Managing the Procurement Process in Service Portals

An Automated Matching Approach with Demand-Side Management Methods

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Abstract. *Because of technological changes (e. g., Web 2.0 and the Internet of Things), service portals like MyHammer, Blauarbeit, and Amazon Home Services become increasingly important for research and practice. To increase the efficiency of service offers, new procurement methods that link service providers and service consumers are necessary. This article uses a scheduling approach that has been applied primary in the context of energy management: Demand-Side Management (DSM). Generally, DSM methods can be used to shift energy demand to favorable timeslots (e. g., lower-cost timeslots or those that help the energy supplier) to achieve goals like a flattened load profile, minimized costs, and grid reliability. In doing so, we argue that the basic concept of DSM is transferable to enable automatic matching of service offers and demands in a service portal. To explore potential benefits and drawbacks, we analyze service portals, including their functionalities and information needs, and compare them with the approaches offered by DSM. Then a mathematical model of an existing DSM approach is used to model the requirements of service portals. As a result, we conclude that DSM strategies can be useful in automating the procurement procedure in service portals, which facilitates more efficient and effective service offers and executions.*

Keywords. Service Portals • Demand Side Management • Procurement Process

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1 Introduction

The economy is influenced by innovative and disruptive technological improvements like Web 2.0 and the Internet of Things. These improvements enable consumers to participate in value chains (co-creation) and to add information that personalizes the final product. As most value creation is related to the tertiary sector, the service sector is especially affected by these changes (Böhmann et al. 2014; Leimeister 2012). For many services, common business models and customer-supplier interactions like (professional) service portals (SPs) have emerged, resulting in Web 2.0. One of the most frequently mentioned portals is the German *MyHammer*, which has spin-offs in countries like Switzerland and the UK (MyHammer AG 2012). Starting as a (reverse) auction model, where service providers can underbid for a job, *MyHammer* has developed into a non-auction-model (MyHammer AG 2012) that mediates between service providers and jobs offered. Other SPs, such as *MyBuilder* and *Amazon Home Services*, provide matching without an auction, so users' influence on the selection is higher, but the user must perform additional actions to choose manually among the offers. These non-auction models match more efficiently than auction models do, have fully booked "order books" of the service providers, and create higher pricing pressure, as services and service providers can be compared more easily in terms of price and quality. Standardization of services is also becoming of interest

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Note: This work is based on Behrens et al. (2016a).

(Ding and Keh 2016; Kasiri and Mansori 2016) as the need for quality and comparability increases (DIN 2016). This need also affects SPs that, for example, offer services with a fixed price (PC Spezialist 2016) and have standardized quality requirements like a craftsman diploma to participate as a service provider (e. g., Amazon 2016; Blauarbeit 2016; MyHammer AG 2016). Nevertheless, because multiple stakeholders are involved and constraints like time and quality must be considered, matching with or without an auction is a challenging task.

The complex synchronization between offers (service suppliers and craftsmen) and demands (jobs that need to be done) is usually decentralized and solved manually, even in SPs. Therefore, external factors like capacity and the distance between the supplier and the location of service delivery have a significant impact on the problem's complexity. New technological developments enable enhancements like the Internet of Things and smart services, but they also have limitations in terms of such issues as data security and privacy concern (Acatech 2013, 2014). Besides providing opportunities for production, these developments also have implications for the services themselves, as they are automatically managed and delivered; service research, as new services are developed and how services are managed and delivered changes; and the procurement of services in SPs, as SPs offer a new way of managing and delivering services. To realize these potentials in the SP field, data (often called smart data in this context) must be managed. Smart data is an essential part of creating and managing services as service bundles (Acatech 2014). Service bundles can contribute particularly well to SPs, as jobs can be performed cooperatively. In this field, common practices are based on methods for managing big data. Practices and methods from other fields that are not directly associated with the service research discipline can be applied as well.

A sector that benefits from digitization and the flexibility that comes with new communication protocols is the energy sector. The challenge of managing energy loads to avoid peaks, ensure grid reliability, and minimize costs can be met by applying Demand-Side Management (DSM), which is based on the use of smart meters[1] . One goal of DSM is to shift flexible energy loads to optimize network use. The characteristics in the DSM field correspond in some ways to those in the field of SPs, so we argue that DSM can be transferred to contribute to managing the procurement process in SPs. Accordingly, *the goal of this study is to determine whether DSM methods can be adopted to achieve the automatic procurement and management of service offers and service demands in SPs*.

In pursuing this goal, we first describe preliminary studies that have been concerned with SPs and services offered (Sect. 2). Following a description of our research approach in Sect. 3, we identify, select, and analyze additional SPs by conducting a literature review in Sect. 4. Then we compare the procurement mechanisms in SPs with those in DSM. To demonstrate the applicability of DSM to SPs, we derive in Sect. 5 a first iteration of a problem definition in the form of a mathematical model that is based on a common DSM approach. Finally, a research agenda is provided in Sect. 6, and the findings and limitations are discussed in Sect. 7.

2 Research Background

2.1 Services and Service Portals

SPs offer various kinds of services, so it is important to define services as they relate to SPs and the underlying assumptions of this article. For some authors, SPs are synonymous with service-level agreements (SLAs) or WebServices, and others look at internet service providers (ISPs), where the focus is on quality assurance achieved by implementing SLAs (Spillner and Hoyer 2009). Another field concerns WebServices, which includes cloud services, in which portals and marketplaces also exist (Barros et al. 2005). WebServices and cloud services differ fundamentally from business services, as the former are usually offered without

[1] More information on smart meters can be found in Molina-Markham et al. (2010) and Rajagopalan et al. (2011).

human interaction and are fully automated (e. g., Dropbox and Google Docs).

Business Services are in researchers' focus. These types of services are services in a classical sense, such as services provided by a craftsperson that are often integrated into a business process. Business webs and SPs support the coordination of these services by combining services to create new services or service bundles (Janiesch et al. 2014). Therefore, the coordination and communication between the service providers involved is important to the success of business webs and SPs.

SPs focus on the supplier-consumer relationship and the mechanism of procuring services. Many SPs can be found in the field of governance (e. g., Brandenburg 2016; Bund 2016; Mecklenburg 2016). The customers of these portals (i. e., citizens) get a service overview and can access online support. The present study focuses on SPs like *MyHammer*, where suppliers and customers are matched in a way that benefits both.

Powered by the expansion of the internet to Web 2.0, increasing amounts of scientific research has dealt with SPs, investigating, for example, the procurement mechanisms of such portals. Some researchers have addressed the "affiliate marketing" that engages in direct selling on the internet (Borchardt 2010). Others have examined the significance for the service providers; for example, Dürig et al. (2012) examined in which regions the SP MyHammer is used and how often and which activities are booked. Zoch (2011) addressed general market potential and actions to achieve it.

Most research in the field does not address the automated procurement mechanism but issues like judicial and ethical conditions (e. g., Kazemi 2014), the pricing policy in the SP (e. g., Hinz and Creusen 2011), or problems of trust between suppliers and customers (e. g., Lysik et al. 2015). The procurement process itself is considered only in specialized research like that on reverse auctions (Kollmann and Häsel 2007) or the principal-agent relationship (Müller 2007), which uses a field study of *MyHammer*. *Nevertheless, to the best of our knowledge, no research has paid attention to the procurement process that is used in SPs or has analyzed its automation.*

2.2 Demand-Side Management

2.2.1 Objectives

DSM can have several goals, including reducing peak loads in the energy grid, reducing energy costs, and flattening the load profile[2]. These goals can be achieved by shifting loads from times of high demand to times when demands are lower, a process that is often called demand response. This concept becomes important because of the rising number of decentralized power generators that depend on external factors like wind speed or solar radiation. The idea of DSM was first formulated by Gellings and Chamberlin (1987). Because of recent ecological rethinking and new technological developments (e. g., smart meters, energy management systems), DSM methods are again the topic of current research.

2.2.2 Loads and Classifications

Because loads and their characteristics vary, not all loads can be shifted in the same way (Behrens et al. 2017). Generally, loads can be distinguished into two classes: shiftable and non-shiftable (e. g. Behrens et al. 2014). Non-shiftable loads cannot be shifted at all and must be served at the time of demand. Examples are lighting, cookers, and televisions. Shiftable loads, which are also called deferable loads, are much more flexible and can be shifted based on when they occur and the load profile itself. Examples are washing machines, dryers, and electric vehicles. We distinguish between loads with a fixed load profile, such as washing machines (whose load profile cannot be changed by using another operational mode or pausing the operation) and loads with a flexible load profile, such as electric-vehicle charging, where the charging capacity can be regulated within certain boundaries (e. g., changing to a fast charging process or pausing and resuming charging).

[2] For a more detailed description of DSM, see, for example, Palensky and Dietrich (2011) or Gellings (1985).

Another restriction deals with user preferences. Not all users are able or willing to shift all possible loads to all possible times (Behrens et al. 2016b). For example, if a washing machine is shifted to operate during the night, it could disturb the homeowners' sleep. In addition, the user needs to unload the washing machine within a certain time; therefore a finishing time needs to be at a time, when the user is available. This requires a timeslot in which the washing machine can be started and has to be finished. In contrast to the washing machine, an electric vehicle can be charged during the night, so long as it has a sufficiently loaded battery when the user needs to use it.

DSM can be applied to various contexts, including residential, commercial, and industrial. Especially in the residential context, the required infrastructure is a challenging task in Germany and needs supported from, for example, legal regulations (e. g., the *Energiewirtschaftsgesetz*: § 21b Abs. 3a, § 14a and § 40 Abs. 5 EnWG) to accomplish the measurement and management of loads. In addition, providers must offer variable charges for electricity – lower when energy demand is low and higher when energy demand is high.

2.2.3 DSM Methods

Various frameworks and methods are available for implementing automated DSM. They differ in several factors and can be divided into a variety of classifications. One of these classifications concerns the optimization radius, which can consist of a single residence, a few multi-unit buildings (e. g., Bassamzadeh et al. 2014; Stüdli et al. 2015), and even the whole power grid. If more than one residence is considered, the classification can differentiate between a centrally controlled optimization that can be solved by, for example, a heuristic approach (e. g., Bashash and Fathy 2013; Constanza et al. 2014) and a decentrally controlled optimization approach with individual residences (units). If multiple living units are considered, two options are available for decision-making: individual units that have a communication channel and those that do not. If they communicate with each other (e. g., Beaude et al. 2012; Kwak et al. 2012), a new peak can be prevented.

The main advantage of centralized grid control is its ability to pursue a global optimum. On the other hand, decentralized grid control can ensure that only a minimum amount of information needs to be transferred to the central control point while still achieving an optimum (cf. Mohsenian-Rad et al. 2010).

An overview of existing and classified DSM methods can be found in Gerwig et al. (2015), which reviewed the literature to find and analyze a total of 58 DSM methods. Balijepalli et al. (2011) found and analyzed a total of 80 articles according to their content (i. e., general concepts, usage, and electricity market). Based on literature in the smart home field and its surrounding activities, Saad Al-Sumaiti et al. (2014) analyzed 77 articles and divided their algorithms into six categories: heuristics, linear and non-linear programming, neural networks, game theory, and others. Barbato and Capone (2014) conducted an overview of the characteristics of DSM methods.

3 Research Approach

We carried out an extensive literature review to identify the functionality and information that are required for automatic service procurement (vom Brocke et al. 2009; Webster and Watson 2002). Following the methodological recommendations from vom Brocke et al. (2009), our review addresses five steps: First, we define our review *scope* (Sect. 1). Then we *conceptualize* the topics of services and related services portals (Sect. 2). Next, in the *literature search*, we specify our search sources, search items, and search phrases to provide a traceable search (Sect. 4.1). Then we *analyze and synthesize the literature* to explore the procurement functionality and the requisite information. In order to ensure that DSM methods are suitable for managing service procurement in SPs, both the required functionality and the required information must be known. Hence, we distinguish

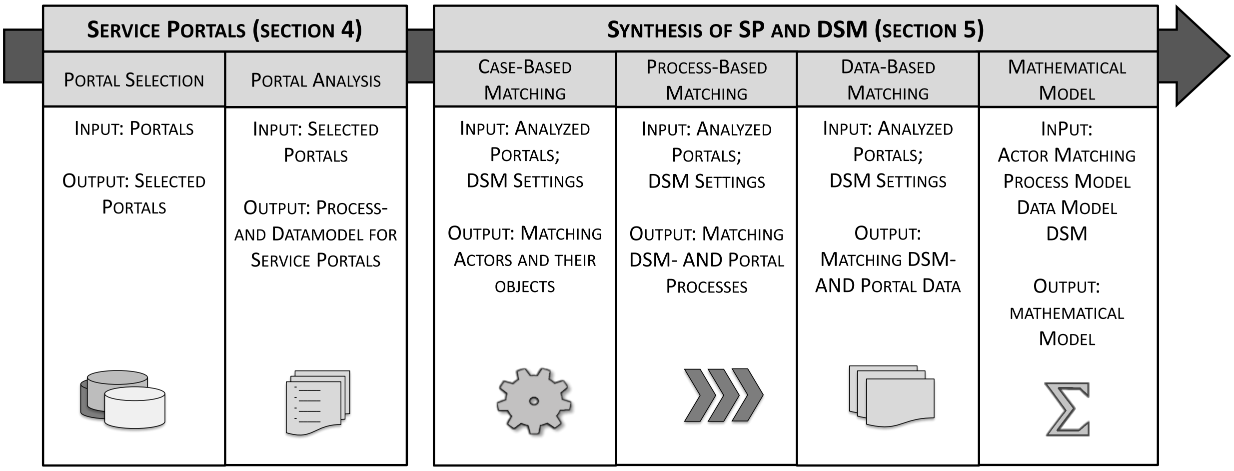

Fig. 1: Research Process

between functionality and data separately in the analysis (Fig. 1) (Sect. 4.2).

The synthesis focuses on the transferability of the procurement mechanisms and DSM methods. As with the previous analysis, the exploration takes a functional and data view and is followed by a discussion of possible transferability. Therefore, we carry out a conceptual-deductive analysis and derive a first mathematical model for describing the procurement. This model is a first step toward deeper research in this field and illustrates the transformation of procurement mechanism from SP to DSM (Sect. 5). Finally, based on our findings and the discussion of benefits and drawbacks, we provide a *research agenda* for improving and further investigation of the automated matching of service offers and demands in SPs (Sect. 6).

4 Analysis of Service Portals

4.1 Portal Selection

Identification of search items and sources. We conducted a Google Scholar search to identify twenty-eight existing SPs during the first search phase. Three search items (English and German) were used both individually and in combination to find these existing portals: “Dienstleistungsportal”, “Service Portal”, and “Service Marketplace”.

Evaluation of the results. After reviewing the results, we looked for related literature that identified the portals directly (Tab. 1).

Definition of exclusion criteria. On closer examination, four exclusion criteria were determined based on the requirement that portals are considered only if they are actually in use and are in the scope of our review (Sect. 2.2):

- *Being Up-To-Date (I)*: If no new jobs were submitted for more than one year, the portal was excluded. This exclusion criterion applied to five SPs: *go4bid*, *dasmachich*, *auftragfinden*, *doozerzone*, and *rentme-online*.
- *Missing number of jobs (II)*: SPs that had fewer than twenty jobs per year were excluded. This exclusion criterion applied five SPs: *my-okay*, *auftrag-spoker*, *Autrago*, *dasmachich*, and *DoMyStuff*.
- *No procurement in the meaning of matching (III)*: SPs that did not broker jobs to suppliers or vice versa were excluded. This exclusion criterion applied to *jobdoo*, *meine-it*, *Homeworker24*, *Facebook Service*, and information sites like *microjobs*, *My-Simon*, *Bomgar*, and *Servicescape*.
- *Occupation (IV)*: SP can also refer an overview of service providers, rather than a portal that provides a procurement of jobs and offers. This exclusion criterion applied to *Gelegenheitsjobs*.

Tab. 1: Overview of Service Portals

Overview of Service Portals		
No.	Portal name	Reference
01	*MyHammer*	www.my-hammer.de/
02	*BlauArbeit*	www.blauarbeit.de
03	*Undertool*	www.undertool.de/
04	*MachDuDas*	www.machdudas.de/
05	*work5*	www.work5.de/
06	*Autrago*	www.auftrago.de/
07	*Jobdoo*	www.jobdoo.de/
08	*my-okay*	www.my-okay.de/
09	*microjobs*	www.microjobs-online.de/
10	*doozerzone*	www.doozerzone.de
11	*go4bid*	www.go4bid.de/
12	*auftragspoker*	www.auftragspoker.de/
13	*dasmachich*	www.dasmachich.de/
14	*auftragfinden*	www.auftragfinden.tumblr.com/
15	*rentme-online*	www.rentme-online.de
16	*meine-it*	www.meine-it.de/
17	*quotatispro*	www.quotatispro.de/
18	*BesteArbeit*	www.bestearbeit.de/
19	*ProReferral*	www.proreferral.com/
20	*MyBuilder*	www.mybuilder.com/
21	*DoMyStuff*	www.domystuff.com
22	*Homeworker24*	www.homeworker24.com
23	*Bomgar*	www.bomgar.com
24	*Facebook Services*	www.facebook.com/services/
25	*MySimon*	www.mysimon.com/
26	*Texterjobboerse*	www.texterjobboerse.de/
27	*Gelegenheitsjobs*	www.gelegenheitsjobs.de/
28	*Amazon Home Services*	www.amazon.com/ Amazon-Home-Services
29	*Servicescape*	www.servicescape.com/

4.2 Classification

4.2.1 Overview

In order to classify the selected SPs (Tab. 2), we analyze them in terms of six general and statistical criteria (Tab. 3).

- *Number of users*: As the number of (possible) service consumers is more difficult to obtain than the number of service supplies and has a weaker impact on the SP, only the number of registered service suppliers was evaluated.
- *Quantity and type of fields*: As the portal can address single fields or several fields, the SPs are divided into "general SPs" and "specialized SPs".
- *Number of jobs*: Average number of new jobs per day.
- *Popularity*: Popularity is difficult to measure, so we approximated it with the help of homepage look ups per day and month and the visitor count per day. Collected by *Wolfram|Alpha4* (WA) and *SimilarWeb5* (SW), this data can only be estimated. As nearly all SPs have a homepage on which users can communicate, this measure seems to be a suitable approximation for popularity.
- *Auction*: Some portals use an auction or reverse auction to obtain the procurement mechanism, so SPs are divided into whether they use an auction or not.
- *Acceptance of private persons*: Most portals allow only professionals to register as service suppliers, while others also allow private persons to register. We differentiate between these two kinds of qualification criteria.

Tab. 2: Relevant Service Portals

Relevant (selected) Service Portals		
No.	Portal name	Reference
01	*MyHammer*	www.my-hammer.de/
02	*BlauArbeit*	www.blauarbeit.de
03	*Undertool*	www.undertool.de/
04	*MachDuDas*	www.machdudas.de/
05	*work5*	www.work5.de/
06	*Quotatispro*	www.quotatispro.de/
07	*MyBuilder*	www.mybuilder.com/
08	*Texterjob-boerse*	www.texterjobboerse.de/
09	*Amazon Home Services*	www.amazon.com/ Amazon-Home-Services

Tab. 3: Classification of Service Portals

SP	Visitors [in Thousand per day] WA	Homepage Calls [in Thousand per day] WA	Homepage Calls [in Thousand in September 2016] WA	Private allowed	Auction used	Jobs [Average per day]	User Count [in Thousand]	Sectors
MyHammer	110	840	880	No	No	4,400	300	All
BlauArbeit	29	170	58	No	Yes	2,000	150	All
MachDuDas	12	59	25	Yes	No	12	N/A	All
Undertool	1.8	3.6	2.5	No	Yes	9	50	All
work5.de	1.1	1.1	3.7	Yes	Yes	2	5	All
quotatispro	N/A	N/A	0.007	No	No	270	20	All
MyBuilder	130	410	1,900	No	No	10*	5.7	All
Texterjobboerse	2.1	13	13	Yes	No	N/A	0.5	Edit.
Amazon Home Services	N/A	N/A	N/A	No	No	500**	N/A	All

(= 28,165 jobs since 2008; **= fixed jobs)*

The procurement process in SPs matches consumers (jobs) and providers (offers), so actors in this context are service consumers and service providers. SPs procure matches using various approaches, including multiple types of auctions, to match service providers and service consumers. Data requirements and the accepted service providers (professionals or also private persons) also differ (Fig. 2). Therefore, the SPs are analyzed regarding their functionality and the required data input. The use of an auction has a significant impact on the procurement process, so the group that uses an auction-based process (*BlauArbeit*, *Undertool*, *work5*) and the group that does not are analyzed separately. The data-based analysis also considers the information about the jobs that is required to achieve the procurement.

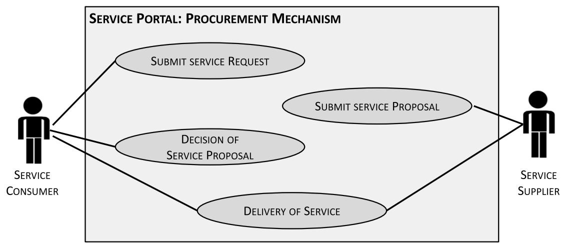

Fig. 2: Use Case Diagram of procurement mechanism

4.2.2 Process-Based Analysis

Auction-Based Portals

Three out of six portals use an auction as the procurement mechanism: *BlauArbeit*, *Undertool* and *work5*. All of these portals' processes follow the same standard process, which can be divided into five phases:

0. *User Registration*: Before using the SP the users have to register. This step can be done parallel to the job creation.
1. *Job Creation*: The service consumer submits the job to the SP, and the SP analyzes the information (Sect. 4.2.2).
2. *Auction Start*: The service consumer defines an ending time for the auction, until which service suppliers can make an offer. In some cases, a price limit can also be indicated.
3. *Auction Execution*: The auction mechanism is usually a "reverse auction", where the prices of offers decrease over time.
4. *Auction End*: The auction ends either when the customer's deadline or the customer's price limit is reached.
5. *Decision*: In general, consumers have three options: choose the supplier with the lowest offer, choose another offer based on factors other than price (e. g., reputation), or decline all offers. The availability of these options depends on the portal and its terms of use.

Non-Auction-Based Portals

In addition to portals like *MyHammer*, *MachDuDas*, and *Quotatispro*, which use auction-based processes, *BlauArbeit* and *Undertool* have a function called estimation of cost to create a mechanism with no auction. This process differs in steps 2 and 5 and removes step 3 completely. Their process, then, has four steps:

2. *Offer Receipt*: Based on the information the consumer provides, suppliers decide whether to make an offer/estimation of cost.
3. *Offer End*: This step is analogous to step 4 of the auction-based process, but only the cost estimation is provided.
4. *Decision*: The consumer either accepts one offer or declines all offers.

In Fig. 3 the two different processes are visualized.

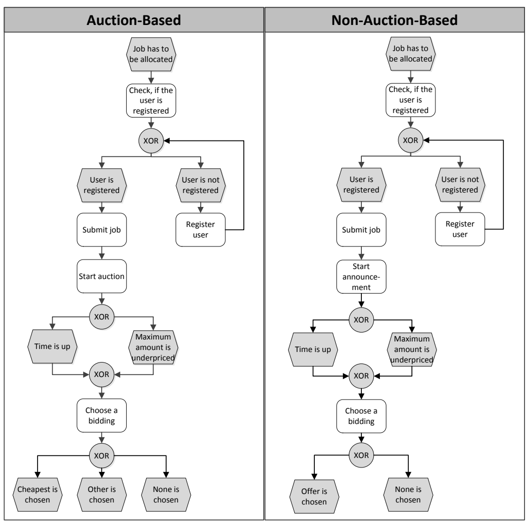

Fig. 3: Event-Driven Process Chain of procurement processes in SPs

4.2.3 Data-Based Analysis

The information that service consumers and service suppliers provide differs and must be accurate in order for the matching to be effective. The selected SPs were analyzed for the kinds of information they require and classified between "must-have" information and "optional" information (Tab. 4).

Tab. 4: Requisite information of SPs

View	Data	MyHammer	BlauArbeit	MachDuDas	Undertool	work5	quotatispro	ProReferral	MyBuilder	Texterjobboerse	Amazon Home Services
Supplier	Contact Data	X	X	X	X	X	X	X	X	X	X
	Sector	X	X	X	X	X	X	X	X	X	X
	Radius	X					X	X	X	X	
	Order Book		X				X				
	Staff	X	X				X				
	Price	X	X	X	X	X			X	X	X
	Qualification	X	X		X		X	X			X
	Rating	X	X	X	X	X		X	X		X
	Additional Index		X		X						
Consumer/Job	Contact Data	X	X	X	X	X	X	X	X	X	X
	Sector	X	X	X	X	X	X	X	X	X	X
	Title, Description	X	X	X	X	X	X	X	X	X	X
	Due Date	X	X	X	X	X	X	X			X
	Volume						X	X			X
	Place of Service Delivery	X	X	X	X	X	X				
	Payment Details			X	X	X					
	Rating			X							
	Job Authentication						X				

Supplier View

Of course, both suppliers and consumers must submit their contact information. In all of the SPs we analyzed, this requirement is met by means of formulas that correspond to names, email addresses, phone numbers, and physical addresses.

Service providers choose one or more fields in which they are active and have experience. All of the analyzed portals are portals in which a broad range of services is offered. For example, *MyHammer* has nineteen service categories, and *BlauArbeit* has thirteen. The type of service required is indicated when a consumer submits a job, enabling the procurement mechanisms to match job offers and suppliers in the same category. *MyHammer* and *quotatispro* also provide a geographic radius in which the service supplier is active, so suppliers can see the jobs offered within that radius (MyHammer AG 2016). This feature can be provided on the web based on the supplier's physical address or on a mobile device based on the supplier's actual position at that moment.

In order to accept jobs, providers must know both their total and available capacity. Meeting this requirement can be complex, as the number of staff varies, but three portals, *MyHammer*, *BlauArbeit*, and *quotatispro*, offer this capacity-planner, although the SPs do not. Nearly all portals require a first price estimation by the service provider in terms of hours, along with a price per hour of work (*MachDuDas*). Only *MachDuDas* and *work5* do not require a qualification certificate or license, but other additional qualifications can be submitted, such as a master craftsman's diploma, membership in a craft chamber, and so on.

Most portals also have a rating mechanism for consumers to rate their suppliers and share their experiences by means of, for example, a star rating from zero to five. Suppliers can also rate consumers on some portals (*MachDuDas*). Furthermore, some portals offer further rating options. For example, *BlauArbeit* has a so called *BlauArbeit*-Index, which quantifies on a scale between zero and ten the quality of a supplier. A similar index is used by *quotatispro*.

Customer View

All portals require the consumer to provide a general description of the job, which may include a title, a description, and pictures. *Quotatispro* also requires the consumer to submit information about volume, such as the size in square meters of a room that is to be painted.

MachDuDas, *Undertool*, and *work5* require payment information, such as whether payment will be made before or after the service is delivered and whether the materials needed for the job are provided or must be procured by suppliers. The consumer also states the starting time for the job, such as "as soon as possible", "by day X", "on day X", or "between X and Y". The place where the service is to be performed is also required.

An entity-relationship model provides an overview of the data required and the relationships between the entities (Fig. 4).

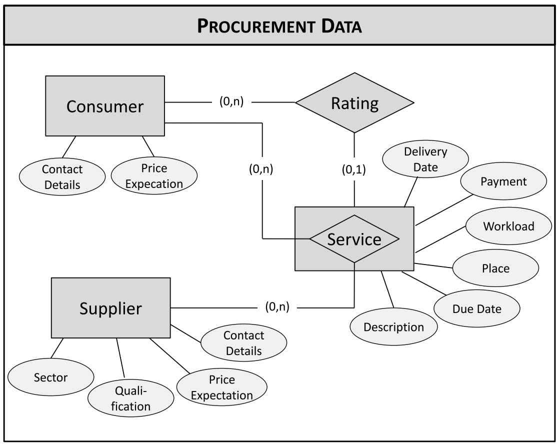

Fig. 4: Data model

5 Service Portals and Demand-Side Management

5.1 Organizational-Based Matching

This section provides an analysis of the transferability of the procurement mechanism from DSM methods to SP methods. Structure-based matching is conducted, followed by process-based and data-based matching, and analysis of the general setting, particularly relevant actors and procurement objects.

5.1.1 Actors

In the SP case, the main actors are service providers who offer their services to consumers who consume these services (Fig. 5). Transferred to the DSM context, this characteristic does not change fundamentally, but the relationship is adjusted such that the service suppliers "create" services that are acquired and consumed when they are needed. Any kind of storage is difficult or impossible to realize, so the services are "created" and consumed simultaneously. In contrast to the SP context, the DSM context allows a storage device to be used and so the energy can be consumed at a later time. Consequently, loading a battery for example is a kind of consumption as well and can be estimated as another consumer/supplier.

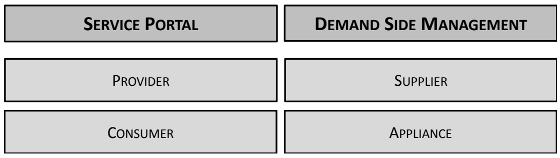

Fig. 5: Actors

The consumer submits a job to the SP. In the DSM context, a service consumer (appliance) represents an unit, such as a house or an apartment. The job in this context is a power demand/load that must be satisfied. If the load is shiftable, the time in which the demanded electricity is supplied can vary, particularly if the load has a flexible load profile (cf. Sect. 2.2). Jobs in the SP context are usually shiftable. For example, a haircut should not be interrupted and is conducted by only one person, while the painting of a room can be done by one or more persons and can be interrupted, so the "load" can be varied within the task, which is comparable to the charging process of an electric vehicle. If a job must be performed at an exact time, it must be assumed to be a non-shiftable load. These restrictions must be addressed when the SP procurement mechanism is transferred to DSM.

5.1.2 Offers

SPs focus on matching job offers to service providers, while DSM focuses on shifting loads to achieve balanced energy consumption. The goal of decentralized energy generation (e. g., PV) in covering the loads in the most efficient way means achieving a good match between loads and energy generation. Transferred to the DSM context, the goal is matching jobs to the service suppliers' capacities.

The ongoing standardization of services and the price alignment that comes along with standardization makes it likely that this approach is suitable. SPs like *BlauArbeit* and *quotatispro* promote their offerings with a filled-order book that divides jobs among service suppliers with available capacity.

Changes in the environment are important. In particular, the Internet of Things and Services and the resulting enlarged information can lead to new procurement mechanisms. While the result of the procurement will stay more or less the same from an external point of view, it will be achieved with the support of automated mechanisms.

5.2 Process-Based Matching

5.2.1 Process with Auction

The DSM approach must be adapted only slightly for use in SP. Typically, the approach consists of five steps following user registration:

0. *User Registration*: This step remains the same.
1. *Load Advertisement*: Instead of the job, the load is announced and certain information is required that is similar to a classic SP process. The preliminaries are described in Sect. 5.3.
2. *Auction Start*: Auctions are part of the decentralized algorithms in which consumers provide information about their shiftable loads. The auction is then executed by a multi-agent-system (cf. Behrens et al. 2014; Deindl et al. 2008).
3. *Auction Execution*: Both regular and reverse auctions can be accomplished with DSM methods (e. g., a multi-agent system).
4. *Auction End*: Similar to the SP context, the auction can end in several ways. As the job has to be matched to the service providers, more information is needed. Therefore, the auction can be finished when the time for the auction runs out or the upper price limit is underbid.
5. *Decision:* The consumer has three possibilities: take the best bid, accept another bid, or accept no bid.

5.2.2 Process without Auction

In addition to these modifications, more than one DSM algorithm can be used, even a heuristic. Because of the considerable amount of data, a decentralized approach with reference to the underlying system could have an advantage and should be chosen (e. g., Gerwig et al. 2015).

5.3 Data-Based Matching

5.3.1 Service Supplier

Contact details. Contact details are not required in the DSM context, but each actor still needs a gateway with which to communicate with others. In the DSM context, only electricity is generated and consumed (although this is not completely correct from an electro-technical point of view). Therefore, there is only one class of business. One could argue that more than one type of electricity is offered because of the multiple methods through which it is generated (e. g., green electricity, electricity generated by nuclear power). However, how the electricity was generated does not affect its usage, although it does matter in the SP context, as a barber may not be the best choice to paint a wall, and a painter may not be the best choice to cut hair.

Operating range. The operating range is not part of DSM methods, as the entire (smart) grid is considered, ranging from a single household to an entire country at any level of granularity and complexity. In order to get some kind of operating range the (smart) grid could be divided into "subgrids" or "virtual grids" that consist of the suppliers and consumers in a certain geographic area.

Order book. The capacity plan in the DSM context – the forecasted and actual energy consumption – is equivalent to the order book in SPs. There are uncertainties in both settings, but from the suppliers' perspective in both contexts, the ability to determine capacity and free capacity is essential. In the DSM context, the energy supplier needs to know the maximum load that can be provided to consumers.

Price call. Price calls are required if service providers are to be matched to jobs. In the case of DSM methods, the price call is represented by a cost function that is based on a calculation and prediction of loads.

Price. Some SPs have a fixed price for each man-hour invoiced (PC Spezialist 2016), but most of the SPs that offer multiple kinds of services do not have such a fixed price. In contrast, a kWh of power usually has the same price, which must be considered in adapting SPs to a DSM method.

Qualifications. Qualifications and ratings are not considered in the DSM context, as there are usually only a few energy suppliers. Still, some DSM approaches use trust-based-methods in controlling a smart grid (e. g., OC TRUST 2011).

5.3.2 Service Consumer

Job description. The job description (title, description, pictures, etc.) defines the job type, which is comparable to the load type in DSM – that is, the device plugged into the power grid (washing machine, dryer, lighting, etc.). A consistent way of labeling load types would make their identification easier but such a way of labeling is not usually implemented.

Time preferences. In SPs, the consumer provides information about his or her preferred time in which the job is to be completed, which is similar to the restrictions of DSM loads. For example, a restriction may be that an electric vehicle must be charged in order to be ready for use in the morning. In general, a flexible load can occur during certain times; for example, a washing machine can be switched on only between 8 am and 10 pm

Service volume. The volume of a service is usually measured in terms of the hours of work required to finish a job. In the DSM context, loads are usually measured in kilowatts per hour, are known a-priori, and are fixed. These two measurements are equivalent in the sense of "load/service" volume to be served.

Place of delivery. The point of delivery is not considered in the DSM context, as the location is the device's location. However, this can be included with a "virtual grid".

Payment. Payment information is not represented in DSM Methods. If a job is authentic it is not checked either. However, a direct or indirect algorithm can be used for validation (e. g., OC TRUST 2011).

In Fig. 6, all the information and its correspondences are summarized.

	Service Portals	Demand Side Management	
Provider	Contact Data	Only interface is needed	Supplier
	Sector	Only 1 sector	
	Radius	Virtual Grid	
	Order Book	Capacity Plan	
	Staff	Maximum load	
	Price	Cost funtion	
	Qualification	Service-Level-Agreements	
	Rating	Trust function	
	Additional Index	-	
Consumer	Contact Data	Only interface is needed	Appliance
	Sector	Only 1 sector	
	Title, Descripton	Loadtype	
	Due date	Load occurance	
	Volume	[kWh]; Loadprofile	
	Place of service delivery	Virtual Grid	
	Payment details	-	
	Rating	Trust function	
	Job Authentification	-	

Fig. 6: Data-Based Matching

5.4 Mathematical-Based Matching

SPs' procurement process is similar to the energy-balance strategies in smart grids. In DSM, flexible loads are shifted to times that are preferable for the use network, while in SPs, jobs can be scheduled in a way that is profitable for the service providers. In order to transfer the SP processes to the DSM methods, we first describe the mathematical model of the DSM scenario and set up a similar model for SPs.

5.4.1 Mathematical Model in Demand-Side-Management

The electricity demand in the smart grid is measured in time intervals: here, every fifteen minutes. The optimization is performed one day ahead. These are typical assumptions for DSM models.

Model for the Appliances

Let N be the set of households in the smart grid, and let A_n be the set of appliances in a household $n \in N$. Let $x^t_{n,a}$ be the electricity consumption of an appliance $a \in A_n$ in the t-th time interval of a day, $t \in \{1, \dots 96\}$, where the day is divided into ninety-six fifteen-minute intervals. The total electricity consumption for the t-th time interval is the sum of these loads:

$$x^t = \sum_{n \in N} \sum_{a \in A_n} x^t_{a,n}. \tag{1}$$

We define $x := (x^1, \dots, x^{96})$ as the demand vector of one day.

One option for realizing the optimization potential of DSM is load-shifting based on the execution time. How the constraint of a load is modeled depends on the type of appliance and the user's preferences. We use the three types of appliances introduced in Sect. 4.2 to model the constraints of the loads.

First, some appliances, such as stoves, have loads that must met immediately, as when they are switched on, the heat is demanded right away. The load schedule x_a of such an appliance a cannot be shifted, so there is no flexibility based on their time of use. In the optimization model, the realization of this demand is given by the expected demand vector x_a, which is passed on as set $X_a = \{x_a\}$.

The second type of load is that required by appliances that have a fixed load profile that can be shifted in time. For example, the load profile of a washing machine's cycle is determined, but it can be started at different points in time, which is modeled as: Let a be the appliance with a load that has to be executed during the time α, β, $\alpha < \beta \in \{1, \ldots, 96\}$. The execution of the load takes δ quarter of an hour and the load profile is given by a sequence $(z_a^1, z_a^2, \ldots, z_a^\delta)$ which describes the load schedule in quarter-hour intervals. We define $\epsilon = \delta - 1$ and model the set of all the possible realizations of the demand of the appliance a as:

$$\mathcal{X}_a = \left\{ x \in \mathbb{R}_+^{96} \;\middle|\; \begin{array}{l} \exists k \in [\alpha, \beta - \epsilon] : \\ x^t = \begin{cases} z_a^{k-t+1} & \text{if } t \in [k, k+\epsilon] \\ 0 & \text{else.} \end{cases} \end{array} \right\} \tag{2}$$

The information that the load is shiftable must be communicated to the optimizing instance as the "type of load." The time preferences given by the time interval $[\alpha, \beta]$ and the load volume given by the load profile $(z_a^1, \ldots, z_a^\delta)$ must also be communicated.

The third type of load is loads of appliances that require a certain amount of electricity without being restricted to a given load profile. An example is the charging process for an electric vehicle. Let e_a be the amount of energy that is demanded between some time intervals α, β, $\alpha < \beta \in \{1, \ldots, 96\}$. The amount of electricity that can be received in one time interval can be restricted to certain limits $[l_{min}; l_{max}]$ because of technical limitations. The set of all possible realizations of the demand of this appliance can modeled as:

$$\mathcal{X}_a = \left\{ x \in \mathbb{R}_+^{96} \;\middle|\; \begin{array}{l} \sum_t x^t = e_a \wedge \\ x^t = 0 \,\forall\, t \notin [\alpha, \beta] \wedge \\ x^t \in [l_{min}; l_{max}] \,\forall\, t \in [\alpha, \beta]. \end{array} \right\} \tag{3}$$

The load description of such a load contains the information that the load is shiftable with a flexible load profile. The time preferences are given by the time interval $[\alpha, \beta]$, and the specification of the volume is given by the parameters e_a, l_{min} and l_{max}.

Model of the Energy Generators

In DSM, we are particularly interested in the volatile energy resources of a smart grid that cannot be regulated, such as the supply of wind and solar power. Let M be the set of volatile energy generators and y_m^t the electricity supply of a generator $m \in M$ in the t-th time interval of a day. The total electricity supply of volatile energy generators for the t-th time interval, then, is:

$$y^t = \sum_{m \in M} y_m^t. \tag{4}$$

We define $y := (x^1, \ldots, y^{96})$ as the supply vector of the day.

Optimization Problem

The goal of DSM methods is to cover the electricity demand as far as possible through renewable, volatile energy sources like solar and wind. The remaining electricity demand should be optimized in favor of the energy supplier, so it should be either uniform or optimized with respect to the electricity prices at the electricity exchange. We model the case in which it should be as uniform as possible, expressed by the following optimization problem:

$$\min_{x \in \mathcal{X}} \sum_{t=1}^{96} (x^t - y^t)^2, \tag{5}$$

where the set $\mathcal{X}$ includes all combinations $\sum_{n\in N}\sum_{a\in A_n} x_{a,n}$ for which each $x_{a,n}$ is in the corresponding set $\mathcal{X}_a$. In this way, it is ensured that the requirements of each order are met.

The optimization problem is a quadratic optimization problem with constraints and several ways to solve it that are reflected in the various algorithms proposed in the existing literature on DSM (cf. Sect. 2.2).

5.4.2 Transferability to Service Portals

A SP can be modeled similarly. We assume that the SP manages services in only one sector and that each order can be performed by each provider.

Model of the Customers

Let N be the set of customers and A_n the set of orders of a customer $n \in N$. We use hours as the temporal unit in this model, and the optimization range is set to one week, as a service can take several days. The service hours are set to start at 8 am and end at 6 pm. Let $x^t_{a,n} \in \mathbb{N}_+$ be the number of man-hours requested in order $a \in A_n$ for the time interval $t \in T := \{8, \ldots, 18, 32, \ldots, 42, \ldots 180\}$. The total demand of man-hours x^t in the t-th time interval is then described by the term (1) of the DSM model. The vector $x := (x^t)_{t\in T}$ describes the requested man-hours for the time horizon T.

An order comes with a job description, the time preference, the volume of the task, and possibly some additional information. The order's requirements can be similarly modeled as the requirements of a load in the DSM model. If the order is shiftable, the time preferences are communicated, modeled by a time interval $\alpha, \beta, \alpha < \beta \in T$. If the order requires a fixed sequence of man-hours, this sequence is specified and passed on. The possible realizations of this order are then modeled as in equation (2). If the sequence of the man-hours is flexible, the order can be modeled as in equation (3). Let $\mathcal{X}_A$ be the set of vectors x that fulfill the orders of $A = \cup_{n\in N} A_n$.

In SPs, additional pieces of information might be needed, such as the location of a job, which has not yet been modeled in the constraints. A regularization term might be added to the optimization problem to integrate into the model the duration of the journey to the job's location.

Model of the Service Providers

Let M be the set of service providers, B_m the set of employees of a service provider $m \in M$, and $y^t_{m,b} \in \{1, 0\}$ the available man-hours of employee $b \in B_m$ for the time interval $t \in T$. The number of available man-hours x^t in the t-th time interval is then described by term similar to equation (4) in the DSM model:

$$y^t = \sum_{m\in M}\sum_{b\in B_m} y^t_{b,m}. \tag{6}$$

The vector $y := (y^t)_{t\in T}$ describes the available man-hours for the time horizon T. The vector of one supplier $y_B := (\sum_{b\in B_m} y^t_{b,m})_{t\in T}$ corresponds to the order book.

The operating range, the prices, and the qualifications are assumed to be the same for all suppliers. If a decentralized algorithm is applied to solve the optimization problem – as set up in the next paragraph – the various prices and qualifications could be integrated into the solution as an auction model.

Optimization Problem

The goal is to schedule the services so as many orders can be accepted as possible by matching x and y, which is also the goal of the optimization problem for DSM. The optimization problem could be formulated with the method of least-squares, as done in equation (5), if missing man-hours can be purchased from additional (perhaps more expensive) companies. While we assume that a uniform occupancy rate is preferable, we want to reject orders if such additional hours cannot be procured. Therefore, we adapt the optimization problem and define a vector $z_x := y - x$ that describes the man-hours still available if the services modeled within x are accepted. That none of the components of z_x are smaller than zero is modeled as follows: Let $A = \cup A_n$ be a set of orders for which a solution to

$$\min_{x\in\mathcal{X}_A} \|z_x\|^2 \tag{7}$$

is found, so that $z_x^t \geq 0$ for all $t \in T$. The norm denotes the Euclidean norm. Let a be a new order that requests man-hours $x_a \in \mathcal{X}_{\dashv} \subset \mathbb{R}^T$. The new order is accepted if a solution for

$$\min_{x \in \mathcal{X}} \|z_x\|^2, \qquad (8)$$
$$\text{s.t. } z_x \leq 0 \ \forall\, t \in T$$

is found, where

$$\mathcal{X} := \left\{ x \in \mathbb{R}^T \mid \exists\, x_a \in \mathcal{X}_a, x_A \in \mathcal{X}_A : x = x_a + x_A \right\}$$

denotes the set of vectors that would fulfill the constraints of the set of orders $\{A \cup a\}$. The DSM methods are applied for the adapted optimization problem, although the constraints are usually not continuous, which makes it more difficult to find the optimal solution. The design of the adapted optimization problem corresponds well to the decentralized optimization algorithms that the suppliers can negotiate successively by adapting their own schedule in each iteration.

6 Research Agenda

In this section, we describe the problem/research opportunity for each agenda point (Fig. 7). and then transfer the problem to the DSM context. A solution or at least some idea on how to deal with the problem is often already available. Finally, we discuss whether the solution can be transferred back to the SP context in order to derive a solution in both contexts.

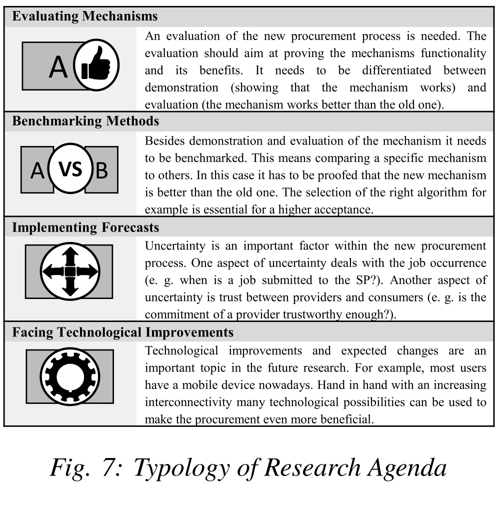

Fig. 7: Typology of Research Agenda

6.1 Evaluation

Challenge. The "new" procurement process must be evaluated to validate its functionality and its benefits over the current process. In this field, demonstration (showing that the mechanism works) and evaluation (showing that the new mechanism works better than the old one) must be differentiated.

DSM context. The problem of evaluation is particularly current in the DSM context. Most DSM methods show that they do their job, but there is no evaluation or it is restricted to the case when no algorithm for load shifting is used. Demonstration and evaluation (if any) are often done with the help of a simulation (Gerwig et al. 2015) that can range from a MatLab simulation to the authors' own implementation. Whether the data is used for demonstration or evaluation, the data's quality is another concern. In the DSM context, most authors use artificial data, but some use available data from datasets that include empirically measured data (Behrens et al. 2016b). The question concerns which dataset should be used and, of course, what case should be modeled with this data. An additional problem is the heterogeneity in the datasets, as they are recorded with, for example, differing frequencies, devices, and formats (Kelly and Knottenbelt 2014). Moreover, the constraints can differ, which must be considered when, for example, they regard time-of-use or guaranteed end times (Behrens et al. 2017).

SP context. Transferred to the SP context, this problem remains more or less the same. A simulation can be used here as well, but the problem with the data differs somewhat, as the SPs have "real data" but it is difficult to obtain. The data about jobs, users, and so on are assets of the SPs, which are unlikely to share it. Because of data security and privacy, the SPS may not even be allowed to do so. A workaround must be used to get suitable data by either generating artificial data or crawling for data from SPs. We crawled for data on handcraft offers from a SP and gathered more than 500 job offers with additional information (e. g., time, place, and description). However, we encountered two difficulties: It was not possible to crawl for the volume of each offer, and we were not able to crawl for suitable provider data. To solve the first problem, we assumed an average number of man-hours for a specified piece of the job. To get provider data, we used random numbers and generated an artificial set of provider data (e. g., staff and price). We conducted a demonstration with this initial dataset, and first results indicated that the procurement works fine with, for example, a greedy-based mechanism andmechanisms based on a multi-agent system.

6.2 Benchmark

Challenge. Demonstration and evaluation is the first step in verifying the functionality of the mechanism(s) in general, but then another question arises concerning how to compare algorithms. The selection of a suitable algorithm is essential, as we already saw different results when we implemented a greedy heuristic in our first demonstration approach.

DSM context. Benchmarking is an open research question in the DSM field. As ours is a kind of multi-factor simulation, the comparison cannot consist of a single factor. Another problem is that the algorithms must be comparable, so all algorithms must take the same restrictions into account (Behrens et al. 2017). In addition, a suitable benchmark-framework/setup must be applied. Disciplines that are similar to DSM have presented benchmark frameworks (e. g., Barta et al. 2014) that address the point's data, the resulting metric, and the class of algorithms. These frameworks select the most common (real) datasets, convert them to a consistent format, and define an interface that allows researchers to submit their algorithms to their toolkits before defining a metric of factors that is applied when the algorithms' results are used.

SP context. In the SP case, a portal's real data can be used or estimated/artificial data can be created. The resulting metric can contain the factors' jobs, matchings, dropout rate, and so on. The class of algorithms in SP (especially when they are transferred to the DSM context) can be structured with the communication form (one-way, two-way, no communication) and the kind of decision-making (decentralized, centralized), which is known from the DSM context (Barta et al. 2014).

6.3 Forecasts

6.3.1 Uncertainty about Job Occurrence

Challenge. Suppliers face uncertainty in forecasting future jobs (job occurrence) in order to plan their capacities, so they need to know when a job is submitted to the SP.

DSM context. In DSM uncertainty refers primarily to when the load appears or whether the load appears at the same time as yesterday/last week/last month/last year. By using past data, forecasters can estimate, for example, at what time it is most likely that a certain load will occur (Gerwig 2017).

SP context. Transferred to the SP context, questions related to uncertainty might refer to when a job will be submitted to the SP or whether we can estimate the same number of jobs as last month. As in the DSM context, forecasting can be used to estimate the number of future jobs.

6.3.2 Uncertainty about Job Delivery

Challenge. Another aspect of uncertainty is trust between providers and consumers. Is the provider's commitment sufficiently trustworthy? Does the provider have the skills required to do the job well? Will the consumer pay the bill on time? Will the consumer cancel the job at the last minute?

DSM context. These questions also emerge in the DSM field. For example, heating, ventilation, and air conditioning (HVAC) loads must be controlled but are difficult to forecast. When an electric heating device needs to heat up a room to 25 °C, calculating the amount of energy needed requires estimating many environmental factors that are unknown (e. g., whether the window is open, the starting temperature in the room, the size of the room). Differential equations and stochastic constraints are often used to manage these kinds of loads.

SP context. The HVAC example can be matched to the SP. To address uncertainties, one must consider many factors, so it might be a good idea to use a similar construct as that of HVAC loads and differential equations.

6.4 Technological Improvements

Challenge. Technological improvements and expected changes are important topics for future research. For example, mobile devices and other forms of increasing interconnectivity can be used to make the procurement of jobs even more beneficial by, for example, allowing reactions to demand to be made roughly in real time.

DSM context. More or less the same technological improvements (e. g., interconnectivity and mobile devices) can deliver a surplus in the DSM context, as the user can manage the loads even when not at home. Moreover, even more data can be gathered und used to improve estimations of the user's lifestyle and controlling of loads.

SP context. DSM seems to be suitable for managing the procurement of jobs in SPs. While whether it is the best option remains unclear, our research provides some important insights into the kinds of factors that future research should consider.

7 Conclusion

SPs are increasing in importance as technological improvements take hold and the number of users and jobs submitted in such portals booms. To achieve better (effective) and faster (efficient) synchronization of service providers and service consumers, the procurement mechanisms should be improved further. Our findings indicate that the DSM context has many analogies to the SP context and that DSM can be adapted to it, which is supported by a mathematical model.

Not all aspects of SPs can be transferred to DSM. For example, the legal situation (law) is difficult to match. Previously, consumers chose a provider and made the contract manually and in person, avoiding many problems. However, with automatic matching using SPs, new potential pitfalls emerge. For example: What happens if a service provider is matched to a job and in the meantime has accepted another job manually outside the portal and so has no free capacity? This and other questions should be discussed in order to achieve greater consumer acceptance through legal certainty. In the DSM context, the legal situation is different, as there are service-level agreements and similar constructs that can define exactly the tasks and responsibilities of the contract partners.

Although we derived some helpful insights, this study is not free of limitations. The review of portals follows an established methodology (vom Brocke et al. 2009) to guarantee traceability and reproducibility, but our selection of items, sources, exclusion criteria, and classification is based on decisions and choices that have limitations. We could have added more search items or more sources (e. g., databases like "Science Direct" and "Web of Science", as well as journals and conferences), as such an extended search may have identified more portals.

Furthermore, data exchange has legal and moral constraints, but data must be shared among the actors in order to achieve the goal of automatic procurement mechanisms. Of course, not everyone must have access to all of the data in the system, such a supplier's order book, but the SP, acting as broker, must have access to this and other information. Such sensitive data is seldom shared voluntarily, but these constraints are weakening over time and might diminish with further technological improvements.

Several stakeholders can benefit from the results of this study. Besides the analysis of SPs, which delivers insights into the current procurement process's functionality, additional potential and research agendas are derived. This contribution to the knowledge base can be used to develop additional artifacts that result in benefits for research and practice. From a practical perspective, several stakeholders can benefit from the realization of a more efficient procurement process in SPs. Service providers can see a filled order book, maximize the use of their employees, and plan reliably. Service consumers can see cost savings and ensure that the service received is of the expected quality and is completed with the expected efficiency. SPs can improve their service quality, the amount of fulfilled jobs, and the transparency of job offers and can increase the number of service providers. Moreover, by increasing service providers' willingness to deliver better, more customized, and more efficient services (smart services), SPs provide benefits to both service providers and consumers.

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