Chapter 8
Product Service Systems for Social Manufacturing

Wei Guo and Pingyu Jiang

8.1 Product Service System in Social Manufacturing

This section explores the basic concepts of product service system (PSS) and its advantages on integrating product with services. Under the context of PSS, many enterprises changed their business models from providing tangible products to integrated product services. However, this transition has been confronted with challenges from enterprises themselves, the society, and the customers. Hence, a novel approach, called as PSS for SocialM, is proposed in our work to solve the problems.

8.1.1 Useable PSSs in Product Life Cycle

The prototype of PSS was originally proposed in the report for the Dutch government in 1999 [1]. In fact, PSS can be understood as a business system which consists of products, services, supporting networks and infrastructure, is able to satisfy customer requirements and brings lower impact on the environment than the traditional business models [2]. One of the most obvious characteristics of PSS is the transformation from product selling to product-service providing. In this way, customers can obtain the services they need without paying for tangible products, and enterprises or service providers can obtain sustainable profits by serving the customers continuously.

On a life cycle basis, the implementations of PSS can be classified into three categories, that is, product-oriented services, use-oriented services and result-oriented services [3, 4]. Product-oriented services simply provide additional services to their original product, such as after-sales service and maintenance repair operating (MRO) service. For use-oriented services, the product is still owned by the service provider but shared to a number of other users, such as product renting, sharing, and pooling. Result-oriented services are pure customer requirements driven PSS that the service provider develops a subversive way to provide services to the customer, such as gas

P. Jiang, *Social Manufacturing: Fundamentals and Applications*, Springer Series in Advanced Manufacturing, https://doi.org/10.1007/978-3-319-72986-2_8

service [5], professional printing service [6] and civil aerospace service [7]. In this chapter, PSS refers to result-oriented PSS by default, and services or product-services refer to the result-oriented product-services by default.

Nowadays, enterprises are aware of such a fact that PSS is a sustainable and powerful tool for getting profits and promoting customer satisfactions. However, most of enterprises still remain in the stages of either product-oriented services or use-oriented services. Transformation to product-service providers (PSPs), which provides integrated product-services to customers, is facing with various challenges and obstacles from enterprises themselves. For example, there exist high labor costs, extreme service complexity, different culture background, and so on [8, 9]. On the basis of the internal barriers of enterprises, we know that the transformational challenges would come from the following three aspects.

The first aspect is about challenge on the enterprises' organization. To provide product-services, PSPs must shift their focus on enhancing their service departments and simplify other departments like manufacturing and sale departments. This may lead to enterprise instability which is difficult to eliminate.

The second aspect is about challenge on labor demands. Services must be consumed as they are provided because they cannot be saved, stored, returned, or carried forward for later use or sale [10]. Due to the variation in labor requirements, too much labor reserve may increase the economic burden of enterprises, and insufficient labor reserve may not be able to satisfy the requirements when more labors are required.

The third aspect is about challenge on complex services. Due to the incensement of product-service complexity and expertise, PSPs have to manage and control all the detailed processes of product-services and cannot concentrate on the core services that represent the core competency of the PSPs.

All these challenges are hindering the development and transformation of the PSPs to a higher level.

8.1.2 PSS for Social Manufacturing as a New Way to Run Products and Attached Services

According to the challenges mentioned above, a flexible and efficient mode should be introduced to enhance the current PSS. Facing the similar challenges in manufacturing, we proposed a new manufacturing paradigm called social manufacturing [11]. This new manufacturing paradigm starts from Internet-based connecting and communicating behaviors in business, focuses on self-organizing socialized manufacturing resources into manufacturing communities, and runs under the support of extended CPS and social factory model so as to implement mass collaboration and share during product manufacturing activities covering the whole stages of a product life cycle [12]. Enterprises in the same communities should have the same or similar manufacturing resources and capabilities. Based on the concept of SocialM, products are produced by gathering the socialized manufacturing resources into manufacturing communities

In service area, there are also many micro-and-small-scale service enterprises (MSSEs) which specialize in providing services. However, their sizes and strategies hinder their possibilities to further develop into very strong PSS providers [13]. In this chapter, two types of MSSEs sources are dealt with. The first one is the traditional MSSEs which can be distinguished by the number of employees, quantity of fixed assets, etc. And the second one is formed by MSSEs decomposed from the large-scale manufacturing enterprise.

In this chapter, the above MSSEs which contains socialized service resources (SSRs) can be cognized as independent PSPs which are gathered into service communities (SCs) to provide product-services. The core PSP only concentrates on the key phase of product-services and manages the others PSPs. In order to solve the problem in PSS under the context of SocialM, we proposed a novel business model called PSS for SocialM that gathers the SMSEs into SCs so as to provide product-services collaboratively. In the context of PSS for SocialM, the MSSEs share their service resources and capabilities on a specified platform, and then the service resources are aggregated into different SCs according to their similarity. Once a customer proposes a service order to the platform, suitable SCs will be selected and arranged according to their service capabilities and established a service community network.

8.2 Concepts and Implementing Architecture of PSS for Social Manufacturing

In the previous section, integrating of PPS and SocialM has been proposed to form a novel business model to tackle the challenges of PSS. Therefore, concepts and characteristics of this new business model should be defined and declared in detail so as to establish the implementing architecture and the operational logic of PSS for SocialM.

8.2.1 Definitions

The following key definitions explain basic concepts and research boundary of PSS for SocialM.

Definition 1: SSRs are defined as a set of the equipments and human resources involved in the processes of service providing, such as products themselves, diagnosis and maintenance tools, maintenance staffs, service packages that are presented as a series of services, etc. Resource sharing is one of the most core characteristics of SSRs to ensure the efficient and effective use of available service resources under the ever-increasing competitiveness [14]. PSS for SocialM aggregates and clusters the decentralized service resources and capabilities into SCs. In this way, problems caused by information islands [15] are solved, such as low resource utilization and low service efficiency.

Definition 2: Service capability is defined as a kind of the ability of using SSRs for operating and completing a specific service to satisfy the service requirements of the customer. Generally speaking, service capability includes stable equipment service capability and ever-increasing labor service capability.

Definition 3: MSSE is defined as a kind of social micro-and-small-scale service enterprise which provides product-services to customers. In a generic meanings, an MSSE also implies that it organizes and uses its own SSRs for product-services under considering its implementing structure and operational logic. To the extreme form, individuals like makers and individual serviceman who provide product-services can also be seen as a kind of virtual "*MSSE*".

Definition 4: PSP is defined as a kind of role an MSSE acts as and also as the representative or agent of an MSSE. It emphasizes the type of SSRs and the versatility of service capabilities.

Definition 5: Service Community (SC) can be defined as an aggregation of inter-related MSSEs and their SSRs and inter-connection relationships among MSSEs, their PSPs and their SSRs. Within an SC, its MSSEs have common or similar benefits and collaboratively complete product-services to satisfy customer requirements. As the core content of PSS for SocialM, SC has two obvious natures. The first is that relationships among SSRs include not only collaboration but also competition within an SC. Since every PSP wants to realize high profits and low costs, correspondent MSSEs need to change their strategies on SSRs to increase competitiveness. The second is that the organization procedure of SC is of self-organization and virus-like propagation. It means that whether an MSSE joins or leaves an SC is up to PSP's own strategy.

Definition 6: SC network is defined as the inter-connection among SCs that have various service types and service capabilities. In fact, PSS for SocialM uses an SC network responsible for different product-service phases and processes. Relationships among SCs are fuzzy and vague. It means that any MSSE together with its PSS and partial or all SSRs can be a member of different SCs. SC network is a typical relationship network which can be used to express the relationships among SCs and MSSEs, such as sequential relationship, supporting relationship, etc.

Definition 7: Service order can be defined as official service requests from customers guaranteed by contracts. It includes service type, service quantity, service capability, order allocation, response time, etc., and depends on customers' requirements analysis. Due to the intangible nature of services, the operation procedure of service order and service consumption is synchronous.

8.2.2 Characteristics of PSS for Social Manufacturing

Since PSS for SocialM integrates the core ideas of both PSS and SocialM, it has its own unique characteristics, which determine how to enable the implementing architecture and operational logic of PSS for SocialM.

The first characteristic is about service relationships. In the context of PSS for SocialM, SSRs from distributed PSPs self-organize into various SCs for collaborative services. Since an SC network may contain vast SCs and SSRs inside them, relationships among SCs and inside an SC are complicated. Generally speaking, there are only two kinds of relationships inside an SC, that is, cooperative relationship and competitive relationship [16]. PSPs either collaborate with each other to complete the product-services or compete with one another to obtain more profits. Therefore, relationships among SCs not only include the above two typical relationships, but also attachment relationship, sequenced relationship, etc.

The second characteristic is service-order-oriented. Due to the intangible nature of services, services cannot be stored like products and cannot have inventory [17]. They must follow a service order and be consumed as they are provided. The operation of a service order relies on triggering and executing a series of service events. Here, a service event is used for changing service state from A to B. Besides the above service order, service contract, service flow, service result and service evaluation are also different from products [18].

The third characteristic is about lean services. In traditional PSS, only the core enterprise provides product-services for customers, this makes it difficult to satisfy the detailed requirements in the service processes and leads to possible economic waste. In the context of PSS for SocialM, a mass of professional service MSSEs act as PSPs for specialized product-service providing and one PSP only needs to concentrate on one kind of service. Since product-services can be divided into different service phases, a lean-philosophy-driven optimal matching among PSPs and service phases can be realized through so-called "*lean services*" [19].

8.2.3 Implementing Architecture of PSS for Social Manufacturing

In order to clarify the concepts and structure of PSS for SocialM, a four-layer implementing architecture of PSS for SocialM is illustrated, as shown in Fig. 8.1. From the bottom to top, there are resource layer, community layer, organization layer and operation layer. A functional platform of PSS for SocialM is created to manage and control the realization of the implementing architecture.

In the resource layer, massive SSRs that belong to different PSPs are socialized and virtualized. A PSP may have one or more SSRs, and each SSR can complete a specific service without assistance from others. However, the SSRs are chaotic and disordered in the resource layer, and unable to provide integral product-services

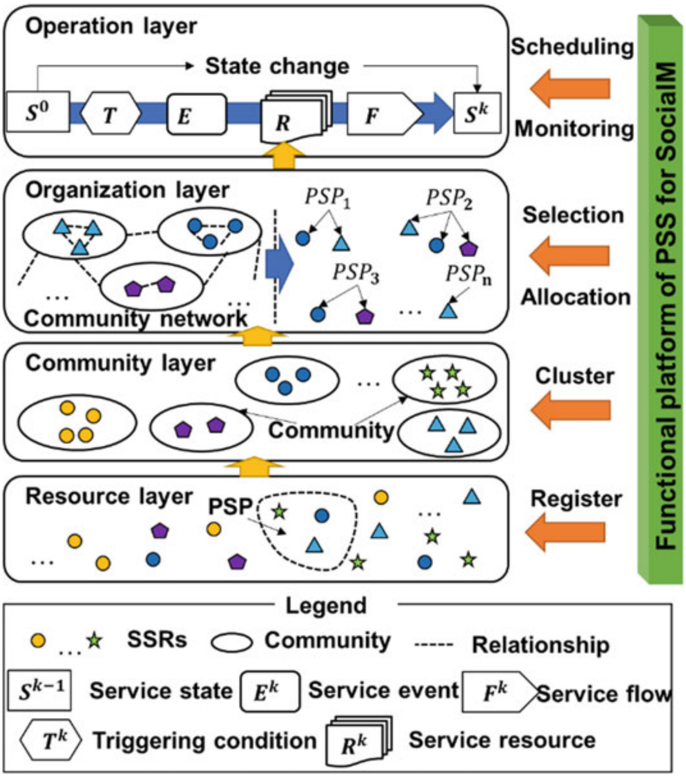

Fig. 8.1 The implementing architecture of PSS for SocialM

for customers. In order to increase the service capability, the SSRs are clustered into different SCs according to their service capabilities in the community layer. However, the results of clustering demonstrate that the prototype of SC is in unstable situations. The SSRs need to change their strategies to form an ordered and stable community structure through self-organization mechanism. Generally speaking, an SC may have the service capabilities for a specific product-service and several SCs may work together to provide integrated PSS. Hence, dynamic SCs may be combined further into an SC network in the organization layer according to the service order and detailed customer requirements. Here, the SSRs are identified by the capabilities of service resources, but the service strategies of SSRs are determined by PSPs. Therefore, the SSRs should be correlated with the PSPs. Different service strategies may affect the service costs and quality of service (QoS), and then affect the service order allocation to the SSRs. The service processes can just be described as that customers acquire services from service providers with service resources through service flows or service channel, and need to consequently change their states through event-based operations in the operation layer, as shown in Fig. 8.2 [20]. As the output of PSS for SocialM in Fig. 8.1, service flows change the states of the customer in the

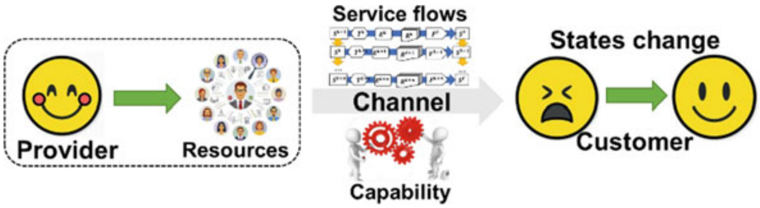

Fig. 8.2 The purpose and definition of a service

operation layer. When the customer is in a state of S^{k-1}, the triggering condition T^k is activated. According to the content of service event E^k, the functional platform organizes the selected communities with service resources R^k to provide service flow F^k to change the customer state to S^k. This four-layer architecture illustrates the service processes from SSRs organization to product-service output.

As the basic for PSS for SocialM, the functional platform of PSS for SocialM can be seen as a web-based platform integrated with various intelligence algorithms to realize the functions of each layer, such as deep learning for resources clustering, genetic algorithm for resources selection, game theory for service order allocation, Petri net for service flows design, etc. The platform is also integrated with instant messaging tools for customer participation and communication among all the PSPs. And it is also integrated with resource management tools to enable SSRs and structured tools for service process visualization.

The implementing architecture constructs an ecological environment for PSPs to mainly increase their service resources and service capabilities to provide the customer with satisfaction of product-services. The other things will also be handled appropriately by the functional platform.

8.2.4 Operational Logic of PSS for Social Manufacturing

Based on the implementing architecture of PSS for SocialM, its operational logic can be organized, as shown in the Fig. 8.3. The operational logic of PSS for SocialM can be explained by means of declaring four issues, that is, modeling of service capability, modeling of service flow, service monitoring and scheduling, and service quality evaluation. The four issues cover the whole operational processes of PSS for SocialM, including service contract establishing (service capacity and capability), product-service providing (service flow), service process controlling (monitoring and scheduling) and service resulting (service evaluation). The detailed steps of these four issues are described as follows.

As to the first issue concerning PSS for SocialM, distributed PSPs release their SSRs for clustering into different SCs according to the similarity of service capabilities. Therefore, the service capability modeling method needs to be proposed so as to describe and analyze the service capabilities of each SSR. Based on the similarity

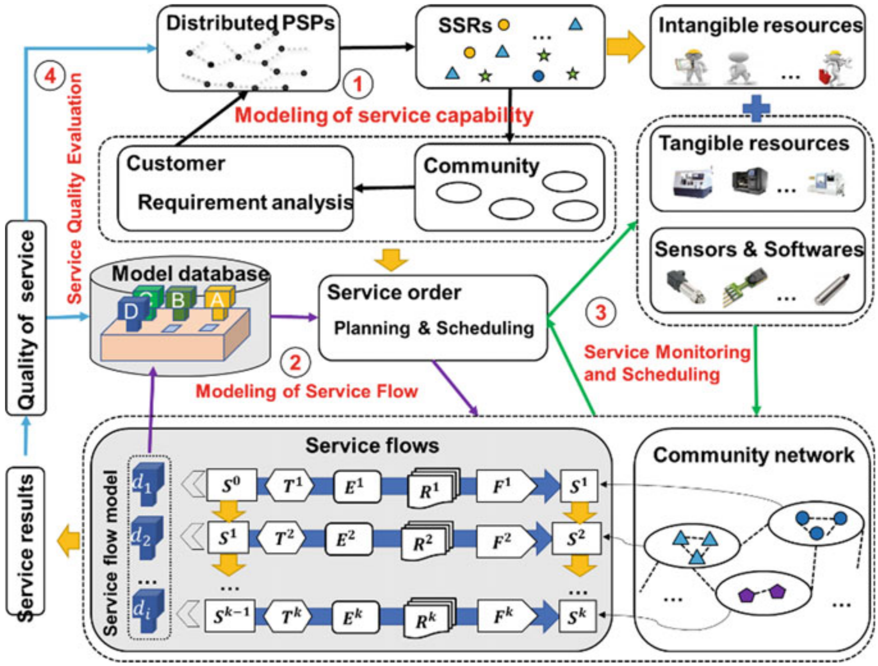

Fig. 8.3 Operational logic of PSS for SocialM

analysis results, SSRs with similar capabilities will be clustered into the same SCs. In order to provide lean services, SCs match with the analysis results of customer requirements and suitable SCs are selected. These matching results are fed back to correspondent PSPs who are representatives of SSRs, based on which PSPs would optimize their service resources and service strategies to fit with the changing market.

According to the matching results, for the second issue concerning PSS for SocialM, service orders and contracts are created between customers and PSPs. SSRs inside an SC or among SCs either collaborate or compete with other each to complete services specified by the above service orders. And service orders allocation must be tackled among SSRs. Generally speaking, a complex service package may be divided into several independent services and each service may be satisfied by an SC. The service flow modeling includes service triggering condition T^k, service event E^k, service resources R^k and the service flows F^k, all of which are the core contents of every service package or its services. The designed service flow may be stored in a model database for reuse when a new service is similar with the stored model. The model database will be updated if a new service flow is designed and is better than the old one in the database.

In order to provide lean services, for the third issue concerning PSS for SocialM, the service processes of PSS for SocialM must have a feedback mechanism to realize closed-loop control. In the context of PSS for SocialM, the services are product-services or product-based services. Therefore, the embedded sensors and corresponding software for products need to be developed to monitor the states of SC network and service flows. Service monitoring mainly includes two aspects. The first is to monitor service flows and schedule service resources according to the service orders. The second is to monitor service states when customers are in specific states, and events would be triggered with the condition to start service flows and change the customers' state to the next step.

As to the fourth issue concerning PSS for SocialM, it should be pointed out that the outputs of PSS for SocialM are product-services and their evaluation criterions are different from products. For products, we usually focus on production costs and product function implementations and neglect benefits from product operations. Since the outputs of product-services are service results of satisfying customer requirements, evaluation criterions need to include not only service costs and service functions, but also service time, service efficiency, service value creation, etc. which can be summarized as QoS. Evaluation results would be fed back to PSPs for assisting them to optimize resources allocation and service strategies. Moreover, the results are used to update the model database if the QoS of the new service flow is better than the stored model.

According to the above four issue, the operational logic of PSS for SocialM becomes clear and its corresponding key enabled technologies will be proposed in the next section.

8.3 Key Enabled Technologies

8.3.1 Modeling of Service Capability and Costs Attached to Products

Service capacity and capability description and modeling of an SSR are the primary work of PSS for SocialM. An SSR includes intangible labor resources and tangible product resources, and can be described from four aspects, that is, service functions, service performances, service structure and service activities. The definitions of the four aspects are declared as follows. Examples of logistics services are provided for better understanding.

Service functions are determined by the basic service properties of an SMR, including service types, service attributes and service contents to be able to provide to customers, physical products and their functions to be used for services, etc. For example, service function of the logistics services includes transporting service types, transport carrier, transportation route, etc.

Service performances describe service quality, service efficiency, service reliability and response time based on service functions, these indexes can be sum up as QoS. For instance, transporting time and on-time rate are the key indicators of logistics services. Service performances directly determine whether an SSR can complete the service order or not.

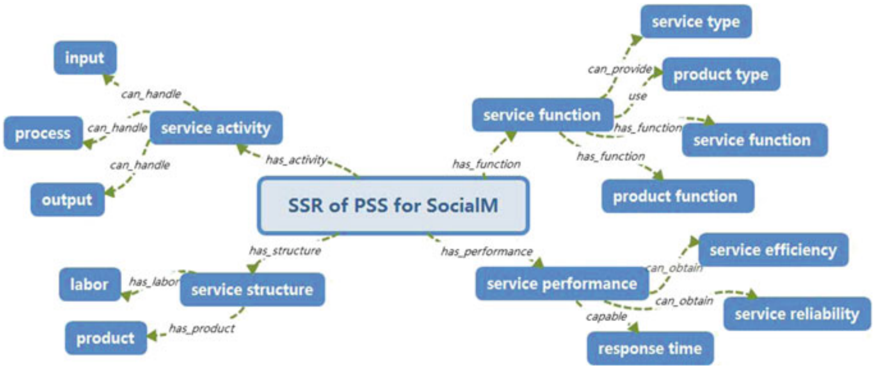

Fig. 8.4 The ontology structure for SSR (top-level)

Service structure denotes the organizational form of an SSR, including the type and quantity of labor, product devoting for services, etc. Service structure represents service strategies of a PSP who devotes more labors and physical products to an SSR or not. It is because that benefiting service performances would increase service costs and vice versa. For example, the number of truck drivers and trucks put into a transportation route are related to the service structure which is decided by the PSP.

Service activities represent a series of nodes in a service flow. Each service activity is correspondent with a node in the service flow and contains three elements, that is, "*service input*", "*service process*" and "*service output*". The detailed service flow will be designed and optimized according to the specific customer requirements. For logistics services, service activities deal with constructing a transportation route from city A to city B, loading and unloading service processes, etc.

Service functions depend on the capacity and capabilities of an SSR. With the help of service structure and service activities, a PSP is able to provide different service capabilities with specific service performances to customers. There exist many models and methods to describe an SSR from the above four aspects. In order to decrease ambiguity and make a more effective explanation of an SSR, ontology method is often used to understand the terms within the service domain and define formal specification [21]. Actually, ontology is commonly defined as an explicit formal specification of describing terms, relations among the terms, rules to generate terms and their relations in a specific domain [22]. The ontology structure for SSR is shown in Fig. 8.4 (top-level abstract classes of an SSR) and the detailed description can be expressed in the form of structural knowledge using Ontology Web Language (OWL) [23].

Whether a PSP can get service orders or not is partly decided based on its service capacity, capabilities and the service costs related to its SSRs. Profits and costs are important concerns for both the PSPs and customers, they all want to reduce costs and improve profits simultaneously. There are various methods for service cost evaluation, such as performance-based contracting [24], pay-for-performance [25],

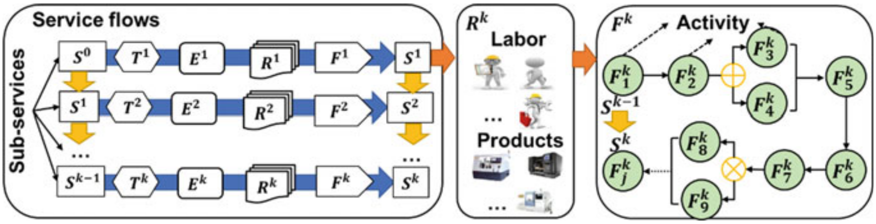

Fig. 8.5 Activity-based costing method for PSS for SocialM

Table 8.1 The parameters of service costs

Parameters	Remarks
$C^n_{k-1,k}$	The costs of PSP n for changing customer from $k-1$ to k
$C_{k-1,k}$	The costs of the sub-service changing customer from $k-1$ to k
C	The total costs of the service
λ^n_i	Service order allocated to SSR i of PSP n
i_n	The number of SSRs in the PSP n
k_j	The number of activities in the sub-service
α	The probability of selecting this SSR in select relation
$C^n_{i,j}$	The costs of SSR i of PSP n for activity j
N	The number of PSPs for the sub-service
K	The number of sub-services in the PSS for SocialM

pay per service unit [26], activity-based costing [27], etc. Considering the PSS for SocialM, a service order which often consists of a service package is completed by various SCs and SSRs, the evaluation of service costs will depend on costing different sub-service flows related to a service task inside the above package. As shown in Fig. 8.5, we propose a refined activity-based costing (ABC) method for the costs estimating of PSS for SocialM.

A service task in PSS for SocialM is usually divided into several sub-services and may be completed by an SC with various SSRs. A service flow includes different kinds of relations, including sequential relation (represented by '→'), concurrent relation (represented by '⊗') and selective relation (represented by '⊕'). The service costs of PSS for SocialM can be calculated as follows. The parameters in the calculation formulas are listed in Table 8.1.

$$C^n_{k-1,k} = \sum_{i=1}^{i_n} \lambda^n_i \cdot \sum_{j=1}^{k_j} \alpha \cdot C^n_{i,j} \tag{8.1}$$

$$C_{k-1,k} = \sum_{n=1}^{N} C^n_{k-1,k} \tag{8.2}$$

$$C = \sum_{k=1}^{K} C_{k-1,k} \tag{8.3}$$

The three formulas illustrate the costs of PSPs, sub-services, and services of PSS for SocialM respectively. The service costs are one of the significant evaluation indicators of QoS.

8.3.2 Modeling of Order-Driven Service Flow

Product-services are intangible and cannot be stored like physical products. Hence, the make-to-stock strategy for physical products cannot be applied to services. Only the make-to-order or order-driven strategy can be applied. To satisfy customer requirements, service flows design must be treated carefully. From macroscopic design to microscopic design, Shimomura developed a service modeling method consisting of four models, that is, "*flow model*", "*scope model*", "*scenario model*", and "*view model*" [28]. It emphasizes that service flow design should include service participators, state changes, outline and detailed service flows. In the context of PSS for SocialM, a complex service can be divided into several simpler sub-services which have the elements of service state ($\boldsymbol{S^k}$), triggering condition ($\boldsymbol{T^k}$), event ($\boldsymbol{E^k}$), service resource ($\boldsymbol{R^k}$) and service flow ($\boldsymbol{F^k}$), as shown in the left side of Fig. 8.5.

Petri nets are widely studied and successfully applied in workflow designing, process modeling and flow modeling for discrete-event dynamic systems [29]. In this section, we use the Petri net to build a service flow model because it has a well-defined mathematical foundation and a clear graphical feature [30]. A typical Petri net can be defined as a directed graph with three structural components, "*Places*", "*Transitions*", and "*Arcs*". "*Places*" represents states or conditions of the system, "*Transitions*" describes events that may modify system states, and the relationships between places and transitions are connected by "*Arcs*". "*Places*" can contain "*Tokens*" with which the number and position may be described during the Petri net execution. A Petri net is a 3-tuple $N = \langle P, T, F \rangle$, where:

$P = \{p_i : i = 1, \ldots, |P|\}$ is a finite set of "*Places*",
$T = \{t_i : j = 1, \ldots, |T|\}$ is a finite set of "*Transitions*", $P \cap T = \emptyset$,
$F \subset (P \times T) \cup (T \times P)$ is the set of directed "*Arcs*" representing flow relations, connecting "*Places*" and "*Transitions*" together.

When applying Petri net to service or sub-service flow design, the three tuples would have specific physical meanings, as shown in Table 8.2. Right side of Fig. 8.5 shows the sequence relation, concurrent relation, selective relation of service and sub-service flow. In fact, a Petri net can be used to explain the logic for ordering and selecting different relations, as shown in Fig. 8.6. Obviously, the Petri net is able to satisfy the requirements of service flow design and can be applied to design the required services and their sub-services. Services of PSS for SocialM emphasize

Table 8.2 Meanings of the three tuples in different contexts

	Typical	Service	Sub-service
Place (P)	States	States	States
Transition (T)	Activity	States change	States change
Arc (F)	Between two places	Between two sub-services	Between two service points
Token	Resources	A community	Resources set
Identification (ID)		Community ID	SSRs ID set
Type (TY)		Labor and product type for service	Labor and product type for sub-service
Quantity (Q)		Quantity of labor and product	Quantity of labor and product
Workload (W)		Orders allocate to the community	Orders allocate to each SSR

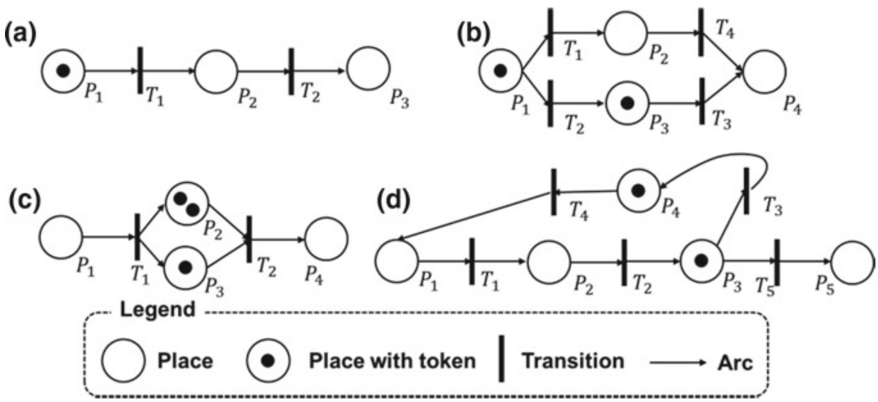

Fig. 8.6 The relationships in a Petri net. **a** Sequence relation, **b** selective relation, **c** concurrent relation, **d** selective relation

utilizing SSRs and collaboration to provide services. "*Tokens*" in typical Petri net is used to represent resources for "*Transitions*". However, "*Tokens*" only emphasizes on existence of the resources and neglects characteristics and quantity of the resources.

Based on the advantages of resource-aware Petri net [31], we proposed an SSR-aware Petri net with 7 tuples, $N = P, T, F, ID, TY, Q, W$. The extended four parameters are defined to assist and support the "*Tokens*" contents, as shown in Table 8.2. A simplified example of logistics services is illustrated in Fig. 8.7. The SSR-aware Petri net and its corresponding explanations are shown in Table 8.3.

To sum up, in this section, an RSS-aware Petri net for service flow modeling is presented. It highlights the SSRs description and service order allocation in the context of PSS for SocialM, and can express service flows clearly and accurately.

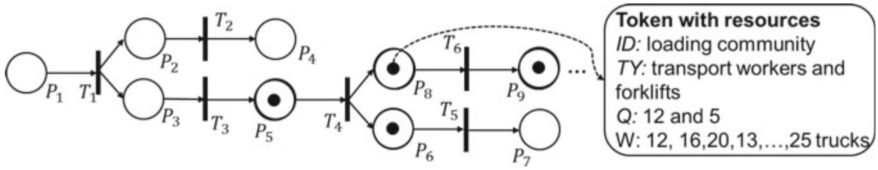

Fig. 8.7 A simplified example of logistics service with Petri net

Table 8.3 The explanation of places and transitions in logistics Petri net

Places	Remarks	Transitions	Remarks
P_1	Logistic order	T_1	Acceptance approval
P_2	Not undertake	T_2	Chargeback
P_3	Undertake	T_3	Goods consolidation
P_4	End	T_4	Goods inspection
P_5	Goods for shipment	T_5	Returned goods
P_6	Disqualified goods	T_6	Loading
P_7	End		
P_8	Qualified goods		
P_9	Loaded trucks		

8.3.3 Planning, Scheduling, and Monitoring of PSS for Social Manufacturing

Planning, Scheduling, and Monitoring are the core contents of PSS for SocialM. The operational logic of these contents is shown in Fig. 8.8. For an order-driven service mode, a service order with customer requirements and service contents is the input of the system. According to the service order that often consists of a service package and SSRs that belong to correspondent PSPs, service planning decides which SSRs should be devoted to the service package, and then selects the appropriate SCs to form the corresponding SC network. Each SC in charge of a sub-service flow of a service and the SC network will complete the entire service flow related to the service package. To monitor the service and its sub-service flow, some sensors are deployed and loaded in SSRs, such as global positioning system (GPS) modules, radio frequency identification (RFID) tags, and web-cameras. They are embedded into physical products to track routes and monitor labors' activities during service processes, and monitoring data will be fed back to a scheduling center. If one or more SSRs cannot complete their tasks with the required time or costs, the original service planning will be changed to schedule or reschedule the SSRs to be consistent with the new service planning.

For the participators of product-services, profits and costs are the most focused points. Such participants always want to reduce costs and improve profits at the same time. Therefore, service planning and scheduling should consider the economic factor

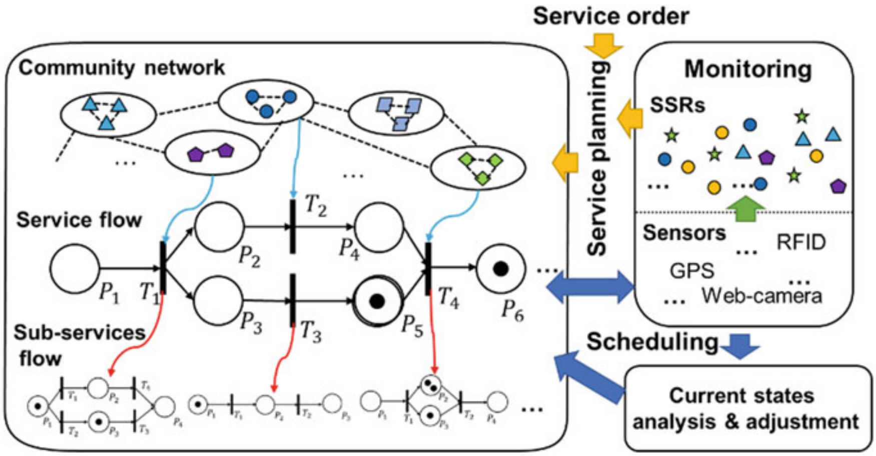

Fig. 8.8 Operational logic of service planning, scheduling, and monitoring

of services. After an SC network establishment and service flow design, the service planning and scheduling can be mapped into a service order allocation problem with criterions of costs or profits. In essence, service order allocation is an optimization problem of allocating the optimal order quantities to PSPs. Focusing on order allocation methods, scholars proposed many kinds of optimization algorithms. For example, Demirtas and Üstün proposed an integrated approach to analyze network process and multi-objective mixed integer linear programming under the consideration of the cost factor [32]. Kannan et al. introduced a set of fuzzy multi-criteria decision-making method and multi-objective programming approach for green supply chain order allocation [33]. Çebi and Otay mainly considered quantity discounts and lead time as main factors that influence order allocation problem, and solved the problem with a fuzzy multi-objective model [34]. Jain et al. introduced the chaotic bee colony algorithm for order allocation with different discounting policies [35].

In PSS for SocialM, there are two types of participators, i.e., customers and PSPs. They can change their strategies to get better payoffs independently. For customers, they can change the quantity of orders allocating to a PSP. And for PSPs, they can change the quantity of labors and physical products devoted to the services in response. If a customer changes the strategy first, correlated PSPs will also change their strategies according to the customer's move and then the customer will response to the PSPs' strategies. The iterations will continue until reaching an equilibrant state.

In order to solve the problem related to the service order allocation, we use a Stackelberg non-cooperative game model in which the leader moves first and then the follower moves sequentially [36]. In this game model, a customer is mapped as the leader and PSPs are mapped as the followers in Fig. 8.9. Based on the concept of Stackelberg game model and PSS for SocialM philosophy, the customer and the correspondent PSPs have the payoffs on costs represented by *LC* and *FC* respectively.

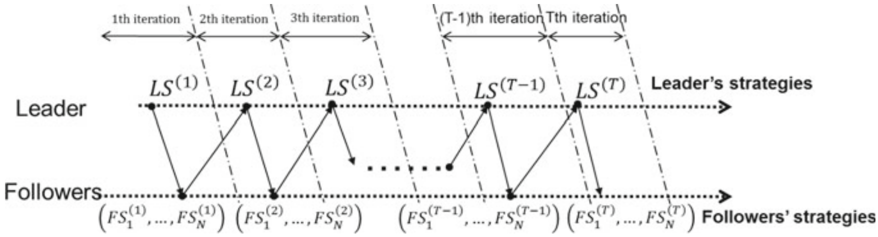

Fig. 8.9 Iterations between leader and followers of Stackelberg game

The payoffs strategies are represented by *LS* for the customer and $FS_1, FS_2, \ldots, FS_n$ for the PSPs, and the gaming goal is to minimize the costs of PSPs and customer.

In order to find the equilibrium of the game (the best *LS* and *FS* for *LC* and *FC*), a modified hierarchical Bird Swarm Algorithm (HBSA) was proposed based on the Bird Swarm Algorithm (BSA) [37]. It mimics the foraging behavior, vigilance behavior and flight behavior of birds. As to foraging behavior, each bird searches for food according to its previous experience and the swarms' experience. This operator aims at searching for feasible solutions and finding dominant solutions. As to vigilance behavior, birds try to move to the center of the swarm for foraging and would inevitably compete with each other according to foraging behavior. To avoid this phenomenon, some birds would not directly move towards the center of the swarm and keep vigilance to avoid trapping in local optimum. As to flight behavior, birds may fly to another site on a frequency *FQ*. When arrived at a new site, some birds acting as producers would search for food patches, while others acting as scroungers would follow the producers.

The BSA can be applied to solve single level problems, but the problem in this section has two levels, i.e., leader level and follower level. According to the core idea of BSA, an HBSA algorithm to solve multi-objective Bi-level programming is proposed. Here, the HBSA consists of two BSAs, one is for solving the leader-level problem and the other for follower-level problem. The flowchart of the HBSA is shown in Fig. 8.10 and the corresponding parameters are demonstrated in detail in Meng's research [37].

According to iteration results, customer and PSPs dynamically adjust the service strategies to minimize the service costs. In the real case, however, the evaluation indicators between customers and PSPs include not only the costs but also the indicators of QoS. Thus the Stackelberg game model will turn into a multi-objective Bi-level optimization problem, which requires further study in depth.

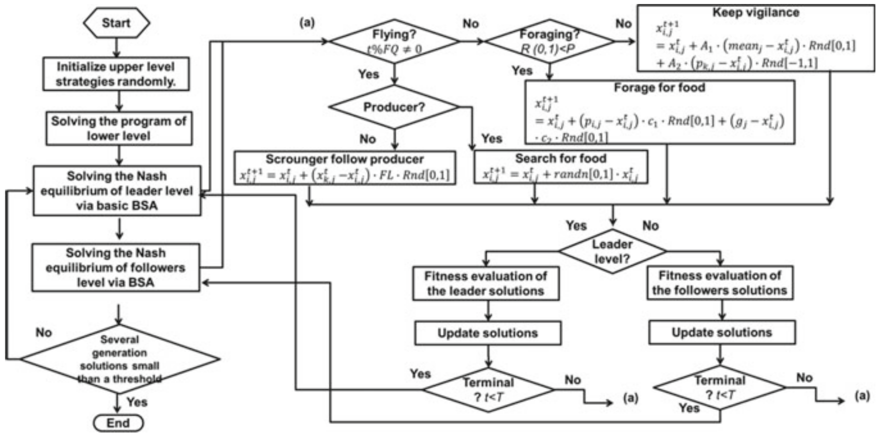

Fig. 8.10 The flowchart of HBSA

8.3.4 Service Quality Evaluation

After modeling the service capacity, service capabilities, service flow, and operation principles, an integrated PSS for SocialM is proposed. However, it is still unknown that whether the PSS for SocialM has the ability to provide high-efficient and sustainable services. It is quite necessary to evaluate its QoS from different perspectives with various criterions. Actually, QoS is the description or measurement of the overall performance of a service that originally applied to telephony computer network services. It considers service response time, packet loss, transmission delay and so on. Recently, QoS is used to evaluate common services and product-services based on its principle [38].

For a kind of product-service, the QoS evaluation can be classified into two categories. The first is to make an evaluation before service operations to predict unexpected failure and adjust unexpected service operations accordingly in advance. The second is to do an evaluation after service operations to provide a reference or guidance for future work by analyzing the service results. The common QoS evaluation processes are illustrated in Fig. 8.11. Qu et al. conducted an evaluation analysis through three aspects, that is, customer value, sustainability and trade-offs between them [39]. Yoon et al. pointed out that evaluation must be considered from two aspects including evaluation from the viewpoint of PSS providers to find the potential risk, and evaluation from the viewpoint of customers based on their satisfaction degree [40]. Key performance indicators (KPI) can be used for measuring and evaluating a service with criterions on service production, customer requirements and so on [41]. The relative weights of the criteria are determined by using fuzzy analytic hierarchy process [42].

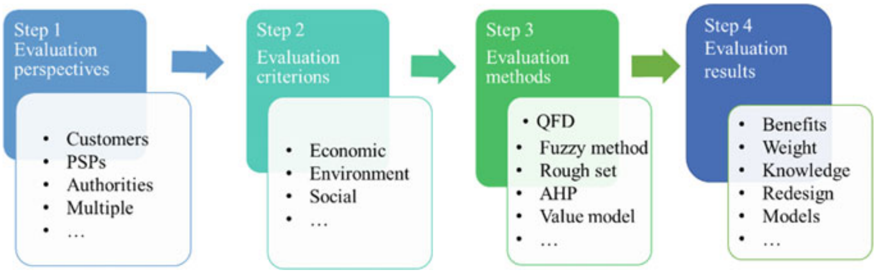

Fig. 8.11 The common processes of QoS evaluation

On the basis of synthesizing the above viewpoints, a Quality Function Deployment (QFD) based evaluation method is applied to evaluate the effects of a service concerning customers served [43, 44]. The four evaluation steps are detailed as follows.

The first step is about evaluation perspectives. QoS can be evaluated from various perspectives based on the focus of stakeholders. Customers always pay attention to value creation, service result, and effect. While PSPs care more about service sustainability, economic income, and competitive power. The authorities keep a watchful eye on social and environmental benefits which are provided by the product-services. Generally speaking, scholars choose one or two perspectives as entry points to evaluate whether a product-service can satisfy the criterions or not, and draw lessons from the evaluation results.

The second step is concerned with evaluation criterions. Different evaluation perspectives require corresponding evaluation criterions. Product-service evaluation criterions can be classified into three categories, that is, economic criterion, environment criterion, and social criterion. For economic criterion, added value, consumption and price are the most significant indicators. For environment criterion, energy consumption, hazardous materials, and emissions of pollutants, etc. are the main indicators. And for social criterion, different service scenarios have different indicators, such as health and safety, customers' culture, job creation, etc. An evaluation criterion may have multiple evaluation indicators and an evaluation indicator can be applied to multiple evaluation criterions.

The third step is about evaluation methods. Before calculating the values of evaluation indicators, the weight of each indicator should be tackled first. Since different weights of indicators have varied effects on QoS, greater weight indicator has greater impact on evaluation criterion, and vice versa. Fuzzy computation and analytic hierarchy process (AHP) methods are always applied to evaluate the weights [42]. In fact, AHP is a structured technique to organize and analyze complex decisions. To improve the precision of AHP, fuzzy computation is integrated with AHP, such as triangular fuzzy numbers and so on. Even though the evaluation criterions and indicators have been determined, different calculation formulas still need to be considered for service evaluation. There are no consensus formulas for evaluation indicators, which should be adjusted according to the characteristics of the service.

The fourth step is concerned with evaluation results. QoS evaluation can be classified into two categories, i.e., evaluation before service operations and evaluation after service operations. Hence, the evaluation results also have corresponding attributes for different kinds of product-services. Due to lack of related knowledge about product-services, PSPs may suffer from unexpected failure during the services. Therefore, necessary service evaluation before service operations should be used to assist the PSPs to optimize and adjust their service strategies. When a service is completed, the service results should be saved into knowledge base as references for future service design and operations. Some product-service models can be abstracted from the knowledge base. In this way, new product-services can be redesigned rapidly by changing the parameters of the models.

The evaluation of QoS plays a role in instructing product-service design and operations. With the above four steps, a product-service may have various evaluation results from different perspectives. It should be pointed out that different evaluation formulas should be applied to different types of product-services according to their natures.

8.4 Examples

In this section, two typical commercial applications are utilized to verify the effectiveness and efficiency of PSS for SocialM. One is from a logistics company where it outsources its logistics orders to individual truck drivers so as to realize wide coverage and high-efficiency logistics services. Another is from an air-conditioner manufacturing company where it outsources its transportation service, installation service and MRO service to related product-service SCs, and the company only focuses on the assembling operations which are the core work of producing air-conditions.

8.4.1 Electronic Product Trucking Services Through Individual Truck Drivers

Nowadays, logistics services have become an important content to support product manufacturing activities. However, there are still many problems to be solved. The first one is low degree of logistics resources intensiveness. When goods are sent from city A to city B in the form of "*Express*", they need to be transferred among many locations. It means that the logistics company has to set up lots of stations and hire many drivers to handle the goods. The second one is asymmetric information between senders and truck drivers. The processes of logistics are complicated and unstable due to the various natures and transportation routes. Because of the asymmetric information of every logistics process, it is difficult for logistics companies to select the optimal transportation route, transportation mode and transportation strategy so

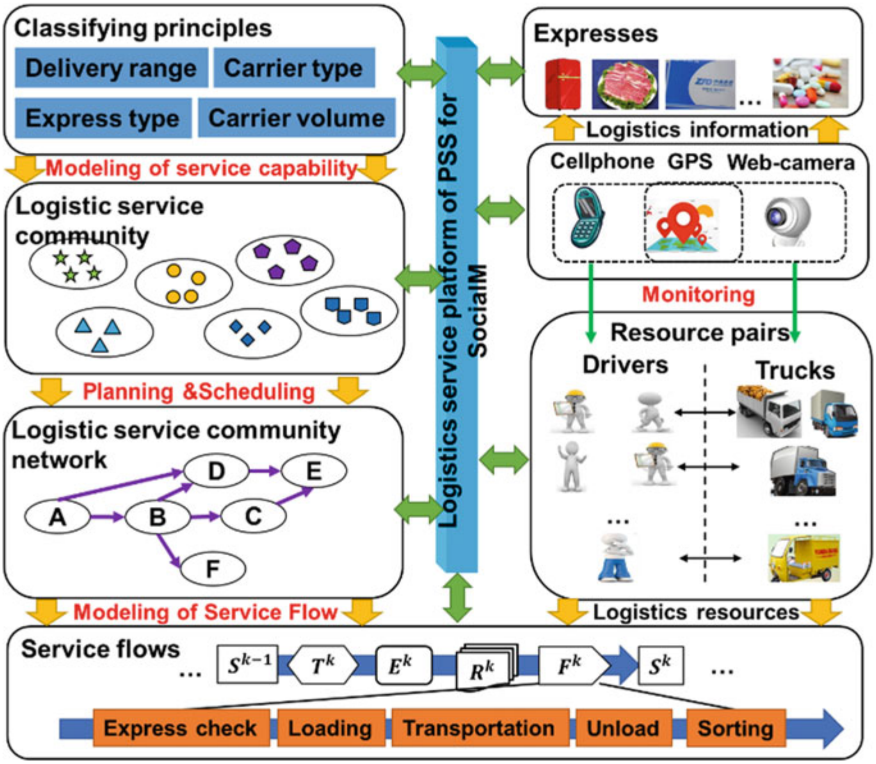

Fig. 8.12 The operational logic of the logistics service platform

as to increase the logistics costs and waste their transportation capacity. The third one is lack of professional logistics. The types of goods are different, including fragile goods, frozen goods, large-scale goods, etc. Different goods should be transported in specialized transportation methods which require specialized transport vehicles.

To solve aforementioned problems, the logistics company, called as RRS, established a logistics service platform based on the theory of PSS for SocialM. The operational logic of the logistics service platform is shown in Fig. 8.12.

The platform is based on the instant interactive information network to attract individual truck drivers, and then truck drivers are classified into SCs for various logistics services. The classifying principles include delivery range, carrier type, "*Express*" type and carrier capacity, as shown in Fig. 8.13. Based on the classification principles, logistics resources can be classified into different logistics SCs. The platform selects and organizes suitable SCs to form the logistics SC network through matching the resources' capabilities with customer requirements. In the procedure of network forming, the platform applies artificial intelligence algorithms to do service planning and scheduling so as to maximize transportation capacity and minimize the logistics costs and logistics time. During the transportation process, cellphone, GPS,

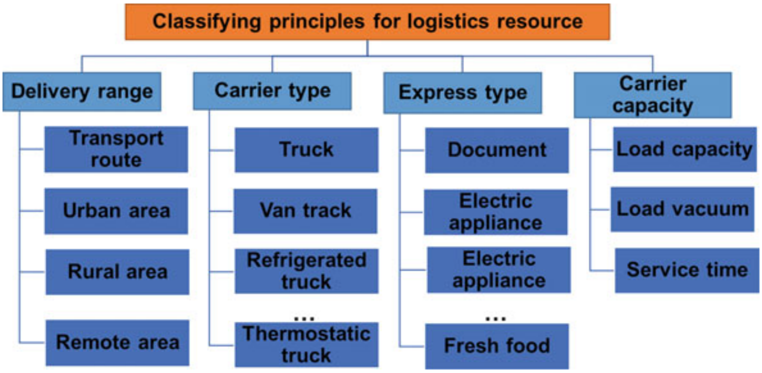

Fig. 8.13 Classifying principles for logistics resource

and web-camera are equipped to ensure the real-time monitoring of the conditions of trucks and goods, and send instant messages to the truck drivers about the weather and road conditions. On the other hand, customers can use the APP or website to obtain the goods information about their locations and expected arrival time.

Besides logistics services, RRS has proposed the installation services especial for household appliances. The company has been training the truck drivers on how to install the common household appliances, this indirectly increases the incomes of truck drivers and satisfy the needs of customers at the same time.

In general, this logistics company takes advantage of PSS for SocialM to form a logistics service platform which integrates individual truck drivers into SCs based on customer requirements. Some advantages can be drawn. The first advantage is to utilize logistics resources with high efficiency. With optimal logistics routes, truck loading and order allocation, the platform builds a bridge between goods and trucks to maximize the logistic capacity of the company. The second advantage is to share information. The platform provides instant communication tools, so truck drivers can share logistics information with each other and eliminate asymmetric information. The third advantage is to provide professional logistics services and add-value services. For some special goods, such as fresh food, medicines and electronic products, professional truck drivers and carriers are required. The platform classifies logistics resources into different SCs to provide specific professional logistics services for certain goods. Installation services and some others add-value services are proposed for better service experiences.

8.4.2 *Air-Condition Service System for Social Manufacturing*

Air conditioner is a common electric appliance in our daily life and we usually buy it from the market. Currently, people from a lot of public places such as office spaces and dormitories want to buy “*cooling*” and “*heating*” services instead of buying air

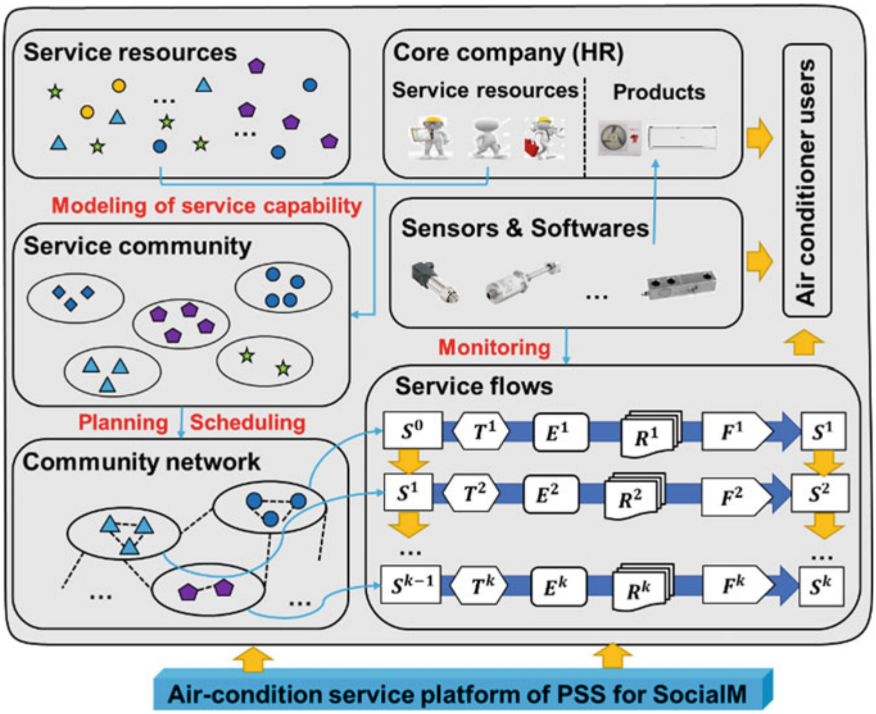

Fig. 8.14 The operational logic of the air-conditioner service platform

conditioners so as to save money. About from 2016, an air conditioner manufacturer, called as HR, started a financial leasing program in which HR rents its products to customers to provide "*cooling*" and "*heating*" services and add-value services around an air conditioner, such as installation, cleanout, MRO, etc. The customers just pay for the "*cooling*" and "*heating*" services without buying any air conditioner. To realize this result-oriented PSS, HR decomposed its resources into several service sectors. Sometimes, HR's service capacity cannot satisfy the customer requirements, the external PSPs should join in the service processes with their service resources. In this context, HR, as a core enterprise, builds an air-conditioner-service platform based on PSS for SocialM philosophy, manage and control it. The operational logic of the air-conditioner-service platform is shown in Fig. 8.14.

Since this product-service mode is core enterprise driven PSS for SocialM, the service resources of external PSPs serve as the assistant for the core company. Within the financial leasing program, HR manufactured customized air conditioners and rent them to the customers without payment concerning products. The customers just pay for the "*cooling*" and "*heating*" services of the air conditioners and the service fees can be calculated according to the followed formulas:

$$T = K_t \times C \times (K_h \times T_h + K_m \times T_m + K_l \times T_l) \tag{8.4}$$

$$P = T \times E \times \alpha \tag{8.5}$$

where T is the equivalent running time of an air conditioner, and K_t is the running time of an air conditioner. C denotes the operation mode of the air conditioner, refrigeration or heating. T_h, T_m and T_l are the running time of an air conditioner in high-grade, middle-grade and low-grade respectively. T_h, T_m and T_l represent the grade coefficients of high-grade, middle-grade and low-grade respectively. E is the unit price of the air condition service and α represents the loss coefficient of an air conditioner.

The core enterprise HR provides the most important "*cooling*" and "*heating*" services and monitors correspondent service processes, the external PSPs assistant the core company to complete add-value services around an air conditioner. The SSRs that belong to external PSPs and service resources from HR are classified into SCs according to their service types and service capacity. Then a SC network is established. It should be pointed out that the product-services around an air conditioner are heterogeneous. It means that different SCs provide different product-services. According to the continuity of the product-services, SCs can be classified into three types, that is, one-time service SC, intermittent service SC and continuity service SC.

After service planning, each SC in the SC network completes one or several services divided from the entire air-conditioner-service package. The sensors and corresponding software are embedded in air conditioners to collect operating data, monitor service processes and operate states. The operating data will be transferred to the platform and feedback the analysis results to HR. Based on the results, HR can optimize the product-service strategies to increase product-service quality and maintain continuous relationships with customers. The customers can monitor the service processes and product states with APPs installed in their cellphones, with which the customers can also participate in the service processes and send their new requirements to HR.

In 2017, for example, HR has installed almost 70,000 air conditioners to dormitories of 12 universities and provides 200,000 times "*cooling*" and "*heating*" services including repair services. In this way, HR has occupied the air-conditioner market of the university by providing "*cooling*" and "*heating*" services and has accumulated enough product-service experiences to compete with others. The air-conditioner-services create a solution that benefits everyone. On the one hand, selling air-conditioner-services bring continuous profits for HR, On the other hand, customers can pay less money to acquire the services they need.

8.5 Concluding Remarks

In this chapter, a novel service mode called PSS for SocialM is proposed to realize mass service collaboration. This mode addresses MSSEs within an SC by collaboration and competition to satisfy customers' requirements and realize product-service value adding. By means of analyzing the implementing architecture and key enabled technologies, we believe that PSS for SocialM can assist MSSEs to realize and adapt product-services. The two practical cases also confirm the feasibility and effectiveness of PSS for SocialM, even though there still are some unsatisfactory aspects. As a newly proposed method, our researches on PSS for SocialM are mainly from theoretical perspective. Hence, more practical applications should be carried out to fully develop and verify this novel business mode.

References

1. Goedkoop M, Halen V (1999) Product service systems, ecological and economic basics
2. Mont OK (2002) Clarifying the concept of product–service system. J Clean Prod 10(3):237–245
3. Tukker A, Tischner U (2006) Product-services as a research field: past, present and future—Reflections from a decade of research. J Clean Prod 14(17):1552–1556
4. Tukker A (2004) Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Bus Strategy Environ 13(4):246–260
5. Gao J, Yao Y, Zhu V, Sun L, Lin L (2011) Service-oriented manufacturing: a new product pattern and manufacturing paradigm. J Intell Manuf 22(3):435–446
6. Visintin F (2012) Providing integrated solutions in the professional printing industry: the case of Océ. Comput Ind 63(4):379–388
7. Kerley W, Wynn DC, Eckert C, Clarkson PJ (2011) Redesigning the design process through interactive simulation: a case study of life-cycle engineering in jet engine conceptual design. Int J Serv Oper Manage 10(1):30–51
8. Vezzoli C, Ceschin F, Diehl JC, Kohtala C (2015) New design challenges to widely implement 'Sustainable Product-Service Systems'. J Clean Prod 97:1–12
9. Martinez V, Bastl M, Kingston J, Evans S (2010) Challenges in transforming manufacturing organisations into product-service providers. J Manuf Technol Manage 21(4):449–469
10. Kundu S, McKay A, de Pennington A, Moss N, Chapman N (2007) Implications for engineering information systems design in the product-service paradigm. In: Advances in life cycle engineering for sustainable manufacturing businesses. Springer, London, pp 165–170
11. Jiang PY, Ding K (2012) Social manufacturing: a new way to support outsourcing production. In: Proceedings of the 2nd International Conference on Innovative Design and Manufacturing, Taipei, Taiwan, 20–23 December 2012
12. Jiang PY, Leng JW, Ding K, Gu P, Koren Y (2016) Social manufacturing as a sustainable paradigm for mass individualization. Proc Inst Mech Eng, Part B: J Eng Manuf 230(10):1961–1968
13. Lelah A, Mathieux F, Brissaud D, Vincent L (2012) Collaborative network with SMEs providing a backbone for urban PSS: a model and initial sustainability analysis. Prod Plann Control 23(4SI):299–314
14. Samaddar S, Rabinowitz G, Zhang GP (2005) An experimental analysis of solution performance in a resource sharing and scheduling problem. Eur J Oper Res 165(1):139–156
15. Tao F, Cheng Y, Zhang L, Nee AYC (2017) Advanced manufacturing systems: socialization characteristics and trends. J Intell Manuf 28(5):1079–1094
16. Ding K, Jiang PY, Leng JW, Cao W (2016) Modeling and analyzing of an enterprise relationship network in the context of social manufacturing. Proc Inst Mech Eng, Part B: J Eng Manuf 230(4):752–769
17. Meier H, Roy R, Seliger G (2010) Industrial product-service systems—IPS2. CIRP Ann Manuf Technol 59(2):607–627

18. Tukker A (2013) Product services for a resource-efficient and circular economy—a review. J Clean Prod 97:76–91
19. Resta B, Powell D, Gaiardelli P, Dotti S (2015) Towards a framework for lean operations in product-oriented product service systems. CIRP J Manufact Sci Technol 9:12–22
20. Arai TŒSY (2004) Proposal of service CAD system—A tool for service engineering. CIRP Ann Manuf Technol 53(1):397–400
21. Vasantha GVA, Roy R, Lelah A, Brissaud D (2012) A review of product-service systems design methodologies. J Eng Des 23(9):635–659
22. Gruber TR (1993) A translation approach to portable ontology specifications. Knowl Acquisition 5(2):120–199
23. Kulvatunyou B, Ivezic N, Lee Y, Shin J (2014) An analysis of OWL-based semantic mediation approaches to enhance manufacturing service capability models. Int J Comput Integr Manuf 27(9):803–823
24. Selviaridis K, Wynstra F (2015) Performance-based contracting: a literature review and future research directions. Int J Prod Res 53(12):3505–3540
25. Langbein L (2010) Economics, public service motivation, and pay for performance: complements or substitutes? Int Public Manage J 13(1):9–23
26. Williams A (2007) Product service systems in the automobile industry: contribution to system innovation? J Clean Prod 15(11):1093–1103
27. Kimita K, Hara T, Shimomura Y, Arai T (2008) Cost evaluation method for service design based on activity based costing. In: Manufacturing systems and technologies for the new frontier. Springer, London, pp 477–480
28. Sakao T, Shimomura Y, Sundin E, Comstock M (2009) Modeling design objects in CAD system for service/product engineering. Comput Aided Des 41(3):197–213
29. Dong M, Chen FF (2001) Process modeling and analysis of manufacturing supply chain networks using object-oriented Petri nets. Robot Comput-Integr Manuf 17(1–2):121–129
30. Salimifard K, Wright M (2001) Petri net-based modelling of workflow systems: An overview. Eur J Oper Res 134(3):664–676
31. Pla A, Gay P, Meléndez J, López B (2014) Petri net-based process monitoring: a workflow management system for process modelling and monitoring. J Intell Manuf 25(3):539–554
32. Demirtas EA, Üstün Ö (2008) An integrated multiobjective decision making process for supplier selection and order allocation. Omega 36(1):76–90
33. Kannan D, Khodaverdi R, Olfat L, Jafarian A, Diabat A (2013) Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain. J Clean Prod 47:355–367
34. Çebi F, Otay I (2016) A two-stage fuzzy approach for supplier evaluation and order allocation problem with quantity discounts and lead time. Inf Sci 339:143–157
35. Jain V, Kundu A, Chan FTS, Patel M (2015) A Chaotic Bee Colony approach for supplier selection-order allocation with different discounting policies in a coopetitive multi-echelon supply chain. J Intell Manuf 26(6):1131–1144
36. Mu H, Jiang P, Leng J (2017) Costing-based coordination between mt-iPSS customer and providers for job shop production using game theory. Int J Prod Res 55(2):430–446
37. Meng X, Gao XZ, Lu L, Liu Y, Zhang H (2016) A new bio-inspired optimisation algorithm: Bird Swarm Algorithm. J Exp Theor Artif Intell 28(4):673–687
38. Sun H, Wang Z, Zhang Y, Chang Z, Mo R, Liu Y (2012) Evaluation method of product-service performance. Int J Comput Integr Manuf 25(2):150–157
39. Qu M, Yu S, Chen D, Chu J, Tian B (2016) State-of-the-art of design, evaluation, and operation methodologies in product service systems. Comput Ind 77:1–14
40. Yoon B, Kim S, Rhee J (2012) An evaluation method for designing a new product-service system. Expert Syst Appl 39(3):3100–3108
41. Waltemode S, Aurich JC (2013) Productivity and quality assessment of services within technical product-service systems In: The philosopher's stone for sustainability. Springer, Berlin, pp 125–130

42. Allen Hu H, Chen SH, Hsu CW, Wang C, Wu CL (2012) Development of sustainability evaluation model for implementing product service systems. Int J Environ Sci Technol 9(2):343–354
43. Sakao T, Lindahl M (2012) A value based evaluation method for Product/Service System using design information. CIRP Ann Manuf Technol 61(1):51–54
44. Shimomura Y, Hara T, Arai T (2008) A service evaluation method using mathematical methodologies. CIRP Ann Manuf Technol 57(1):437–440