triggered by the customer;
- $t_e \in T$, t_e is the activity of service delivery completion, and the customer must be the actor of it.

Definition 5. Service process value model is a service value annotated petri net $SVAN = (P, T, F, a_s, a_e, A, V)$, where

- P, T, F, t_s , and t_e are the same as in the customer-oriented service petri net SN ;
- A is a set of actors, $\forall a \in A$, a can participate in at least one activity t_i ;
- V is a set of values, $V \subseteq (A \times T) \cup (T \times A)$ is the input value and output value between actors and activities.

Let raw data be D , and event log be L , then take the “from BPM to SPM” path as an example, the steps of building the service process value model are described as follows:

1. Input the event log, L , to generate a business process model, N , by using process mining techniques.
2. Check the first activity in N , if the value of the “org:resource” is a customer, then add the customer as the actor of it, and make it as t_s of the service petri net SN ; or else add an activity, t_s , as the first activity of the whole process, and take the customer as its actor, and consider whether the co-actor exists in it or not.
3. Check the activities in N , if an activity to complete the delivery of the service, then add the customer as the actor of it and make it as t_e of the service petri net SN ; or else add an activity, t_e , in the appropriate position in the process, take the customer as its actor, and consider whether the co-actor exists in it or not. Then generate the service process model SN .
4. Check all activities in SN , to extract the value of the “org:resource” from the raw data, D , and event log, L , then get the set of actors, A ;
5. Combined with the domain knowledge, check the input value and output value between actors and activities in SN , to extract the set of values, V , from the raw data, D , and event log, L .
6. To annotate the value set V between actors in A and activities in T of the service process model SN , then get the service process value model $SVAN$.

As shown in Figure 8, this is the general form of the service process value model. There are five activities and six actors in the model. The first activity is A, which is completed by two actors, that of the Customer and Actor1. We used a dashed box to enclose the Customer and Actor1 to indicate that they are working together to complete the activity. Since the customer’s service requirement is the trigger of the process, we put the Customer in front of Actor1. Both the Customer and Actor1 have input and output value in the activity. Activity B is completed only by Actor2 and activity C is completed by Actor3 and Actor5 together. Activity D can be performed by Actor2 or Actor4, which is not cooperative, but alternative. Finally, the service needs to be delivered to the customer, so activity E needs to be completed by Actor5 and the Customer together. Since the customer is the receiver of the service, we put the Customer after Actor5. The service process starts from the customer’s service demand and ends at the service delivery to the customer. Every activity in the service process is involved in value creation.

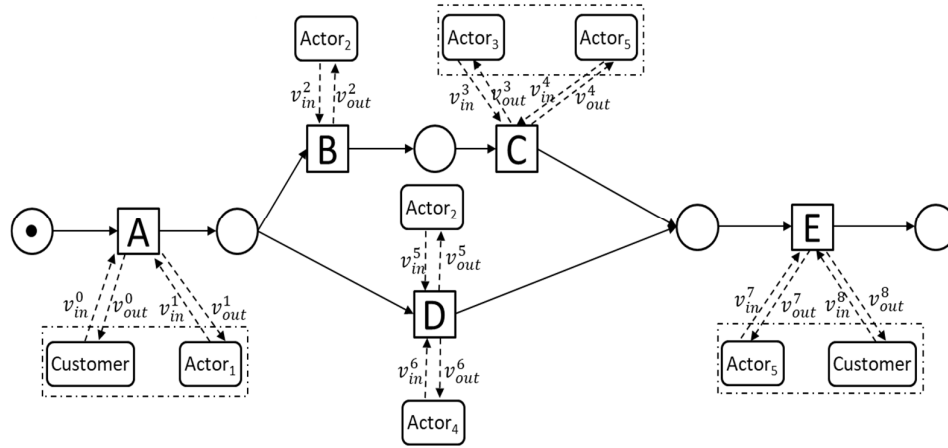


Figure 8. The general form of the service value model.

3.3. Case Study

In this section, we use the event log, according to the repair example mentioned in Section 3.1, as the data source for a case study. The log file can be downloaded from the process mining website. Since our focus is on the whole process, we exclude the incomplete instances in the event log and take the filtered event log as the running example. We use one of the two ways mentioned in Section 3.2.3 to demonstrate how to build a service process value model based on the running example. We use the ProM framework as the experimental environment. The version of ProM framework is 6.9, which was released in 2019, and its revision is 41850.

3.3.1. Business Process Model of the Example

From the tutorial in reference [36], we know that each trace in the event log represents a specific process instance, which starts with an activity to register the telephone, and ends with an activity to archive the instance. By using the α -algorithm plug-in for ProM to mine the running instance, the business process model, as shown in Figure 9, can be obtained. The first activity of the process is “Register”, which means registering the telephone sent by the user. The next activity is “Analyze Defect”, which means analyzing the defect category of the phone. Once the defect category is determined, it needs to be told to the customer through the “Inform User” activity, and according to the defect category, the “Repair(Simple)” activity or “Repair(Complex)”, activity on the phone will be carried out. After the repair work is finished, the phone must go through the “Test Repair” activity to determine whether it has been actually fixed. If the telephone is fixed, the instance is archived through the “Archive Repair” activity and the telephone is sent to the customer; otherwise, the “Restart Repair” activity will be launched and the telephone needs to be repaired again.

Going back to the running example itself, we find that some event attributes in the log are not reflected in the process model. This is because the business process model obtained by mining is the abstraction of all instances with the aim of discovering all the possible execution paths of the process from a global perspective. The business process model shows a series of activities and their sequence in the telephone repair process. In the tutorial, these activities are performed by different departments in the company. If we regard each department as an independent enterprise, then this is a cross enterprise cooperation process.

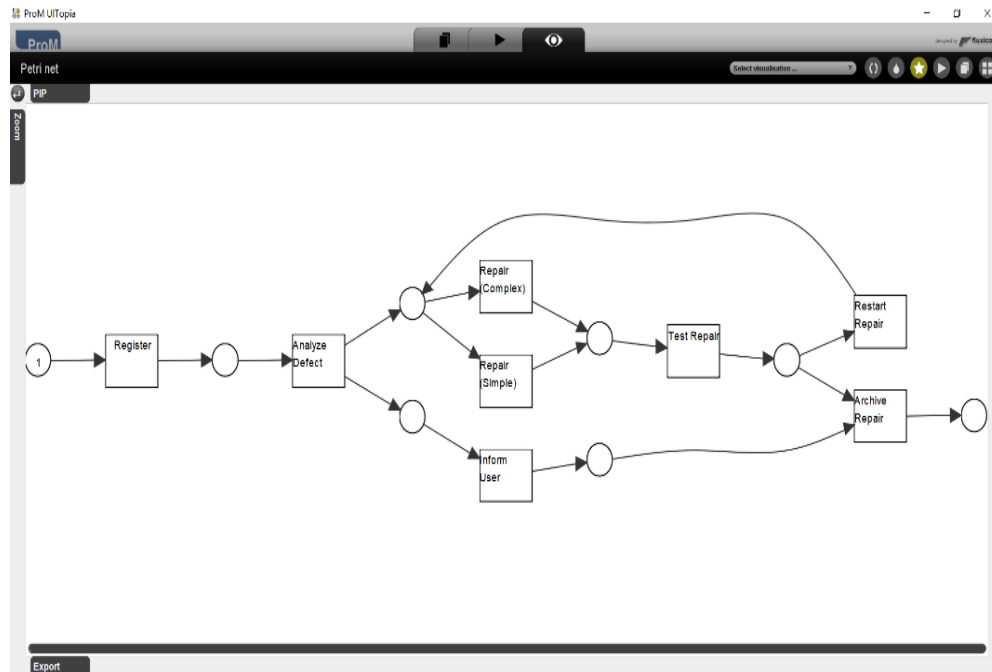


Figure 9. The business process model of the running example.

3.3.2. Process Servitization

The service process is customer-oriented, in which there must be customer related activities. However, the activities of the business process in Figure 9 are performed by the employees of the repair company and have nothing to do with the customers. Although some customer related activities are described several times in the tutorial, we cannot find them in the process model. For example, the description that the phone will be sent to the customer if it is fixed is not shown in the model. Therefore, we need to deal with the model according to step 2 and step 3 in Section 3.2.5 to get the service process model.

In real life, the repair service of the phone should be initiated by the customer, because only the user of the phone will find that it is defective. We look at the first activity, Register, which was not initiated by the customer. Hereby, a new activity needs to be added to replace the “Register” activity as the first activity of the process. We named this new activity “Apply”, which means applying for a telephone repair service. The customer is the applicant of the activity, and the service personnel of the repair company is the receiver of the application. Moreover, we cannot find any activity in the process model to deliver service to the customer. Generally, the “Archive Repair” activity should be the aftercare of the whole service process. In the telephone repair service, the service delivery should be after the telephone is fixed and before the end of the whole service process. Therefore, a new activity is added between “Test Repair” and “Archive Repair”, and we named it as “Accomplish”. The “Accomplish” activity means to complete the delivery of the service. In fact, there are two cases of delivery. One is that the phone is actually fixed and delivered to the customer; the other is that the phone is not fixed, and a brand-new device is sent to the customer. We can find in the running example that the “Test Repair” activity has an important attribute “numberRepairs”. In the tutorial, the description of this attribute is as follows: to save on through time, the company only tries to fix a defect a limited number of times. We argue that it is the same, because not all defects can be fixed. Just like in the production process, the scrap rate is inevitable, it is impossible for all products to be 100% qualified. Therefore, the repair company may deliver a fixed phone or a new one to the customer. The actors of the “Accomplish” activity are the company’s service personnel and the customer.

Through the above operations, the process is changed to being triggered by the customer, and the delivery of service becomes part of the process. We can now get the service process model, as

shown in Figure 10. The customer's demand for a telephone repair service can be met through the implementation of this service process. In the service process, in addition to "Apply" and "Accomplish" activities, there is another activity "Inform User", which should also involve the customer. As the object of the notification is the customer, the customer will receive the result of the defect analysis from the company.

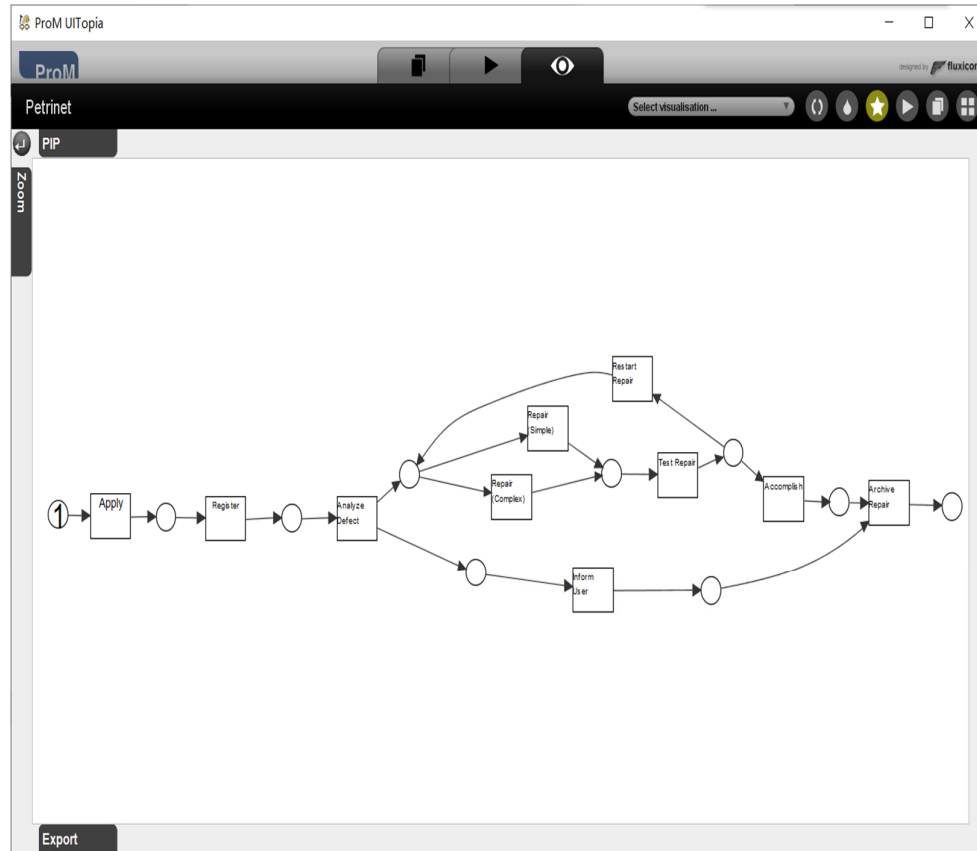


Figure 10. The service process model of telephone repair.

3.3.3. Value Annotation

Now we start to extract the actors of each activity in the service process. For "Apply", "Accomplish", and "Inform User" activities, based on the analysis in the previous section, their actors are the customer and the company service personnel. Considering consistency with the follow-up activities, we call the company's service personnel "System". The actors of other activities can be extracted from the corresponding attributes of each activity in the running example. As described above, an actor may participate in completing multiple activities; an activity can be completed by different actors. For example, we find that the "Analyze Defect" activity can be independently completed by six actors, namely Tester1, Tester2, Tester3, Tester4, Tester5, and Tester6. Similarly, we find that the "Test Repair" activity can be completed by Tester1, Tester2, Tester3, Tester4, Tester5, and Tester6. However, "Analyze Defect" and "Test Repair" are done by two different departments in the company, so we believe that the actors in these two activities are just different entities with the same name. As shown in Figure 11, we developed a new plug-in for Prom to extract the actors of each activity from the running example. A dashed box is used to enclose the actors to indicate that the activity is performed by these actors together. The actor who initiated the activity is put at the top of the box. In addition to the activities described above, the three activities of "Register", "Restart Repair", and "Archive Repair" are performed by the actor "System"; the "Repair(Simple)" activity can be completed by SolverS1, SolverS2, and Solvers3 respectively; and the "Repair(Complex)" activity can be completed by SolverC1, SolverC2, and SolverC3, respectively.

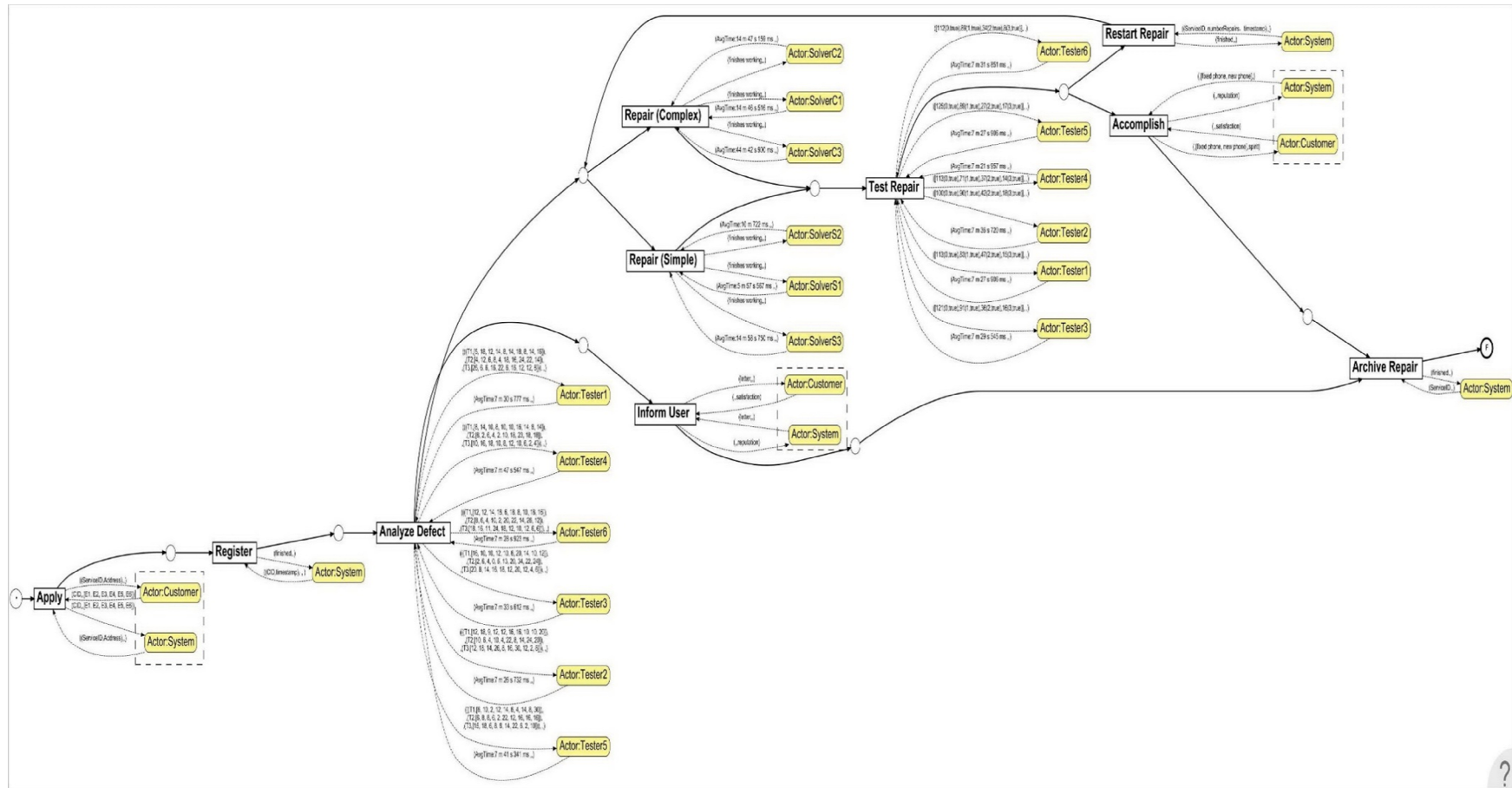


Figure 11. Service process value model of the running example.

After getting all the actors, we need to find out their input value and output value for the corresponding activities. Since there are not many attributes related to value in the running example, we cannot describe all dimensions of value completely, but we need to extract the value of at least one dimension from the running instance or supplement it with domain knowledge. For the “Apply” activity, since it is an activity added according to the domain knowledge, there is no information about it in the running example, so we need to add value information, according to the actual situation. In the “Apply” activity, the “Customer” needs to tell the “System” the characteristics of the telephone defect. The “System” receives the information from the customer and needs to give the customer a service number and mailing address. Here we assume that there are six kinds of defect characteristics of the telephone [E1, E2, E3, E4, E5, E6]. Then the input value of the “Customer” is $v_{in}^{11} = (cid, , [E1, E2, E3, E4, E5, E6])$, and the output value is $v_{out}^{11} = ((serviceid, address), ,)$; the input value of “System” is $v_{in}^{12} = ((serviceid, address), ,)$, and the output value is $v_{out}^{12} = (cid, , [E1, E2, E3, E4, E5, E6])$. Here, *cid* represents the customer number, and *sid* represents the service number. Since each specific service instance faces different customers, each specific *cid* and *sid* are different. We abstractly use *cid* and *sid* to represent them. The customer can query the progress or status of service through *sid*. For the “Analyze Defect” activity, we can extract the value of actors from the corresponding events in the running example. Figure 12 shows specific “Analyze Defect” activity information in a service instance. From the information, we can find that the participant of the activity is “Tester3”, the start time is “1970-01-02T12:23:00.000+01:00”, the end time is “1970-01-02T12:30:00.000+01:00”, and the analysis result shows that the type of phone is T2 and the defect type is 6. Hereby, in this specific activity instance, the actor “Tester3” spent a certain amount of time to get the analysis results, then his input value is time, and the analysis result is his output value. Therefore, from the perspective of model, the value of each actor in activity “Analyze Defect” needs to be calculated for all instances. We can get that the input value of each actor, which is $v_{in}^{3i} = (avgTime, ,)$, and the output value is $v_{out}^{3i} = ((phoneType, [num_defectType_1, \dots, num_defectType_n]), \dots, ,)$. Here, *avgTime* represents the average time spent by the actor; (*phoneType*, [*num_defectType*₁, ..., *num_defectType*_n]) represents the collection of the numbers of defect types that occur on the *phoneType*. The new plug-in developed for ProM to extract actors can also be used to extract value information from the running examples.

Based on the above two methods, the input value and output value of all the actors in the service process can be obtained. As shown in Figure 11, this is a key part of the service process value model of the running example. We can see the input value and output value of each actor on every activity in the model. Both input value and output value have a value in at least one dimension. If the running example has enough value related attributes or has a corresponding domain knowledge library, the value information in the service process value model will be more abundant.

```

<event>
  <string key="org:resource" value="Tester3"/>
  <date key="time:timestamp" value="1970-01-02T12:23:00.000+01:00"/>
  <string key="concept:name" value="Analyze Defect"/>
  <string key="lifecycle:transition" value="start"/>
</event>
<event>
  <string key="defectType" value="6"/>
  <string key="org:resource" value="Tester3"/>
  <string key="lifecycle:transition" value="complete"/>
  <string key="phoneType" value="T2"/>
  <date key="time:timestamp" value="1970-01-02T12:30:00.000+01:00"/>
  <string key="concept:name" value="Analyze Defect"/>
</event>

```

Figure 12. A specific “Analyze Defect” activity information in a service instance.

4. Discussion

Within the trend of manufacturing servitization, there is an interesting topic of how to co-create value by the service process of cross enterprise facing, over the whole life cycle of the product service. The content discussed in this paper is from the initial stage of our research, and the purpose is to establish a research framework for service-oriented process value for cross enterprise multi-actor collaboration. For the description and definition of service value, we mainly referred to some studies in the literature, such as [31,41,42]. Based on the classification of tangible value and intangible value, starting from the vital interests of service actors and considering the contribution of actors to specific activities, three dimensions and three granularities were introduced to better describe the value creation in the service process. The definition of service value in this paper is still abstract, but it is more concrete and operable than the value in the SVN. Since the focus of the SVN is mainly on the value of collaborative creation, based on service composition and the level of attention to service, the specific processes and activities in the service are rarely mentioned. The actors in SVN are usually firms. However, we focus on the specific processes and activities in the service, and mainly consider value creation at the activity level. The actors of the activity can be employees, departments within the service provider, or outsourcing companies. Therefore, the description of value is more specific and operational. Follow-up research will be combined with the relevant theories of SVN and the industrial value chain [44,45] to refine and quantify service value, so that the value can be calculated and optimized. Although we also recognize the impact of resources on value creation in the service process, due to the fact that there are many types of resources, and resources involved in the actual service process, including personnel, tools, vehicles, product components, etc., we will discuss the relationship between resources and service value in following research.

We did not use the traditional modeling method, but one based on the event log of service performance in the information system. The main reason why we introduced process mining technology into the construction of the service process model was that process mining can discover the process from the actual event log in the service system. As mentioned in reference [39], “the main benefit of process mining techniques is that information is objectively compiled”. Due to the existence of many event logs in information systems, it is possible to cover all paths of the process execution. As we know, there may be differences between the actual implementation of the process and the ideal situation. Therefore, research on the actual service process is more meaningful, and at the same time, avoids the error of manual construction of the service process. The research results of many scholars on process mining provide us with a solid research foundation. Using the existing process mining algorithm, we can build a process model faster. However, the model obtained by using process mining technology is not the final model that we need. Since the service process is customer-oriented, value is driven and determined by customers, and value creation is domain related, we must improve the existing algorithms and tools to meet the needs of research, and experiment by combining the specific service domain knowledge.

It was not an easy task to find interesting data for case study. Since the data coming from our project cannot be exploited here, we used the event log provided by the process mining website. It is used as an illustrative example to illustrate the method mentioned in Section 3.2.2, but both methods have been tested in the study. Our initial purpose was to investigate the value creation of multiple actors across enterprises in the service process. Although the actors in the process shown in the example log are all from the repair company, we can treat the departments of the actors in different activities as independent entities or enterprises. This is because in an actual telephone repair service, multiple enterprises are required to cooperate to complete the process. The customer has to apply for repair from the product manufacturing enterprise, and the repair is completed by the outsourcing of the production enterprise to the professional repair company, and the telephone also needs to be transported by the logistics company. In the step of building the service process value model, since the event log in the example had been formatted and saved in XES file, we omitted the operation of getting and selecting data from the raw data. However, we also encountered the problem of insufficient raw data support. Although we could establish the service process value model, the value information in the event log was relatively lacking. We need to add more value information,

combined with domain knowledge, to improve the model. Therefore, we expect to be able to get data support from our project, and work with experts in relevant service fields. Therefore, we could carry out the research better. This study is a proof of concept, and it needs to be refined and deepened in the future.

In the case study, to show how to build the service process value model, we developed a new plug-in for ProM based on α -algorithm. The plug-in has three basic functions: first, it can extract the actor(s) and the corresponding value of each activity from the raw data and event log; second, it can transform the business process model mined by α -algorithm into a service process model; third, it can annotate the extracted actors and value information to the corresponding activities in the service process, to form the service process value model. As the current plug-in is developed for the examples in the case study, there are some limitations. For example, the practical use of the α -algorithm is hindered because of problems with noise, infrequent behavior, and complex constructs; although for the running example, the result of the α -algorithm was acceptable, we will adopt more robust techniques such as a fuzzy algorithm, heuristics algorithm, or inductive algorithm in future research work and plug-in development. Considering the two methods for the construction of the service process value model in Section 3.2.3, if the newly developed plug-in is to be universal, it must be supported by the corresponding domain knowledge library, when converting from business process to service process and extracting activity actors and value, or the event log must be customer-oriented and contain enough domain knowledge. Therefore, we hope to collect more relevant knowledge of the service domain and establish a domain knowledge library. On this basis, the rules for model transformation and event log enrichment should be formulated and improved. This is also one of the important tasks for us to do next.

5. Conclusions

In this paper, we proposed a service process value model construction method, based on process mining. Based on the theory and materials of services and service processes, process modeling and process mining, and service value networks, we introduced the concept of value in service, and defined it by dimension and granularity. In the model, activity is regarded as the basic unit of the service process and value creation unit in the service. At the same time, taking the raw data and event log of the information system or service system as the starting point, the service process model can be obtained from the log in two ways by using process mining techniques. Combined with domain knowledge, we can extract the corresponding actors and their input and output values on each activity in the service process from the raw data and event log. Through the value annotation of the service process, we built the service process value model. We developed a plug-in for ProM and validated the proposed methodology using the telephone repair event log provided by the Process Mining Group. The model will help to understand the mechanism of multi-actor collaborative value creation in the service process. As a result, the service process of cross enterprise collaboration, can provide enterprises with a basis for value optimization, as well as the choice of service process that meets the needs of customers. On the other hand, the mastery of domain knowledge, and the quality of raw data and event log have an important impact on the construction of the model. The representation of the model is still very dependent on the process mining algorithm and corresponding tools. Therefore, the method has some limitations in the scale of service process and requires some extra manual work. However, with the plug-in, the method will be assisted in the modeling process, from raw data and event log, to the service process model.

The scientific contribution of this paper was to propose a new service process modeling method. From raw data and event logs to business process model, which was inspired by Van der Aalst, then generating the service process model, and service process value model, our proposition that is completely new. The research on the actual service process execution in the product and service system is more meaningful. Although the model proposed in this paper is conceptual, it provides a framework for future work. For the follow-up research work, the first step is to improve the measurement indicators of service value, each parameter in value " $V = (v_{ls}, v_p, v_e)$ " is a set of indicators, and then we want to define a standard log format through these indicators; the second is to adjust

the mining algorithm used, such as the heuristic algorithm or inductive algorithm, and develop a generic Prom plug-in to validate our ideas, which will be applicable to other scenarios. Moreover, since different services may have different forms of value, it is difficult to give a set of indicators for the value of services in different fields. We will continue to focus on the service value in the product and service system. In addition, we may carry out in-depth research on the service process value model in combination with value chain theory.

Author Contributions: All authors contributed to the overall methodology investigation and analysis; X.Z. and D.C. (Dianhui Chu) focused on modeling methods by using process mining; X.Z., G.Z., and D.C. (David Chen) defined the concept of service value and the method of establishing service process value model; X.Z. and G.Z. organized the case study. X.Z. implemented the plug-in for ProM; X.Z. and D.C. (Dianhui Chu) contributed in funding acquisition; X.Z. wrote the first draft of the article; X.Z. and G.Z. edit the final version. All authors have read and agreed to the published version of the article.

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References

1. Frank, A.G.; Glauco, H.S.; Mendes, N.F.; Ayala, A.G. Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technol. Forecast. Soc. Chang.* **2019**, *141*, 341–351.
2. Barnett, N.J.; Parry, G.; Saad, M.; Newnes, L.B.; Goh, Y.M. Servitization: Is a paradigm shift in the business model and service enterprise required? *Strateg. Chang.* **2013**, *22*, 145–156.
3. Baines, T.; Lightfoot, H.; Benedettini, O.; Kay, J.M. The servitization of manufacturing: A review of literature and reflection on future challenges. *J. Manuf. Technol. Manag.* **2009**, *20*, 547–567.
4. Van der Aalst, W.M.; Adriansyah, A.A.; De Medeiros, A.K.; Arcieri, F.; Baier, T.; Blickle, T.T.; Bose, J.C.; Van Den Brand, P.; Brandtjen, R.; Buijs, J.; et al. Process Mining Manifesto. In *Business Process Management Workshops 2011*; Springer: Berlin/Heidelberg, Germany, 2012; Volume 99.
5. Van der Aalst, W.M. *Process Mining: Discovery, Conformance and Enhancement of Business Processes*; Springer: Berlin, Germany, 2011.
6. De Leon, M.; Van der Aalst, W.M.; Dees, M. A general process mining framework for correlating, predicting and clustering dynamic behavior based on event logs. *Inf. Syst.* **2016**, *56*, 235–257.
7. Schimm, G. Mining exact models of concurrent workflows. *Comput. Ind.* **2004**, *53*, 265–281.
8. Agrawal, R.; Gunopulos, D.; Leymann, F. Mining process models from workflow logs. In *International Conference on Extending Database Technology*; Springer: Berlin/Heidelberg, Germany, 1998; pp. 467–483.
9. Herbst, J.; Karagiannis, D. Workflow mining with InWoLvE. *Comput. Ind.* **2004**, *53*, 245–264.
10. Günther, C.W.; Der Aalst, W.M. Fuzzy mining—adaptive process simplification based on multi-perspective metrics. In *International Conference on Business Process Management*; Springer: Berlin/Heidelberg, Germany, 2007; pp. 328–343.
11. Van der Aalst, W.M.; Schonenberg, M.H.; Song, M. Time prediction based on process mining. *Inf. Syst.* **2011**, *36*, 450–475.
12. Wang, P.P.; Ming, X.G.; Zheng, M.K. A framework of value creation for industrial product-service. In *IFIP International Conference on Product Lifecycle Management*; Springer: Cham, Switzerland, 2015; pp. 311–320.
13. Yip, M.H.; Rizvi, M.A.K.; Chew, E. Managing Value Co-Creation: An Integrated Design Framework for Service-Centric Product-Service Systems. In *Proceedings of the 2019 Portland International Conference on Management of Engineering and Technology (PICMET)*, Portland, OR, USA, 25–29 August 2019; pp. 1–13.
14. Takahashi, H.; Nishino, N.; Takeshi, T.; Ishikawa, R. Interpreting value creation model by case-based decision theory. *Procedia CIRP* **2020**, *88*, 584–588.

15. Spohrer, J.; Maglio, P.P.; Bailey, J.; Gruhl, D. Steps toward a science of service systems. *Computer* **2007**, *40*, 71–77.
16. Ren, J.; Zhao, L.; Li, B.; Liu, L.; Xing, R. Measuring Service Utilities in Service Value Networks. *Int. J. Inf. Syst. Serv. Sect.* **2017**, *9*, 1–26.
17. Bitner, M.J.; Ostrom, A.L.; Morgan, F.N. Service blueprinting: A practical technique for service innovation. *Calif. Manag. Rev.* **2008**, *50*, 66–94.
18. Zappatore, M.; Longo, A.; Bochicchio, M.A. SLA composition in service networks: A tool for representing relationships between SLAs and contracts. the 30th Annual ACM Symposium, ACM: Salamanca, Spain, 2015, 13–17.
19. Netto, M.A.S.; Bubendorfer, K.; Buyya, R. SLA-based advance reservations with flexible and adaptive time QoS parameters. In *International Conference on Service-Oriented Computing*; Springer: Berlin/Heidelberg, Germany, 2007; pp. 119–131.
20. Zhai, Y.; Zhang, J.; Lin, K.J. SOA Middleware Support for Service Process Reconfiguration with End-to-End QoS Constraints. In Proceedings of the IEEE International Conference on Web Services, Los Angeles, CA, USA, 6–10 July 2009.
21. Li, J.; Ma, D.; Mei, X.; Sun, H.; Zheng, Z. Adaptive QoS-Aware Service Process Reconfiguration. In Proceedings of the IEEE International Conference on Services Computing, SCC 2011, Washington, DC, USA, 4–9 July 2011.
22. Nan, Z.; Qiu, X.S.; Meng, L.M. A SLA-based service process management approach for SOA. In Proceedings of the International Conference on Communications & Networking in China, Beijing, China, 25–27 October 2006.
23. Yang, X.X.; Yu, T.; Xu, H.H. A Survey on Workflow Verifications of Petri Nets based Service Process Management. *Int. J. Grid Distrib. Comput.* **2015**, *8*, 79–90.
24. Schabacker, M.; Szélig, N.; Vajna, S. Suitable methods for process modeling and process optimization. In Proceedings of the 19th International Conference on Engineering Design (ICED13), Design for Harmonies, Vol. 1: Design Processes, Seoul, Korea, 19–22 August 2013.
25. Aguilar-Saven, R.S. Business process modelling: Review and framework. *Int. J. Prod. Econ.* **2004**, *90*, 129–149.
26. Businska, L.; Kirikova, M. Knowledge dimension in business process modeling. In *International Conference on Advanced Information Systems Engineering*; Springer: Berlin/Heidelberg, Germany, 2011; pp. 186–201.
27. Villarreal, P.D.; Salomone, E.; Chiotti, O. Modeling and Specification of Collaborative Business Processes with a MDS Approach and a UML Profile. In *Enterprise Modeling and Computing with UML*; IGI Global: Hershey, USA, 2007; pp. 13–44.
28. Van der Aalst, W.M.; Weijters, T.; Maruster, L. Workflow mining: Discovering process models from event logs. *IEEE Trans. Knowl. Data Eng.* **2004**, *16*, 1128–1142.
29. XES Working Group. Ieee standard for extensible event stream (xes) for achieving interoperability in event logs and event streams. *IEEE Std 1849*, **2016**, 1–50.
30. Heck, E.; Vervest, P. Smart business networks: Concepts and empirical evidence. *Decis. Support Syst.* **2009**, *47*, 275–276.
31. Blau, B.; Kramer, J.; Conte, T.; Van Dinther, C. Service value networks, In Proceedings of the 2009 IEEE Conference on Commerce and Enterprise Computing. Vienna, Austria, 20–23 July 2009.
32. Lusch, R.F.; Vargo, S.L.; Tanniru, M. Service, value networks and learning. *J. Acad. Mark. Sci.* **2010**, *38*, 19–31.
33. Chu, D.H.; Wang, Z.J.; Xu, X.F.; Lu, Z.M. Progressive Service Value Network Design for Bi-lateral Service Applications. *Inf. Technol. J.* **2013**, *12*, 1152–1159.
34. Schulz, F.; Michalk, W.; Hedwig, M.; McCallister, M.; Momm, C.; Caton, S.; Haas, C.; Rolli, D.; Tavas, M. Service Level Management for Service Value Networks. In Proceedings of the Computer Software and Applications Conference, Izmir, Turkey, 16–20 July 2012; pp. 51–56.
35. Fu, W.; Wang, Q.; Zhao, X. The influence of platform service innovation on value co-creation activities and the network effect. *J. Serv. Manag.* **2017**, *28*, 348–388.
36. Process Mining in Action. Available online: <http://www.promtools.org/prom6/downloads/prom-6.0-tutorial.pdf> (accessed on 18 August 2020).
37. Alter, S. Service system fundamentals: Work system, value chain, and life cycle. *IBM Syst. J.* **2008**, *47*, 71–85.

38. Vargo, S.L.; Lusch, R.F. The Four Service Marketing Myths. *J. Serv. Res.* **2004**, *6*, 324–335.
39. Banerjee, P.; Friedrich, R.J.; Bash, C.E.; Goldsack, P.; Huberman, B.; Manley, J.; Patel, C.; Ranganathan, P.; Veitch, A. Everything as a Service: Powering the New Information Economy. *IEEE Comput.* **2011**, *44*, 36–43.
40. Zacharewicz, G.; Diallo, S.; Ducq, Y.; Agostinho, C.; Jardim-Goncalves, R.; Bazoun, H.; Wang, Z.; Doumeingts, G. Model-based approaches for interoperability of next generation enterprise information systems: State of the art and future challenges. *IseB.* **2017**, *15*(2), 229–256.
41. Xu, X.F.; Liu, Z.Z.; Wang, Z.J.; Min, X.Y.; Liu, R.L.; Wang, H.F. S-ABC—Service Domain-Oriented Artificial Bee Colony Algorithm Paradigm. *Chin. J. Comput.* **2015**, *38*, 2301–2317, doi:10.11897/SP.J.1016.2015.02301.
42. Allee, V. Value network analysis and value conversion of tangible and intangible assets. *J. Intellect. Cap.* **2008**, *9*, 5–24.
43. Basole, R.C.; Rouse, W.B. Complexity of service value networks: Conceptualization and empirical investigation. *IBM Syst. J.* **2008**, *47*, 53–70.
44. Porter, M.E. *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press: New York, USA, 1985.
45. Du, Y.F.; Li, S.M. Industrial value chain: The innovative format of value strategy. *Stud. Sci. Sci.* **2004**, *22*, 552–556.

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