CrowdStrom: Analysis, Design, and Implementation of Processes for a Peer-to-Peer Service for Electric Vehicle Charging

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Abstract

(a) **Situation faced**: An inadequate number of publicly available charging points is among the main reasons that consumers do not buy electric vehicles (EVs). To address this problem, we suggest a peer-to-peer (P2P) sharing approach for private charging infrastructures. We formed a joint consortium between academia and industry to design and implement a web platform and an underlying business model for an infrastructure of individually owned EV-charging stations for public use. Currently, there are no standardized processes for EV charging, so we had to look elsewhere for processes that could be adapted or partly adopted as a foundation for the proposed web platform.

(b) **Action taken**: We interviewed representatives of seven organizations that are already operating in the domain of EV charging about the relevant business processes. Applying the BPM lifecycle (Dumas et al., *Fundamentals of business process management*. Springer, 2013), we

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analyzed the resulting as-is processes for best practices and redesigned them for the scenario of a P2P platform for EV charging.

(c) **Results achieved**: Sixteen to-be processes that comprised registration, authentication, charging, billing, and administration were modeled in BPMN and implemented in a software prototype. The prototype and associated processes are currently being evaluated to ensure their validity and effectiveness in the target environment while the partnering utility company prepares the solution's staged roll-out to operate their own charging stations and then open the system to other providers.

(d) **Lessons learned**: Analyzing and then designing business processes to reach a common goal has been a unifying factor in our joint research project, where partners from industry and academia have differing backgrounds, expectations, and individual goals. BPM practices enabled the project team to create an innovative business model and corresponding business processes that will have an impact in practice.

1 Introduction

In 2010, Germany's Federal Government announced the goal of one million registered electric vehicles (EVs) in Germany by 2020 (BMBF 2010). Although this goal might be too ambitious, increasing the number of EVs that are fueled by power from renewable sources is still a goal worth pursuing in the effort to reduce global carbon dioxide emissions.

Since EVs have a comparatively low range of distance, effective electric mobility must be built on an extensive network of charging points (Steinhilber et al. 2013). Currently, only 5800 public charging points at 2500 public charging stations are available in Germany (BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. 2016) for the approximately 18,000 registered EVs and 100,000 registered hybrid vehicles in the country (Kraftfahrtbundesamt 2016).

Figure 1 compares the number of registered EVs to the number of publicly accessible charging points in Germany from 2006 to 2015. A sufficient network for the target of one million EVs requires, in addition to private charging points, roughly 110,000 charging points in semi-public spaces and 70,000 in public spaces (Nationale Plattform Elektromobilität 2014). Developing such an extensive charging infrastructure for EVs requires a substantial investment that would be rational only if demand increased well over its present level. So what should come first: demand with insufficient supply or supply with insufficient demand?

The joint academia-and-industry research project "CrowdStrom" addresses this "chicken-and-egg" problem. The local utility Stadtwerke Münster and the global testing and certification organization TÜV SÜD collaborated with researchers from the University of Münster's departments of Information Systems and Marketing and the University of Duisburg-Essen.

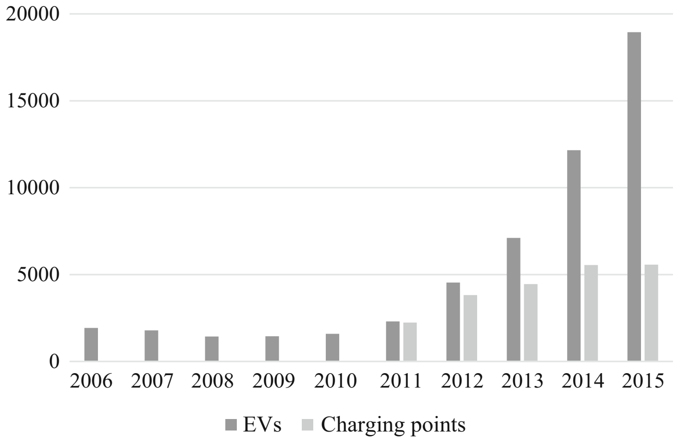

Fig. 1 Number of EVs and publicly accessible charging points in Germany from 2006 to 2015 (Nationale Plattform Elektromobilität 2015; Kraftfahrtbundesamt 2016)

The project's main goal is to support the establishment of a well-developed network of publicly accessible charging stations that can help to accelerate the diffusion of EVs. Our central tasks are to design, implement, and evaluate a business model, business processes, and the IT architecture of a peer-to-peer sharing service for charging EVs that networks individuals and small businesses and their charging stations with charging-service customers. A major obstacle in this endeavor is the absence of standards and best-practice processes for EV charging because of the novelty of and rapid technological developments in this field. The innovativeness of the proposed business model also requires additional processes that are new to either the field of EV charging or that of P2P sharing and so require modifications or even new development from scratch. Our review of the German market for EV charging identified seven organizations that participate in this market. We interviewed these players to capture and model their existing processes, scanned them for best practices, assessed these practices' applicability to the proposed business model, and remodeled them into to-be processes for the service. We are currently evaluating the resulting software prototype regarding the socio-technical aspects of the service and its viability for real-world application. Its roll-out in several stages into live operation is planned.

The remainder of this article is structured as follows: The next section delineates the current situation in more detail, focusing on the participating parties' motivation and existing obstacles. The third section describes the steps we took to derive to-be processes for CrowdStrom from several related organizations' as-is processes. The fourth section describes the analysis of the as-is processes and the resulting to-be processes in detail. The article concludes with a summary of the findings and lessons learned for future cases.

2 Situation Faced

An EV owner typically purchases a private charging point along with her or his EV in order to be able to charge the car more quickly than it is possible using a regular household outlet. Because there is usually only one user, these charging points tend to be underused. In the spirit of the sharing economy, the use rate and productivity of these charging points can be increased if they are rented to other people when the owners do not need them, an approach that would simultaneously increase the number of available charging points for other EV owners and make the purchase of an EV more practicable. This basic idea has been implemented in many peer-to-peer sharing and collaborative consumption (P2P SCC) business models, such as Airbnb (sharing of rooms) and Uber (sharing of cars).

The charging infrastructure landscape is fragmented, with many isolated small providers and little interoperability. These isolated solutions present a major obstacle for EV owners who travel long distances and must search for charging points along the way. Intercharge networks like *ladenetz.de* and *Hubject* approach this problem by interconnecting existing public charging providers. CrowdStrom follows this approach but expands it to include private providers to create an open charging infrastructure.

Sharing a charging point in return for monetary compensation requires the individual charging station to adopt the general P2P SCC paradigm, which poses challenges because of the nature of the resource that is shared. In addition, the whole process should be fully automated so the need for the provider's direct intervention is minimal or, at best, unnecessary. That the individual charging points are embedded in systems and have limited influence on their internal behavior adds another layer of complexity to the business processes because the processes have to be carried out within and across these systems, rather than by only one or a few application systems. In addition to the lack of knowledge about the required processes and how they should be implemented, the diversity of stakeholders' perspectives and expectations creates complexity. In a P2P SCC model, participants can take a variety of roles so service and monetary flows become bidirectional. Facing the absence of standards or reference models for many aspects of the service to be developed, we found the adoption of BPM practices like the BPM lifecycle appropriate for structuring and guiding our efforts. Our focus was not primarily on improving processes but on identifying best practices and their consequent adaptations for our project. In addition, Business Process Model and Notation 2.0 (BPMN 2.0) is a valid instrument for modeling the processes and communicating the various roles and tasks involved in service delivery in a way that every stakeholder can understand.

A crowdsourcing-based approach for the expansion of the charging infrastructure adds challenges concerning legal implications and the service's profitability. The proposed business model poses novel legal questions regarding network technology, laws for electricity-providers, and calibration and measurement techniques (Chasin et al. 2015). The service's profitability depends heavily on external factors like the prevalence of EVs and users' acceptance of the service, especially users who provide the charging infrastructure. Because of the approach's novelty and the general public's lack of involvement in the EV domain, many aspects of the service are not yet clearly defined. For example, the factors that motivate potential service providers to use CrowdStrom and how to incent them to participate remain unknown.

The project partners from industry provided important insights for the project's success. As a local utility, Stadtwerke Münster provides customers with electricity, heat, water, and public transportation and offers the PlusCard program, which enables their customers to do cashless payment for services provided by various partners. In the field of electric mobility, Stadtwerke Münster operates a local charging infrastructure for EVs. However, proper accounting is a major issue for the company, as customers of the utility currently charge their cars for free because of legal and technical restrictions. Consequently, Stadtwerke Münster's goal in participating in the project is the development of a profitable business model for its charging infrastructure that can be integrated into its current PlusCard service environment and accounting infrastructure.

TÜV SÜD is a German-based global certification and testing company with 24,000 employees in more than 60 countries. The company also provides consulting services in the EV mobility domain. Its focus in participating in the CrowdStrom project is on the development of data privacy, data security, and governance mechanisms in the business model and business processes.

3 Action Taken

The emerging domain of EV charging has brought organizations with a variety of business models and processes into the market. Therefore, instead of developing the necessary processes for the CrowdStrom web platform from scratch, we analyzed other organizations' existing processes for their suitability for CrowdStrom. The seven organizations whose processes for EV charging we analyzed are introduced next.

Stadtwerke Münster
The local utility Stadtwerke Münster introduced a radio frequency identification (RFID)-based customer card (PlusCard) for the authentication and payment of certain cashless services, including parking lots, taxis, and associated services. The experience of Stadtwerke Münster from the everyday use of the PlusCard system can inform the derivation of RFID-based customer processes for EV charging.

Ebee Smart Technologies
Ebee develops and distributes components for setting up and managing charging infrastructures to customers who provide infrastructure as a service. As a unique characteristic, Ebee's charging points are compact enough to be mounted on ordinary streetlights. The primary customer group consists of municipalities,

municipal utilities, and electricity-supply companies. Ebee acts only as a hardware provider, not as the operator of charging points, and does not compete with the large number of charging-point operators. A similar business model with an extended focus on private providers is offered by PunktLaden.

Hubject

Hubject, founded in 2012 as a joint venture of car manufacturers and electric utilities, is an IT service provider in the domain of EV and charging infrastructure integration that serves all of Europe. The Hubject IT platform has been available since 2013, offering the possibility of eRoaming for charging-point infrastructures and enabling the independent use of charging points by connecting existing isolated solutions. While this roaming approach grants end users access to a large network of charging points, Hubject's core business area is in the B2B area. Primarily addressing end users is not part of the company's business model or processes.

ladenetz.de

Founded in 2010, ladenetz.de is a cooperation among municipal utilities with the goal of introducing, developing, and facilitating a well-developed charging infrastructure. Smartlab, ladenetz.de's parent company, was founded in 2010 as a subsidiary of Stadtwerke Aachen, Duisburg, and Osnabrück (municipal utilities of the cities of Aachen, Duisburg, and Osnabrück). These utilities focus on the development and distribution of innovative services, products, and concepts in the area of EVs, mainly directed at local energy utilities and municipal utilities.

RWE Effizienz

RWE Effizienz is a subsidiary of the large German electric utilities company RWE, which is primarily active in the domain of EV charging. The company offers the technical infrastructure and an extensive portfolio of services for the installation and operation of charging infrastructures. RWE Effizienz also manufactures charging points with two lines of its own charging points that are targeted to private and business customers, respectively.

The eLine products, which do not support any form of communication with backend systems, target primarily private users. The stations do not offer authentication methods, but RWE offers the possibility of regulating the access via locking systems in the context of private use.

eLine Smart offers several authentication methods, differentiated between local and remote authentication methods. The latter include requests to unlock the station via RWE's smartphone application and requests sent via text message. Local authentication methods are supported through intelligent charging cables with Powerline Communication and the use of RFID cards.

sms&charge

The research project sms&charge developed a simple authentication and accounting system for charging stations. Users write and send text messages to sms&charge, which then grants access to the charging point for a certain time slot. Since virtually every potential user carries a mobile phone, this solution gives users non-discriminatory access to the public charging infrastructure. Services used are billed through the user's mobile service provider.

The New Motion

The New Motion, founded in 2009 in the Netherlands, offers charging infrastructure and services for EVs. The New Motion, which develops intelligent charging points and advanced charging services for EVs, is currently working on a comprehensive network of charging points. Since 2012, The New Motion has also been active in Belgium and Germany (The New Motion Deutschland). Its widely used charging network is the largest in Europe, with over 12,000 charging points. The New Motion provides services to both businesses and private customers. In addition to the distribution and installation of charging points, the company offers to operate the stations and to manage accounting of charging transactions.

Following Dumas et al.'s (2013) BPM lifecycle, our approach is comprised of the phases of *process identification*, *process discovery*, *redesign*, *process analysis*, *process implementation*, and *process monitoring and controlling*. In *process identification*, processes that are relevant to the problem are identified, their scope is delimited, and relationships between the processes are identified. *Process discovery* (or *process modeling*) describes the phase of documenting the process, as in *as-is process models*. *Process analysis* includes the identification and assessment of issues in the as-is processes. *Process redesign* addresses the issues identified in the previous phase and identifies and analyzes potential remedies that result in to-be process models. *Process implementation* performs the changes necessary to reach the to-be processes. Finally, during the *process monitoring and controlling* phase, relevant data is collected to identify necessary adjustments to the processes.

In the following, we describe the steps we undertook in applying the BPM lifecycle to our case. First, we conducted *process identification* by means of several workshops in which researchers, students, and company representatives who were involved in the project identified four process categories with regard to the proposed business model for an EV-charging service. In the *process discovery* phase, a comprehensive market analysis identified the aforementioned seven organizations that provide charging services. These organizations' processes were then elicited with regard to the processes category identified in the process identification phase, resulting in 23 as-is processes being modeled in BPMN 2.0. The as-is processes were then *analyzed* for best practices and their suitability for the CrowdStrom business model. Processes that indicated weaknesses during the analysis phase were *redesigned*. Eventually, a total of 16 to-be processes were derived and *implemented* in a software prototype that is currently being used in a field test in which two actual charging points are being operated. After the initial implementation of the to-be processes, an iterative improvement of the to-be processes began. It started with using the insights gathered during the first *process monitoring and controlling* phase to identify gaps in the processes landscape and to trigger the subsequent iterations of the BPM lifecycle. Continuous process improvement is important in the CrowdStrom case, as the developed software is scheduled to

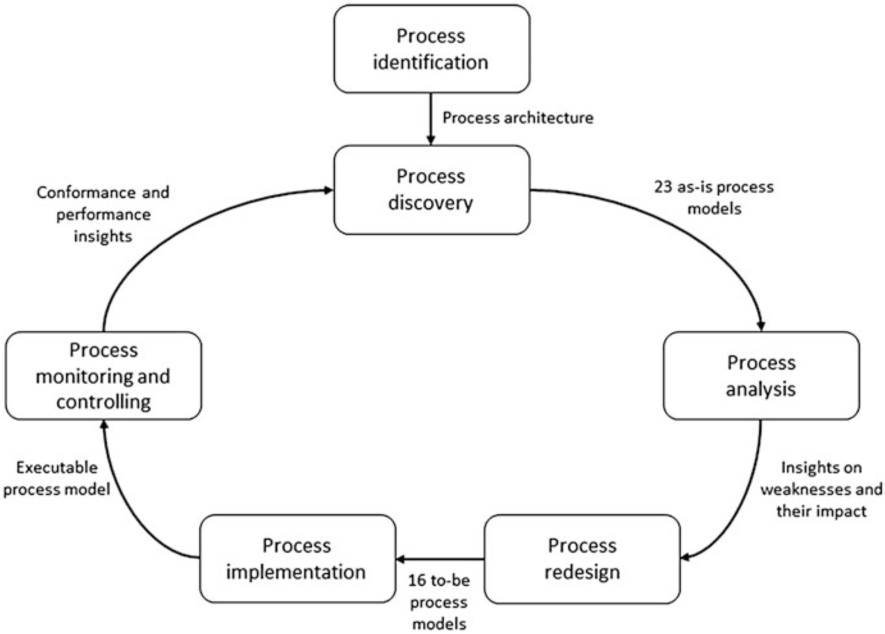

Fig. 2 Approach based on the BPM lifecycle (Dumas et al. 2013)

operate all of the project partner's charging points in the near future. Figure 2 visualizes the chosen approach according to the BPM lifecycle.

3.1 Process Identification

Since the focus of this assessment is on the operation of the charging service and all related processes, identifying all processes from authentication to billing of the charging service was required. Four process categories—registration, authentication, charging, and billing—were identified as particularly critical in this context.

Registration
The registration process is the basis for all user-oriented and provider-oriented processes. It collects all of the involved persons' relevant data and initiates the contractual relationship between the company and the users and providers of the service. All subsequent processes are designed based on the initial registration.

Authentication
The purpose of authentication is to ensure that only eligible persons are granted access to the service (in this case, the use of a charging point) so the provider is assured of receiving payment for the service. The legitimacy of use is evaluated through an identification measure determined by the provider. In most cases, the

identification measure is a customer-specific ID that can be read and compared to a list of authorized IDs (whitelist) and unauthorized IDs (blacklist). If the potential user does not have such an identification measure, or in case of authentication failure, he or she will not be granted access. If the authentication is successful, the person can use the service and be billed accordingly.

Charging

The charging process starts after successful authentication and continues until a stopping event—such as unlocking the charging cable on the vehicle side, cancelling the request via mobile application, or repeating the authentication at the charging point—occurs. The transaction data must be transmitted and saved throughout the charging process, as they are required for subsequent billing processes.

Billing

Billing is considered from two perspectives in the context of CrowdStrom: the user billing and the provider settlement. The user billing refers to the billing of services used by the user—that is, the consumption of electricity at a charging point after successful authentication. The transaction data gathered at each process step build the basis for the user billing and are used to create an invoice that is delivered to the user. The billing process is concluded after the invoice is paid.

The provider settlement refers to the payment for services that a charging-point provider delivered to a user. After each charging process, transaction data are transmitted from the charging point and allocated to a single, distinct charging point. They are then aggregated and the total costs calculated in order to pay the provider on a monthly basis.

3.2 Process Discovery

Since companies' processes are generally not public, we conducted interviews with business professionals from the organizations we identified. All of these organizations have been operating successfully for some time, so they are likely to have reliable processes in place. In the interest of capturing the processes in detail and observing their interactions, the interviewees we chose were all domain experts who were deeply involved in the processes or even the process owners or managers.

The project team drafted an extensive questionnaire with 85 questions on the topics of registration, authentication, charging, and billing to ensure comparability. The questions focused on the identification of a process's systematic series of actions, the actors involved, and the master data and documents that were relevant to the process. An interview guideline in the form of a checklist was created to provide guidance in preparing and conducting the interviews and modeling and documenting the processes. One interview was conducted in each organization, with two interviews taking place during personal meetings and the remaining five done via phone. Each interview lasted from 45 to 90 min, and each was tape-recorded, transcribed, and sent to the respective interviewee for audit and confirmation. We worked in groups of two, with one person responsible for tracking the questionnaire and the other guiding the interview.

3.3 Process Modeling

Based on the interviews, we modelled 23 as-is processes in BPMN 2.0. As expected, the organizations we interviewed handle their core processes differently, so we identified up to five variants per process category. Provider and user billing was identified and modeled only twice, as not all of the organizations had implemented these processes. The as-is processes were numerous and diverse, so they provide a good basis for identifying and deducing the to-be recommendations that take place during the *analysis* and *redesign* phases. Table 1 provides an overview of the processes we modeled and the organizations from which they were derived.

Table 1 Overview of as-is processes and corresponding organizations

Process category	Process identified	Organization
Registration	Registration	ladenetz.de
	Registration PlusCard	Stadtwerke Münster
	User registration	The New Motion
	Registration for customer portal	The New Motion
	Provider registration	The New Motion
Authentication	Authentication	Hubject
	Remote authentication	Hubject
	Authentication	ladenetz.de
	Authentication	sms&charge
	Authentication	Stadtwerke Münster
	Authentication	The New Motion
Charging	Start charging procedure	ladenetz.de
	End charging procedure	ladenetz.de
	Start charging procedure	sms&charge
	End charging procedure	sms&charge
	Service use and response	Stadtwerke Münster
	Charging procedure	The New Motion
Billing	Response	Hubject
	User billing	Stadtwerke Münster
	Provider billing	Stadtwerke Münster
	User billing	The New Motion
	Provider billing	The New Motion
Administration	Administration of customer account	Stadtwerke Münster

3.4 Process Analysis

The modeled as-is processes were subsequently analyzed and used as a foundation for the derivation of to-be processes. In the first step of the process analysis, we grouped the as-is process models according to the categories of registration, authentication, charging, billing, and administration. In the next step, we analyzed the as-is processes qualitatively. Traditional techniques for qualitative business process analysis, such as value-added analysis and root-cause analysis, were not applied because they would not have been expedient in our context. As our goal was to identify best practices and processes that were suitable to the proposed business model, we analyzed the modeled as-is processes for similarities, differences, and consistency with regard to their planned application. We selected three predefined process categories for later application: standard processes that were not specific to EV-charging (e.g., billing), large parts of which could be reused without modifications, especially when they included direct customer interaction; EV-related (but not EV-specific) processes that revealed new concepts and comprehensive best-practices for planned operations (e.g., a variety of options for authentication); and processes that were directly related to EV-charging, especially processes connected to communication between the backend system and charging stations using the Open Charge Point Protocol (OCPP), for which we treated the communication part as a black box that was implemented after the protocol's documentation. Additional information that the interviewees provided and that could not be fit into formal process models, such as Hubject's remote authentication procedure,[1] was taken into account. As a result, five best-practice process models out of nine core processes and additional details were derived from the information gathered on the elicited process models and the advantages and disadvantages of specific models. Since CrowdStrom's focus is on charging EVs, we did not classify administration processes as core processes.

3.5 Process Redesign

During the *process redesign* phase, we designed the to-be process models based on the identified best practices with regard to their applicability in the project context. The application of a P2P sharing approach to EV charging results in certain characteristics that differ from those of the established providers we interviewed. For example, the integration into the network of customers as peer-providers requires differentiating customers as peer-providers, peer-users, or both. Other issues included the processes' suitability for use with the future providers' existing

[1]A requirement for using Hubject's method is a backend system at the charging-point provider that can communicate with the Hubject backend system via the Open InterCharge Protocol. Such requirements were not modelled explicitly in BPMN but were considered informally in the accompanying textual descriptions.

processes as well as those of the local utility, and the partner concept that enables a third party (a partner) to offer participation in the CrowdStrom network and its corresponding services as a (white-label) service to the partner's own customers.

These issues required individual changes and additions to the identified best-practice processes and even whole processes to be conceptualized and modeled anew in order to obtain the desired to-be processes. In the end, we designed 16 processes, out of which we defined nine core processes. While five core processes were derived from best practices, the remaining 11 processes were designed from scratch to align with CrowdStrom's new concept. For example, registrations will be possible directly at CrowdStrom but also via contract partners like Stadtwerke Münster.

Applying the *Heuristic Process Redesign* methodology, we followed the three stages of *initiate*, *design*, and *evaluate* that Dumas et al. (2013) suggested. In the *initiate* stage, the project team gained a deep understanding of the targeted domain of EV charging by conducting the interviews and modeling the respective as-is processes. The goal of applying the BPM lifecycle was to devise suitable best-practice processes for the software prototype. Therefore, the primary focus in the application presented was not the traditional goals of process redesign, such as flexibility, time, cost, and quality (Dumas et al. 2013) but adapting and altering the existing processes so the resulting solutions comply with the proposed business model's technical and business requirements.

For the second stage, *design*, we considered Dumas et al.'s (2013) design heuristics; however, because of the project's special character, we deemed only the heuristics from three classes to be applicable: *customer heuristics*, *technology heuristics*, and e*xternal environment heuristics.*

From the class of *customer* heuristics, we applied the heuristics *control relocation* and *integration* to the integration of peer providers into the processes by giving them access to the web platform, where they can add their charging stations and configure parameters like opening times and prices. We applied *contact reduction* to the process of customer registration, rejecting other alternatives in favor of online-only registration for direct customers in order to save administrative resources.

From the class of *technology heuristics* we applied the heuristics of *activity automation* and *integral technology*. We added new technology, such as that which enables user authentication via smartphone and offers users an integrated data analysis tool with a dashboard in the web platform, wherever possible. In order to increase the level of automation, we deliver bills only digitally, eliminating manual postal processes.

From the class of *external environment heuristics* we applied the *trusted party heuristic* by adding the partner concept, enabling third parties to add their customer bases to the CrowdStrom network and offer them participation in the network as a value-added service.

The project team and experts from our project partners, Stadtwerke Münster and TÜV SÜD, conducted the final stage of *evaluate*, after which we deemed the resulting to-be processes to be ready for implementation. After the processes were implemented in the software prototype, we conducted an extensive qualitative evaluation by means of several workshops with experts from Stadtwerke Münster, resulting in new insights and minor alterations to the prototype.

4 Results Achieved

Here we describe the resulting to-be processes sorted for each process category. For reasons of clarity, we do not describe all to-be processes in detail or show the respective process models. Instead, we provide four process models that illustrate our approach and the results.

Registration

The processes we captured differentiate between online and offline registration (service desk) procedures. The latter cannot be considered a best practice, as our goal is to provide fast, standardized process-handling. The installation of service desks also leads to additional cost and disproportionate effort. Since all of the providers we consulted offered online registration—with the offline option simply an optional addition—the online registration was determined the best practice. The online registration collects data on the customer's surname, first name, address, e-mail address, and payment method. (At present, only a bank account from which charges can be debited and to which payments can be deposited is allowed.)

The best-practice process identified was extended to include application for the CrowdStrom RFID card and the possibility of the customer's adding his or her own charging points and becoming a provider. The partner concept requires a special process with which to add a partner's customers to the CrowdStrom database. In this process, the partner transmits the customer's ID, a related RFID card number (if available), and existing charging points to be added to the CrowdStrom database. In return, CrowdStrom provides transaction data to the partner, who handles the billing of his or her customers.

Authentication

We captured authentication processes from six organizations that have only a few principal differences. The organizations can be categorized in terms of the authentication medium they apply, with the most common medium (five out of six providers) being the RFID card. Figure 3 depicts an extract of an as-is process using RFID technology that we observed during our interviews. The customer initiates the authentication by holding the RFID card in front of the charging station's card reader. The charging station requests authentication using the provider's information system, which looks up the transmitted contract ID and checks it for validity. If it's valid, authentication is successful, and the customer may continue.

Ebee, Hubject, and ladenetz.de provide the additional service of unlocking charging points via a smartphone app, although only sms&charge provides authentication via text message. When issues arise during the authentication procedure

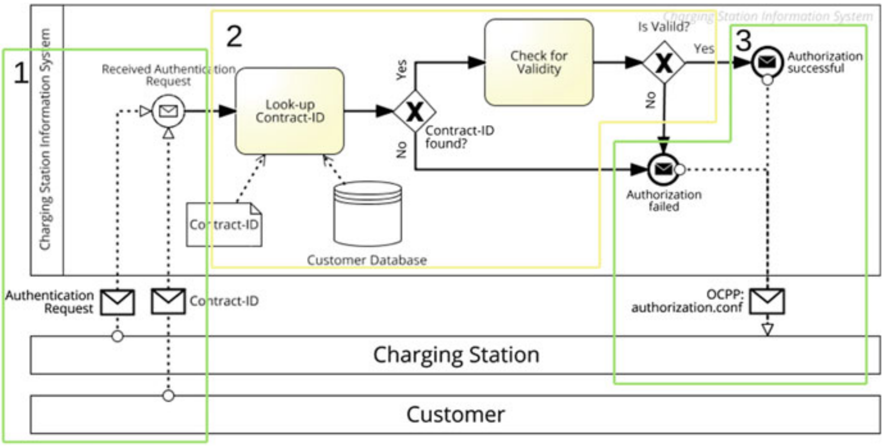

Fig. 3 Section of as-is authentication process

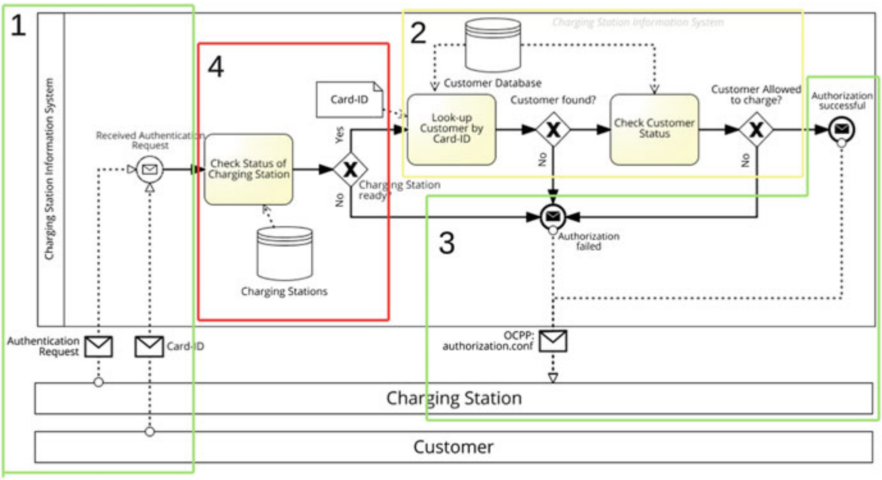

Fig. 4 Section of to-be authentication process with adaptations

because of unreadable cards, The New Motion offers authentication via phone call. The best-practice process in the context of CrowdStrom is the authentication via RFID card, as it is the most common variant, it corresponds to the recommendation of the project partner Stadtwerke Münster, and it was the method of choice in a survey that measured the preferences of potential customers (Matzner et al. 2015).

In the resulting to-be process, during the authentication process, the system automatically determines whether the current time falls within the opening hours the provider set. This feature was added for CrowdStrom since private charging-station owners should be able to define when others are allowed to charge at their stations. Figure 4 illustrates how we derived the to-be process from the as-is process represented in Fig. 3. While the tasks and messages covered by the green boxes (number 1 and 3) are directly derived from the as-is process, the parts within the yellow box (number 2) only differ in detail, but handle similar tasks. However, the contents within the red box (number 4) introduce our new approach of checking opening hours before continuing with authentication. The card ID should be compared with the customer data on the backend. A whitelist that is locally stored in the reading device supports the authentication services in case the Internet connection is temporarily interrupted, so charging points that are ready for CrowdStrom must support RFID and be able to store a whitelist locally. The alternative authentication via smartphone app (e.g., with a customer number and a PIN) should also be integrated. For this purpose, the charging point could be equipped with corresponding QR codes, which simplify transmitting the charging point's ID and speed up the unlocking process.

An optional smartphone app would enable authentication when users do not have their RFID cards, thereby enhancing the customer experience. (Reasons to decline an authentication also include non-readability of cards, a missing card ID in the customer data, and defective charging points—.) Such an app also has potential to offer additional services, such as searching for nearby charging points, navigating to the chosen one, and inspecting the most recent charging transactions and the corresponding costs or profits from the customer's or provider's point of view. An optional smartphone app was also reflected in the survey that measured user preferences (Matzner et al. 2015).

Charging

Processes that are related to the vehicle-charging procedure were elicited from Ebee, Hubject, ladenetz.de, sms&charge, and The New Motion. The analysis revealed that communication between charging points and the backend depends heavily on the charging point and the supported communication protocol. Most of the interviewees implement the OCPP 1.5 protocol[2] for initialization but use a variety of ways to cancel the charging process.

The user's authentication is required twice during the charging process: at the beginning to insert the charging cable into the charging station and start charging, and at the end to unlock the charging station and remove the charging cable from the station (or the vehicle). As authentication via RFID was identified as a best practice, it was implemented as the default solution to both start and terminate the charging process. With this approach, the RFID card's ID is transmitted from the charging point to the central charging station controller at the company's backend, which verifies whether the user is eligible to start/terminate the charging process. When the verification is successful, the charging process is started/terminated

[2]Open Charge Point Protocol (OCPP) is an open standard that was published in 2010 by the Dutch E-Laad Initiative. Its purpose is to create independence between the charging station and the backend or the control center. As a result, a charging station's provider can choose among all available electricity suppliers without being dependent on proprietary interfaces.

centrally by the backend, ensuring that only eligible users (i.e., registered customers for starting and users who initiated the charging process for terminating) can order the start/termination of the charging process. The entire communication uses the OCPP 1.5 protocol. Ebee, ladenetz.de, and The New Motion all use this approach.

Another possibility for initiating and terminating the charging process is direct communication with the backend. For example, text messages or a smartphone app can be used to communicate with the backend and to ensure proper authentication. The backend verifies whether either the phone number or the content of the text message (e.g., user ID) indicates the sender is eligible to use charging services. For maintenance and emergency service purposes, we implemented the ability to start or terminate a charging process remotely by a technician or service staff via the backend (Fig. 5).

The best-practice processes we identified include the application of the OCPP 1.5, with the data stored in a database at the company's backend and exported from there. Transaction data can also be stored locally in the charging point in case there are connection problems. The separate storage of customer data and transaction data can also be considered a best practice. No adjustments to the best practices identified had to be made for the CrowdStrom's to-be termination process.

Billing

In the CrowdStrom business model and its business processes, billing is considered from two perspectives: user billing, which is concerned with the settlement of all services provided (i.e., the power consumed at a charging point); and provider billing, which is concerned with monetary compensation for the services provided (i.e., the charging point, parking spot, and energy). The processes for user billing are the authentication and charging procedures discussed above, as they capture all relevant transaction data for the billing process.

We captured processes regarding end-user billing from Stadtwerke Münster and The New Motion, both of which conduct user billing monthly and send a personal invoice; the only major difference is that The New Motion sends the invoice via

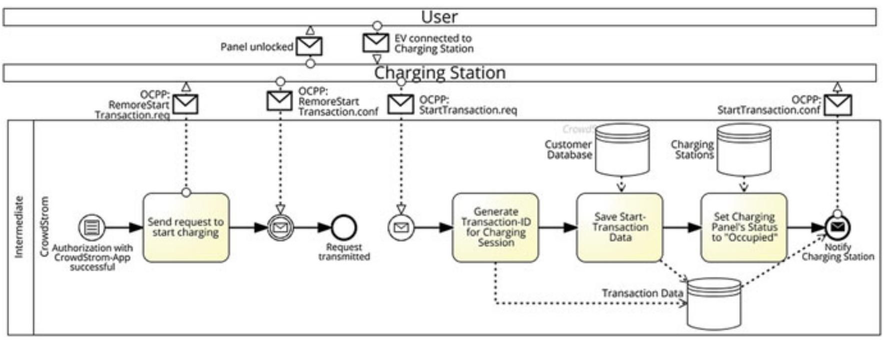

Fig. 5 Section of CrowdStrom's subsequent authorization and remote start-charging processes

e-mail, while Stadtwerke Münster uploads the invoice to its web portal. As for provider billing, both organizations bill monthly, calculating the amount payable using transaction data and the corresponding price models. They differ primarily in that The New Motion serves as an intermediary, collecting all data captured by the charging point and starting the billing process based on this data, while Stadtwerke Münster has service providers collect the data themselves and then send an invoice to Stadtwerke Münster.

The resulting to-be processes for billing consist of monthly billing for both users and providers via e-mail and within the web platform. The partner concept must also be considered in adapting these best practices for the CrowdStrom to-be processes. The user- and provider-billing of partner customers is not done directly via CrowdStrom but indirectly by the partner from whom the customers came. In another adaptation the peer providers are not charged for using their own charging points, and the difference between balances from the provision of charging points and from charging at other charging points is settled in the monthly billing. Invoices are created only when there have been transactions associated with the user—that is, when the user has charged at other charging stations or other users have used the user's charging station (Fig. 6).

Administration

In addition to the core processes, we designed to-be process models for administrative tasks that are concerned with actions that the user can perform on the online portal. Since the focus of the process analysis is on registration, authentication, charging, and billing, only one reference process was captured (from Stadtwerke Münster), and the remaining processes were designed from scratch. Required processes are concerned with registering a bank account, applying for (and possibly suspending) an authentication card, registering and removing charging points, changing opening hours, and eventually deactivating the user account.

Registering a bank account is essential for the CrowdStrom service, as at present customers can use the service only if they register a valid bank account. Customers can register a bank account in the customer portal, which is then validated by

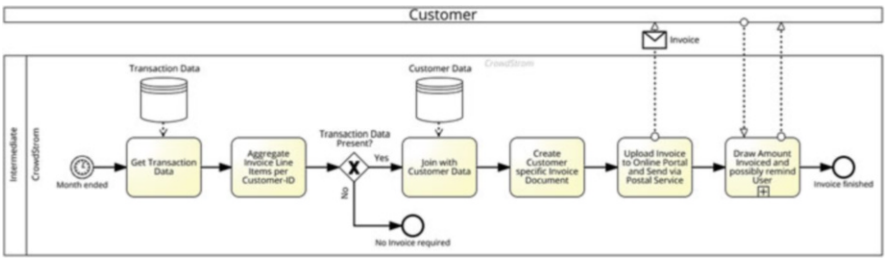

Fig. 6 Section of CrowdStrom's user billing process

CrowdStrom. If a registered bank account is invalid, the customer is informed via e-mail and asked to correct the details; otherwise, the customer is prompted to authorize a SEPA direct-debit mandate.

The CrowdStrom RFID card, which is required for customers to authenticate at the charging points of the CrowdStrom network, can be ordered via CrowdStrom's customer portal. The card is sent only if a valid bank account has been entered; otherwise, the customer is prompted via e-mail to enter a valid bank account. Only one active card is allowed per customer, so customers who request duplicate cards are informed that they can receive a new card only if the old one is suspended. When the card is sent, the card's ID is connected to the customer's user account. The card is sent by mail and is instantly operational.

If the card is lost or stolen, the customer can suspend the card via the customer portal. The request is transmitted to CrowdStrom, and if a card is linked to the requesting customer, the card's ID is removed from the customer data and stored in an archive with the customer ID, and the card can no longer be used for authentication.

Customers can register additional charging points on the user portal at any time by entering the required data into a form and transmitting it to CrowdStrom. CrowdStrom determines whether the customer has a valid bank account, assesses whether the charging point conforms to CrowdStrom's standards, and informs the customer of the result via e-mail. Then an external service provider connects the charging point to the CrowdStrom network, after which CrowdStrom determines whether the information entered conforms to the actual charging point and whether the station is connected to the power network correctly. Only after the station passes these tests is a corresponding record created in the database.

Active charging points can be removed from the network when a customer requests it on the customer portal. In such cases, the charging point's status is changed to "deactivated" in the database so users can no longer be authenticated and so the charging point is no longer displayed by the search function on the homepage.

Opening hours ensure that the owners of charging points can use their station exclusively at certain times. Opening hours are defined during the initial registration of a charging point but can also be changed on the customer portal. Changes take effect immediately, as long as the charging point is not in active use by a customer.

Customers can also disable their accounts via the customer portal. Deactivated customers cannot offer charging points or authenticate at the charging points within the CrowdStrom system.

Sorted by the respective process category, Table 2 provides an overview of all to-be processes for CrowdStrom that were the result of the *process analysis* and *process redesign* phases.

Table 2 Overview of to-be processes for CrowdStrom

Process category	To-be process
Registration	Registration
	Registration via contracting partner
Authentication	Authentication
Charging	Start charging procedure
	End charging procedure
Billing	User billing
	Provider billing
	Settlement contracting partner
	Response to contracting partner
Administration	Register bank account
	Apply for CrowdStrom card
	Suspend CrowdStrom card
	Register charging point
	Remove charging point
	Change opening hours
	Deactivate user account

5 Lessons Learned

After eliciting and analyzing as-is processes from organizations that are working in the EV-charging field for best practices and their applicability to CrowdStrom, we derived to-be processes tailored to CrowdStrom's requirements. Most of these to-be processes have already been implemented in a software prototype[3] that is currently used to gain insights into how well the processes perform in a real-world environment. In line with the *process monitoring and controlling* phase, the experience and feedback is being used to resolve issues and to adjust and improve the processes and the corresponding software.

Looking back at the approach chosen and the results achieved, we made several observations and derived corresponding lessons learned.

A joint research project with consortium members from industry and academia benefits all stakeholders but also poses challenges. Divergent interests and cultures must be combined and aligned in order to reach a common goal. In our case, analyzing and adapting the as-is processes to derive the to-be processes for CrowdStrom was the connecting and unifying element. Although the participants' understanding of and approaches to business process management differed initially because of their different backgrounds, discussing and deciding on final to-be

[3]A link to the prototype web portal can be found at the project's website, www.crowdstrom.de. The prototype is still under development and is subject to frequent changes. The online version is for testing and demonstration purposes only and is not connected to real charging stations or fed with real customer data. The project's website and the prototype web portal are available only in German.

processes provided all members with a joint basis for future activities regarding the further development of the project. Furthermore, joint research activities can have a real impact. We created real innovations regarding the business model and the corresponding business processes that Stadtwerke Münster plans to put into practical application.

Another observation concerns the nature of our case. Developing a P2P sharing platform for EV charging requires combining the technical aspects of EV charging with the allocative function of the Sharing Economy that connects supply and demand in a market. EV charging can be seen in the context of concepts like *Industrie 4.0* and *Cyber-physical systems*, where the goal is to develop a *smart service*. The P2P business models of the Sharing Economy focus on administrative processes that connect users and provide them with a comfortable customer experience. Although connecting these two domains poses a plethora of challenges, most of the fundamental problems can be solved by means of existing solutions that are either directly applicable to the case (administrative processes from the Sharing Economy) or adaptable to the requirements of the case (technical processes regarding the charging of an EV).

Based on the results from the application of the BPM lifecycle, CrowdStrom will advance in the near future into a mature solution operated by Stadtwerke Münster. Once the system has proven its functionality in the Stadtwerke Münster environment, the next step is to test the inclusion of peer providers in a local market. To this end, an extensive market analysis is underway to determine the number of potential customers (both providers and users) in the local market and the potential users' willingness to pay for such a charging service.

The BPM lifecycle provided the right tools for the problems we faced in our project—the absence of standards and reference models for the domain of EV charging—by providing a framework with which to elicit process models from organizations active in the field and to analyze, redesign, and implement them in a software prototype that is on the brink of live operation.

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