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Capturing the Bigger Picture? Applying Text Analytics to Foster Open Innovation Processes for Sustainability-Oriented Innovation

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Abstract: In open innovation initiatives for sustainability-oriented innovations, it is indispensable to have a wide array of engaging stakeholders. Yet, as not all relevant actors are able or willing to participate, important opinions can go unnoticed. Due to such stakeholder selection effects, aspects of high relevance may remain uncaptured. To address this issue, we first define the concept of silent stakeholders and relate it to sustainability-oriented innovations. We then discuss the new approach of employing analytical methods to examine existing sources outside the innovation process for silent stakeholder opinions. For this purpose, we conduct an action research study demonstrating how to examine broad discourse data with text analytics for an open innovation project aiming to create a sustainability-oriented innovation. To this end, we develop an approach for the efficient integration of external sources in open innovation processes. We find that text analytics of broad discourse data can particularly support the orientation and idea generation phase for sustainability-oriented innovation. Furthermore, we identify possibilities for the application of further data mining methods to complement open innovation approaches along the innovation process. Building on that, we propose an integrated framework. Hence, we add to the literature on stakeholder participation, analytical methods and innovation management, as well as sustainability-oriented innovation.

Keywords: sustainability-oriented innovation; open innovation; text analytics; data mining; discourse data; silent stakeholder; action research

1. Introduction

Innovation can be specified as "the multi-stage process whereby organizations transform ideas into new/improved products, services or processes, in order to advance, compete, and differentiate themselves successfully in their marketplace" [1] (p. 1334). As such, it can contribute to the deployment of more sustainable processes, organizational methods, products, and services [2] and has, thus, been identified as an important means to support sustainable development [3,4].

However, the development of—particularly from a long-term perspective—successful sustainability-oriented innovation (SOI) requires wide knowledge of societal and ecological interrelations which usually does not exist within individual organizations [2]. In line with that, Hansen and Grosse-Dunker [2] emphasize that the creation of SOI can be facilitated through stakeholder participation. An instrument that can enable stakeholder involvement is open innovation (OI).

Yet, the challenge in OI processes for SOI is not merely the integration of stakeholders directly involved along the value chain, but also of those stakeholders concerned by (negative) social or environmental effects [5]. Therefore, it is vital to gather a wide range of relevant arguments. Thus, such OI initiatives call for the broad involvement of diverse actors.

While OI can give voice to stakeholders who freely share their arguments in the innovation process, the perspectives of actors not able or willing to take part may remain uncaptured [6]. Such selection effects of stakeholders can, thus, leave aspects of high relevance unconsidered. For example, Wendelken et al. [6] point out research gaps in examining such a non-participation bias.

One possibility to address this issue of what we define as "silent stakeholders" is to analyze external sources which may contain perspectives of pertinent stakeholders regarding the OI project. Such sources can range, for example, from social networks, forums of specialized communities, or other social media to news websites. So far, however, direct search OI methods [7] are neglected by research on OI [8].

Examining this kind of sources might represent an approach to include arguments of silent stakeholders in the innovation process despite their formal non-participation. Thereby underrepresented or unknown positions and aspects can be taken into consideration throughout the innovation process. Yet, evaluating such sources requires analyzing, structuring, and processing huge volumes of data. For that, analytical methods such as text analytics (TA) provide a suitable approach to address those issues with limited resources [9].

Against this backdrop, the following research question arises: *How can TA of broad direct search data support OI for SOI?*

To address this question, we conduct an action research study [10] within a research project in which OI processes serve to create sustainability-oriented services for electric mobility (e-mobility). First, we analyze in which innovation phases direct search methods can support conventional OI methods effectively. Second, to demonstrate how external sources can be analyzed efficiently for the integration of further perspectives in the OI process, we exemplarily examine the public digital discourse in leading German news websites concerning e-mobility. For the processing and examination of this rich database, we then apply methods of TA.

We find that the TA of broad discourse data is particularly suitable for supporting the early innovation phases of SOI. As these phases are of major importance in reducing risks and uncertainties regarding sustainability issues [11,12], we highlight the significance of our approach for the development of SOI. Moreover, we examine the potentials of other data mining approaches to supplement OI methods throughout the innovation process and propose a framework for that. Thereby we especially add to the discussion of the importance of OI for the development of SOI [13–15], to the literature on direct and indirect stakeholders [16–19], (open) innovation management [7,20–24], and analytical methods [25–27], as well as SOI [2,3,21,28–31].

This paper's structure is the following: Section 2 reflects the state of the research on OI and SOI based on the literature and explains the issue of silent stakeholders. Our methodology and study implementation is outlined in Section 3 before our findings are summarized and interpreted in Section 4. In Section 5, the applicability of broad direct search data analyzed by TA is discussed. Based on these insights, theoretical and managerial implications are derived in Section 6. Moreover, limitations and topics for future research are reflected upon.

2. Background and Terminology

2.1. Complexities of Sustainability-Oriented Innovation

Research on innovation from a perspective that includes economic, environmental, and social dimensions has emerged during the last decade [28]. Various terms exist that describe this holistic and integrative approach [29] including "sustainable development innovation" [32], "sustainable innovation" [33] or SOI [3,21] but to date, no clear definition of those terms has prevailed [30,34].

In the present paper, our understanding of this approach is based on the term SOI which Hansen and Grosse-Dunker [2] (p. 2407f.) define as "the commercial introduction of a new (or improved) product (service), product-service system, or pure service which—based on a traceable (qualitative or quantitative) comparative analysis—leads to environmental and/or social benefits over the prior version's physical life-cycle ("from cradle to grave")". This broad concept emphasizes economic, environmental, and social target dimensions along the innovation's life-cycle. Furthermore, it includes relative enhancements compared to former versions or another object and can thus also be considered as a process toward sustainability [29].

To specify sustainable innovations, Blind and Quitzow [30] collected different criteria from literature reviews of Hansen et al. [3], Schiederig et al. [28], Klewitz and Hansen [29], and Adams et al. [31]:

- The innovation object encompasses product, process, service, product-service system, and methodological innovations as well as organizational innovations.
- The market orientation of the innovation is characterized by the satisfaction of needs and their competitiveness on the market.
- The innovation should reduce negative environmental and/or social impacts.
- The whole life-cycle of an innovation should be considered, especially material flows and their ecological but also social effects.
- The intentions of the innovation are economic and ecological and/or social aspects.
- At the organizational level, the innovation should set a new standard.

Those aspects confront innovation management with increased complexity, risks, and uncertainties [35]. Traditionally, innovation management mainly focuses on the innovation object's economic success [36]. This creates already a great challenge for the management of conventional innovations since the difficult predictability of customer needs and behavior, besides future economic conditions, makes an innovation's market success uncertain [37]. The success of SOI, however, is not only measured in economic terms but takes social and environmental layers into account. Following that argument, Hansen and Grosse-Dunker [2] emphasize that economic, social, and ecological aims which form the "target dimension" of SOI are strongly interrelated. Bio-fuels, for instance, can contribute to reducing the transport sector's CO_2 emissions (positive ecological effect), but its cultivation may also lead to increasing food prices (negative social impact) [3,38,39]. Consequently, the management of SOI cannot consider the layers separately without considering the impacts on the others [2].

Another issue related to the target dimension is the uncertain direction of the environmental and social effects of innovations referred to as "directional risks" [40], i.e., their contribution to sustainable development is difficult to predict, especially in the long term [3]. Those types of risks include rebound effects or growth risks [21]. For instance, electric cars are discussed as a sustainable alternative to fuel-based automobiles if they are charged with energy from renewable sources (e.g., [41]). This can, however, lead to increased car ownership of environmentally conscious consumers who previously did not own a car [21].

Together with the target dimension, Hansen et al. [3] describe the 'life-cycle dimension' as vital to define the desired results of SOI. To detect and approach sustainability issues at their source, it is considered essential that SOI takes the whole value chain into account [2,42]. Innovation management in the context of SOI, thus, has to widen its traditional focus from the direct value creation for customers (phase of usage) to the complete life-cycle of an innovation [2]. In particular, as critical sustainability effects arise here, Hansen et al. [3] point out the major importance of five life-cycle phases for SOI: supply chain, manufacturing, packaging plus distribution, usage, and end-of-life. Along those phases, the management of SOI needs to consider economic, ecologic, and social target spheres which are interrelated and affected by directional risks. Therefore, the complexity, as well as success-related risks and uncertainties increase significantly by considering those three spheres in the target dimension along the entire life-cycle of an innovation [2].

Moreover, as SOI encompasses various forms of innovations, the "innovation type dimension" [3] adds further complexities. Since efficiency gains from technical innovations are often overcompensated by rebound effects and many life-cycle improvements depend on the intensified interaction between the producer and customer, Hansen et al. [3] emphasize the leveraging role of product-service system innovations and business model innovations for SOI. For example, car-sharing systems can reduce car ownership [43] and if the fleet is equipped with electric vehicles, it can raise acceptance for e-mobility and thereby induce a transition from fuel-based to electric cars [44].

As a consequence of the described multidimensional complexities, developing SOI requires a wide knowledge on social and environmental aspects exceeding the scope of one single organization [2]. To face the complexities and special challenges of SOI, Paech [21] suggests keeping the innovation object as moldable as long as possible to interact with various stakeholders when carrying out the innovation processes. Such stakeholder engagement can be enabled through OI.

2.2. Open Innovation as an Instrument for Participation

The concept of OI was originally introduced to describe emerging models of innovation that strongly rely on the contributions of external actors. These models are in contrast to the traditional organization of innovation which focuses on experts within the organization [45]. Today, OI has been researched extensively from different scholarly perspectives and is applied in various industrial domains [24]. Chesbrough and Bogers [8] define it as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries" (p. 17). In the literature, different advantages of following the OI paradigm are discussed [46–48]. Particularly, it is seen as a chance to innovate successfully and to improve the effectiveness ("fit-to-market") as well as efficiency ("time-to-market" or "cost-to-market") of the innovation process [20]. Furthermore, Yun et al. [49] show in their patent analysis that OI can have a positive impact on the sales of companies from the IT convergence sector.

OI can be conducted through different phases of innovation. Reichwald and Piller [20] adopt a linear development process comprising five phases: idea generation, concept development, prototype development, product/market test, and market launch. According to the authors, each phase can serve as the starting point for including external actors into development activities. Considering the above-described sustainability-related complexities, Paech [21] suggests adding a phase of orientation with respect to the problem definition at the beginning while Vahs and Brem [22] recommend supplementing a control phase at the end of the process. We use a combination of these suggested phases as our underlying innovation process model which is shown in Figure 1 and described in Section 3.2 in detail.

Figure 1. The model of the innovation process following Reichwald and Piller [20], Paech [21], as well as Vahs and Brem [22].

Dahlander and Gann [47] distinguish four basic OI approaches (cf., Table 1) based on the different directions of knowledge streams (outbound and inbound) and the kind of compensation (non-pecuniary and pecuniary).

As we seek to support the development of SOI from an innovator's perspective who sources information, our article focusses on inbound OI. Gaining external information is the heart of such approaches. For the operationalization of inbound OI approaches, Chesbrough and Bogers [8] identified different OI methods such as licensing IP, crowdsourcing, contests, and communities which enable organizations to manage purposive knowledge inflows. In our article, we particularly consider the following OI methods:

- Innovation workshops: Such workshops enable face to face interactions among their participants to find creative solutions for innovation-related problems. Often they are carried out with lead users of the product or service under consideration [50,51].
- Online innovation communities: Such communities allow their members to collectively discuss ideas and develop solutions. As they are realized via a web-based infrastructure, they foster knowledge transfer without any spatial or temporal barriers [52–55].
- Ideation contests: In an innovation contest, the organizer broadcasts a particular innovation-related challenge for which participants can contribute their proposals. Typically, these contests include certain rewards to foster motivation and are realized via the internet to ensure a broad reach [56–58].

Innovation workshops, online innovation communities, and innovation contests foster the inbound knowledge transfer from the perspective of the organizer. Amongst others, they can be applied to discover and harness ideas and expertise from various stakeholders such as customers, business partners, research institutes, as well as non-governmental or governmental organizations [13–15]. Furthermore, research indicates that solutions developed in a co-creative manner are more likely to be accepted by stakeholders than solutions derived from closed development initiatives [59]. Hence, OI can be a powerful means to foster successful and stakeholder-focused innovation. In the next subsection, we examine how innovation workshops, online innovation communities, and innovation contests can contribute to the development of SOI.

Table 1. The open innovation approaches following Dahlander and Gann [47].

	Pecuniary OI	**Non-Pecuniary OI**
Inbound OI	Acquiring: e.g., paying for ideas or technologies	Sourcing: e.g., obtain ideas or technologies without payment
Outbound OI	Selling: e.g., getting paid for ideas or technologies	Revealing: e.g., providing ideas or technologies without payment

2.3. Sustainable-Oriented Innovation and Open Innovation

Moving towards increasingly sustainable production and consumption forms typically requires more than just technological innovations but a systemic change in technologies, behaviors, and structures. As OI allows such complex questions to be addressed, it can contribute to the sustainability-oriented transition of organizations and society [60] and, therefore, also to SOI. Arnold [13] argues that each OI method has different potentials for the identification and resolution of sustainability challenges. In our action research study (cf., Section 3), we implemented a mix of the above mentioned OI methods (ideation contests, innovation workshops, as well as online and offline communities) to innovate services for e-mobility. Therefore, the following paragraphs focus on these methods and their potential to contribute to SOI.

Table 2 gives an overview of the potentials and target groups, as well as the costs of different OI methods. Regarding sustainability-oriented challenges, ideation contests allow the generation of a broad range of proposals. Nevertheless, the ideas submitted must often be refined. Due to their interactive elements, communities, as well as workshops, are appropriate to address and to discuss sustainability issues in more depth and to bring together diverse perspectives [13].

Regarding user groups, participants tend to be more specific, the higher the degree of user integration is. Innovation workshops, for instance, are particularly appropriate for lead users. With regard to our illustrative case in Section 3, such lead users could be, for example, drivers who already own and/or use electric vehicles. They are more capable and motivated to innovate new services for e-mobility than skeptics of this mobility form. Different user types participate in ideation contests and communities, but all of them are affected by or interested in the topic [13].

Table 2. The potential and costs of open innovation methods to contribute to sustainability-oriented innovation. Source: adapted from Arnold [13] (p. 372). In her overview, Arnold originally focused on the link between open innovation and corporate responsibility. As corporate responsibility and sustainability-oriented innovation relate to the contribution of a firm to both social and ecological objectives, we re-interpreted her overview, focusing on sustainability-oriented innovation.

Criteria of OI Method	Innovation Workshops	Community	Ideation Contests
Aims and functions	• Expand the knowledge base • Seek and find possible solutions • Initiate change processes • Support and legitimize decisions	• Expand the knowledge base • Initiate change processes • Legitimation of SOI • Discussion of interests and ideas	• Expand the knowledge base • Improve the organizations' image • Legitimation of SOI • Initiate change processes
User groups	Lead users, dedicated users	Very involved individuals interested in interaction and knowledge exchange	People concerned with the specific topic
Phases of innovation process	Depends on the desired objective	Depends on the desired objective	Depends on the desired objective
Users' knowledge	Need-based and solution-oriented	Solution-oriented	Need-based and solution-oriented
Costs	Appropriate—high	Very high	Appropriate—high
Influence on SOI	• Not just incremental, but also radical marketing or product innovations possible • Novel product or service strategy	• Not just incremental but also radical service or product innovations; • Announcing novel products or services	• Primary radical product, service, or marketing innovations • Announcing novel products or services • "Green Marketing" of enhanced products or social actions; • Novel product and service strategy

In order to acquire solution- and application-oriented knowledge, workshops and ideation contests are particularly helpful because users typically provide this kind of knowledge. On the other hand, working with communities may prove difficult because filtering ideas and solutions could be a time-consuming and costly procedure. In this context, organizations are advised to use communities only to address specific issues or problems which require a solution. Thus, a combination of communities and idea competitions can be better to refine specific ideas as well as to combine these ideas with issue-related and existing communities. Moreover, the coordination and programming of platforms for such communities are expensive. In contrast, innovation workshops and ideation contests require moderate organizational effort and thus have reasonable costs. In general, the following rule applies: the more comprehensive the solution should be, the higher the costs [13]. Section 3 describes the interaction of these methods to develop a specific SOI.

In summary, OI poses an important participatory approach for SOI, as it allows different stakeholders to be brought together around commonly perceived sustainability issues [13–15]. In line with that, Hansen and Grosse-Dunker [2] argue that the participation of stakeholders along the innovation process can ease the creation of SOI and decrease directional risks. Despite the existence of such arguments, however, little is known about OI in the context of SOI [30,34].

2.4. Silent Stakeholders

Scholars classify stakeholders as direct and indirect [16,17]. According to Rowley [18], direct stakeholders are actors related to an organization by direct exchange flows of resources, while indirect stakeholders are not related by such flows. Friedman et al. [19] describe direct stakeholders as actors interacting directly with a system or its output, and indirect stakeholders as "all other parties who are affected by the use of the system" [19] (p. 3). Considering the particular complexities of SOI, it is of uttermost importance to integrate not merely the direct stakeholders throughout the innovation procedure who take part in value creation (e.g., suppliers, manufacturers, lead users), but also those indirect stakeholders who might be (negatively) affected by the innovation's social or environmental effects (e.g., residents, road users, communities) [5]. Hence, collecting a wide range of relevant viewpoints is essential for SOI. For that, OI initiatives for such innovation rely on the participation of an extensive circle of diverse actors.

However, the arguments of actors who are either not able or not willing to participate may not be considered [6]. Actors may not be able to participate because they lack the time or competencies; or because they are simply unknown which makes it difficult to address and invite them. Actors may not want to participate in OI formats if they oppose lead actors, specific formats, or a focal technology. Environmental activists may, for example, hold relevant information about challenges of nuclear energy but may be hesitant to share it in an innovation process to improve (and thus legitimize) nuclear technology. We group these actors with the term "silent stakeholders" which we define as direct and indirect stakeholders of a potential innovation who are not willing and/or not able to participate in OI initiatives for that innovation. Because of the stakeholder (self-)selection effects resulting from this phenomenon, relevant perspectives may remain uncaptured. This is particularly critical in innovation processes for SOI as increased complexities such as growth risks or rebound effects [21] require a lot of knowledge on social and environmental aspects [2] which silent stakeholders may hold.

Integrating silent stakeholders can thus be of great importance for SOI processes. First, the consideration of silent stakeholder voices is useful for improving an innovation's sustainability contributions. What is more, the consideration of silent stakeholders is also relevant to increase an innovation's social robustness and legitimacy. After all, if an innovation violates the interests of so far silent stakeholders later on, they might not stay silent indefinitely. Yet, if silent stakeholders turn loud and voice their criticism, organize a protest, and veto an innovation at a much later stage, then adapting an innovation is much more difficult if not impossible.

While silent stakeholders' voices can be potentially relevant for SOI, they are, by definition, difficult to capture with conventional OI methods. Furthermore, the implementation of OI methods can be costly and time-consuming [13]. Online innovation communities, for example, enable participants to exchange available solutions or novel ideas without spatial or temporal hurdles. Thus, such communities can serve as a platform for ideation contests as well as broadcast search and thereby support innovation processes [52–55]. Yet, such communities need to be programmed, built up by acquiring members, and managed. In the long term, online community building is interesting as, once established, the thriving communities can provide a permanent participation infrastructure. However, in the short term, such OI methods can hardly produce better solutions for SOI [61].

A possible option to address those issues is to apply open direct search approaches to support OI initiatives. According to Piller and Hilgers [7], direct search relates to the classical method of information discovery in which actors actively search for suitable information, applying certain search terms and algorithms. If a direct search is oriented as broadly as possible to a wide range of sources, it can be defined as open [62]. Examples of open search methods are netnography and the lead-user approach [7].

Netnography is defined as a "qualitative research methodology that adapts ethnographic research techniques to study the cultures and communities that are emerging through computer-mediated communications" [63] (p. 61). As such, the approach provides a framework allowing scholars to analyze the culture of social media and online community data including chat rooms, virtual worlds, blogs, wikis, or social networking sites [63,64]. In doing so, netnography can provide information on cultural members, structures, and values [64] including consumer insights such as feedback on brands and products or innovative ideas [63]. Thus, it can generate information on stakeholder needs in an open direct search process by monitoring and analyzing the existing contributions of users in online communities [7].

The lead-user approach aims to integrate a selection of users in the innovation process who have particular desires prior to the average user and actively search for solutions [51]. This approach has proven to be particularly successful in finding technical solutions for a specific question [7]. For the identification of experts holding solution and market knowledge, an open but targeted search process in analogue markets is recommended [65]. Facing the specific challenges and complexities of SOI, we argue that this approach needs to be extended from lead users to lead 'affected' who hold knowledge about social and environmental interdependencies. Considering that, an extended lead-user approach would have great potential for the development of SOI.

OI research, however, has neglected research on open direct search methods and their integration in the innovation process. This is surprising as OI processes typically rely on voluntary participation and direct search methods could be used to mitigate the stakeholder self-selection effects and thereby give voice to the otherwise silent stakeholders. The following subsection, therefore, describes efficient and effective direct search approaches to improve the "fit-to-market", as well as "time-to-market" or "cost-to-market", of the innovation process for SOI.

2.5. Research Focus: Text Analytics in Direct Search Methods for Sustainability-Oriented Innovation

Open direct search might represent an approach that can address the issues described above by effectively examining external (from the perspective of a certain OI process) sources in which possibly pertinent stakeholders have shared their arguments in other formats thematically related to the respective OI project. Thus, considering their ideas, knowledge, and concerns can supplement any inbound OI process.

Depending on the innovation object, these sources can range from social networks (e.g., Facebook), micro blogs (e.g., Twitter), intermediary networks (e.g., LinkedIn), forums of specialized communities, to wikis, review-related websites, or news websites, etc. The examination of such sources might represent an approach to include perspectives of silent stakeholders in innovation processes, even without their direct participation in a certain OI initiative. For example, Twitter users might have discussed critical aspects of e-mobility such as visually impaired pedestrians having problems orienting themselves without engine noises. Discovering such issues might support the development of new services in that field such as special noisemakers. Thus, by analyzing such sources, unknown or underrepresented positions and aspects might be discovered and taken into account throughout the innovation process.

However, the amount of data from these sources can be immense. For instance, in Twitter, we monitored over one million e-mobility-related tweets in 2017 by applying respective search terms. Furthermore, each source has different properties such as search functions or filter options, and various kinds of extractable data such as (user-generated) topics, texts, videos, pictures, number of shares, likes, answers, etc. Filtering relevant aspects from such databases is, thus, highly complex. Therefore, evaluating this kind of sources requires analyzing, structuring, and processing large volumes of data. To this end, modern analytical methods, such as TA, can provide a suitable and efficient approach [9].

Yet, OI research has neglected research on open direct search methods [8], particularly in combination with analytical methods. However, some scattered approaches exist in the innovation and consumption research literature. Kaiser and Bodendorf [26] conducted a study on mining and analyzing opinions from consumer conversations in online forums concerning the iPhone. Their study shows how to identify opinion tendencies and influential users through applying different TA methods and a social network analysis [26]. Pajo et al. [27] proposed a "Fast Lead User Identification" (FLUID) approach by which data mining methods are applied on social networking websites to discover lead users in an automated and precise way. Kozinets [25] also mentions data mining and content analysis approaches in connection with data analysis for netnography. Furthermore, Lee et al. [66] developed an advanced method to observe trends in technological changes by analyzing patent relations based on the formal concept analysis tool for grouping objects with mutual characteristics, while Jeon et al. [67] processed patent information data to establish an approach to find potential innovation partners.

Yet, those approaches are scattered and barely linked to the innovation process. Examining a specific case about the applicability of TA on broad direct search data in OI processes for SOI can, thus, pose an important first step in examining the possibilities and restrictions of data mining in the context of sustainable development and innovation. Based on this review, the research question of the present paper can thus be restated: *How can TA of broad direct search data support OI for SOI?* While reflecting that specific case, we seek to give a holistic overview of the possibilities of the integration of direct search methods supported by data mining in OI processes for SOI.

3. Action Research Study

3.1. Description of the Action Research Cycle

To answer this question, we conduct an action research study [10] within a nationally funded research project on creating service innovations for e-mobility through an OI approach, which can be categorized as inbound and non-pecuniary (cf., Table 1). As some of the targeted service innovations, sustainability labels in the field of e-mobility were created through the combination of different OI methods. To demonstrate how external sources found through a broad direct search can be analyzed efficiently for the integration of further information in the OI process, we exemplarily examine the public digital discourse in articles on e-mobility published on leading German news websites. For the processing and examination of this rich database, we then apply methods of TA. Next, action research is outlined followed by an illustration of the project background.

According to Hult and Lennung [68] (p. 247), "action research simultaneously assists in practical problem-solving and expands scientific knowledge. It enhances the competences of the respective actors, being performed collaboratively in an immediate situation using data feedback in a cyclical process, aiming at an increased understanding of a given social situation. It is primarily applicable to the understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework". In order to tackle a real world challenge, action research is based on collaboration between academics and practitioners [69]. Often, the action research process is depicted in a cyclic model [70]. According to Susman and Evered [10], an action research project comprises five stages (cf., Figure 2): (1) diagnosing, (2) action planning, (3) action taking, (4) evaluating, and (5) learning.

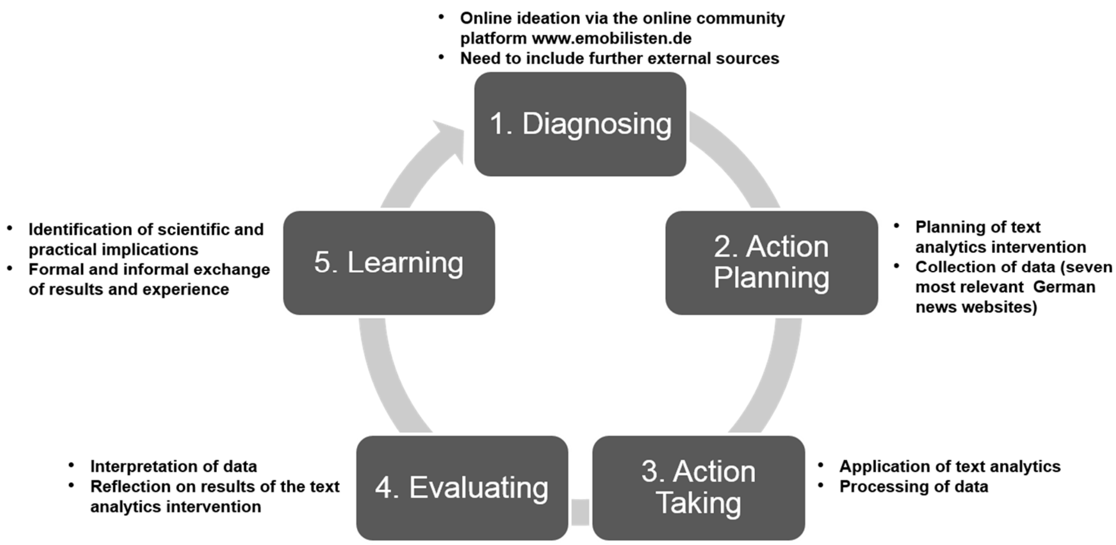

Figure 2. The applied action research cycle following Susman and Evered [10].

First, throughout the (1) diagnosis stage, as mentioned below (cf., Section 3.2), we encountered the challenge that most ideas were provided by a very active set of community members, mostly convinced proponents of e-mobility. Hence, we reflected on the possibilities to overcome this potential bias and to include heterogeneous demands of relevant stakeholders besides these community members. As a promising solution, we identified the public digital discourse concerning e-mobility in Germany as an already existing external source of knowledge. In order to analyze the public discourse on e-mobility, we (2) collected the data through direct search as well as planned and prepared the use of TA methods (e.g., cleaning the data), which we (3) applied in the third stage. Afterward, we (4) interpreted the results and reflected the application of TA methods. On the one hand, the (5) insights gained might be useful for a refinement and evaluation of the applied methods and, on the other hand, for the integration of further external data sources in the development of the sustainability labels.

3.2. Diagnosing the Project Background

We performed our study as part of the interdisciplinary multi-year research project "Community-based Service Innovation for E-Mobility" (CODIFeY). We chose CODIFeY because the fitting setting and the project duration allowed us to accompany the initiative for three years from 2014 to 2017. The main objective of CODIFeY was to raise the acceptance and amount of users of e-mobility within Germany by causing behavioral changes in individuals [71,72]. To reach this aim, an online community platform named eMobilisten (URL: www.eMobilisten.de) was set up in 2015. This platform incorporated three central elements:

1. Knowledge Creation: To reduce the lack of knowledge and to qualify community members to participate in service innovation, e-learning courses on e-mobility topics were provided. Additionally, community members were allowed to take part in the development of e-learning courses by contributing e-mobility-related experiences or knowledge.
2. Service Innovation: This module built upon several of the OI methods previously (cf., Section 2.2) described, namely ideation contests, the online innovation community, and innovation workshops. Based on these methods, community members cooperatively created novel services and solutions for e-mobility. After defining a certain innovation object, the services were developed in four consecutives phases (see Figure 1). In the early stages, ideas were collected, filtered, and selected. After that, the chosen ideas were transferred into concepts which were then evaluated. Based thereon, development and testing of prototypes took place. Subsequently, the market launch and management phases would have been conducted, but were not performed within the project CODIFeY.
3. Community Analytics: The behavior of participants on eMobilisten was monitored and evaluated by data analytics. Thereby, the interaction between service innovation and knowledge creation was promoted.

Moreover, permanent community management measures such as participant acquisition and relationship management supported the online innovation community.

As part of the service innovation component, the project consortium decided to develop sustainability labels for e-mobility. Such labels can assist in making sustainability-related attributes more transparent, reduce complexities as well as information asymmetries and thus support customers in purchasing situations [73]. Thereby, it can provide incentives for businesses to make their e-mobility solutions more social and environmentally friendly. Hence, those certifications can be categorized as product-oriented service SOI [2]. During the development of sustainability labels, questions emerge such as which stakeholders should be involved, which aspects should be certified, and which sustainability-related benchmarks should be included. Furthermore, the cost factors and complexities of such labels have to be limited to ensure the ease of implementation.

To facilitate the label development while addressing these questions, the OI methods communities, ideation contests, and innovation workshops were combined along the innovation process in CODIFeY. To do so, we followed the innovation process model shown in Figure 1.

- The "Orientation" phase serves to identify and analyze opportunities for SOI [21]. In this phase, the focus lies, in particular, on exploring the sustainability context including the concrete problems and legislation changes [74]. Thus, the boundaries of the innovation space are defined. In CODIFeY, secondary data were collected and analyzed manually followed by a workshop with e-mobility experts. As a result, this step yielded a categorization of sustainability-related effects and stakeholders of e-mobility (see [61]). Based on that categorization, opportunities for sustainability-oriented service innovations in the field of e-mobility such as sustainability labels were determined.
- In the next phase "Idea Generation", ideas for the determined innovation objects are obtained in a broad way e.g., [11]. For the idea collection in CODIFeY, we used different online and offline channels. Online community members were encouraged to contribute their ideas and opinions by a call for ideas for the creation of sustainability labels for e-mobility. To reach out to many stakeholders and ensure participation, we promoted this call on social media (i.e., Facebook and Twitter) and via direct acquisition (i.e., email and telephone). Furthermore, ideas were collected during relevant offline events. During the idea generation, however, we encountered the challenges explained below. As our action research study is conducted during this phase, we explain the subsequent development process of the sustainability labels only hypothetically.
- Next, the phase of "Idea Selection and Concept Development" serves to screen and evaluate the obtained ideas according to their environmental, economic [74], or social relevance. We then selected and transformed the most promising ones into concepts of new offerings [75]. In CODIFeY, the collected ideas were first subjected to a quantitative and qualitative content analysis. Based on that, an offline innovation workshop was initiated in which heterogeneous stakeholders such as lead users or experts develop concepts for the respective SOI.
- In the "Concept Evaluation" phase, these concepts are then evaluated by relevant stakeholders, experts, and lead users [76]. To realize that, in CODIFeY, the online innovation community on eMobilisten assessed the SOI concepts in a survey format.
- Subsequently, the "Prototyping and Testing" phase serves to develop prototypes of the respective innovation based on the assessed concepts which are tested afterwards [76]. In CODIFeY, we created the prototypes internally in collaboration with experts. Testing was then realized by offline workshops in which experts and lead users, among others, participated in.
- The phase of "Market Launch" is about subsequently developing the final prototypes to market maturity and commercializing them with implementation partners. At this point, the final outcome reaches the end users in the market and is implemented on a larger scale addressing the actual target group [20].
- During the "Management" phase, the innovation is subject to a continuous examination in order to adapt it to possible changes or for repeated applications in the future [22]. Thus, the innovation is reviewed regarding, for example, its sustainability impacts. Tufte and Mefalopulos [77] emphasize the role of stakeholder engagement in this phase to give feedback and participate in formulating indicators as well as measurements for evaluation.

Throughout the idea generation phase, 54 ideas with 68 related comments regarding sustainability labels in the field of e-mobility were collected. Based on a content analysis, we identified four categories for which contributors take a label into account: car manufacturer, electric cars, charging stations, and providers of mobility services (e.g., delivery services). Afterward, we assigned the mentioned criteria including frequencies to the topics. In the category charging stations, for example, the origin of the electricity was mentioned 18 times, the usability six times, and the material of which the stations are made four times. However, we encountered the challenge that most of the submitted ideas and comments were contributed by a rather small number of e-mobility lead users. Thus, particularly with regard to SOI-related complexities, there was a need to enrich their ideas with the demands of other stakeholder perspectives, including silent stakeholders, in order to foster a broad acceptance of developments. The next section describes our approach to do so.

3.3. Action Planning and Taking—Application of Text Analytics

Since a manual analysis of the text data is virtually impossible due to the large number of news articles, we decided to apply computer-aided TA. By using TA, we are able to integrate a very large amount of unstructured information (in this case, news articles) into the innovation process in a short time and with manageable effort. In other words, the application of computer-aided analytical methods enables for the potential integration of silent stakeholders in the innovation process in order to better capture the bigger picture. A manual processing and evaluation of this information would not be justifiable from an economic point of view.

In particular, we used the TA software Leximancer to retrieve information from the texts and, thereby, gain insights into the public digital discourse on e-mobility in Germany. Leximancer can be used for quantitative content analysis on a relational and conceptual level by means of unsupervised machine learning algorithms [78]. Concisely, the tool extracts word frequency and co-concurrency information from natural text data and transforms this information into semantic concepts (words or phrases with similar or identical meanings) which are then visualized in so-called concept maps (cf., Figure 3) [79]. As shown by Martin and Rice's [80] study on enterprise risk profiling concepts, the concepts identified by Leximancer are very similar to the results of time-consuming manual coding. Leximancer is suitable for recognizing contextual relationships and structures in large amounts of unstructured text data and it is, thus, well-established in various research disciplines including health care services [81,82], information systems [83,84], and corporate sustainability management [85,86].

Our approach is inspired by Debortoli et al. [87], who applied the Cross-Industry Standard Process for Data Mining (CRISP-DM) [88] for their text mining tutorial. The CRISP-DM model is considered the most established methodology for analytics projects within the data science community and is therefore well suited for our context [89]. We roughly structured our analysis into the six phases problem understanding (modified from business understanding in the CRISP-DM), data understanding, data preparation, modeling, evaluation, and deployment. We explain these phases in more detail below.

First, in the problem understanding phase, we defined the objectives for our TA project from the initial situation in the research project CODIFeY. As mentioned above, we planned to capture the public digital discourse related to e-mobility in Germany in order to enrich the development of sustainability labels. More explicitly, our goal was to understand and structure topics of interest with regard to sustainability and e-mobility as well as to delve deeper into certain concepts and their semantic connections in the news articles.

Second, in the data understanding phase, we collected our initial data set, which consists of e-mobility-related online articles of German news websites (Bild, SPIEGEL ONLINE, FOCUS Online, WELT, ZEIT ONLINE, stern.de, and SZ.de) within a period of five years (2010–2015). These news websites have been selected by considering the following aspects:

- We have only included primary sources and no news aggregators, search engines, or other secondary sources.
- Since we aimed to capture the general discourse on the topic of e-mobility in Germany and no discussions in expert communities or specific regions, we have selected nationwide general interest media that are thematically broad-based.
- In order to ensure reliability and to achieve comparability within our sample, we chose only news websites operated by renowned German publishers.
- Since we analyzed articles published during a period of several years, we included only websites offering an online archive that allows us to access all articles published in the period from 2010 to 2015.

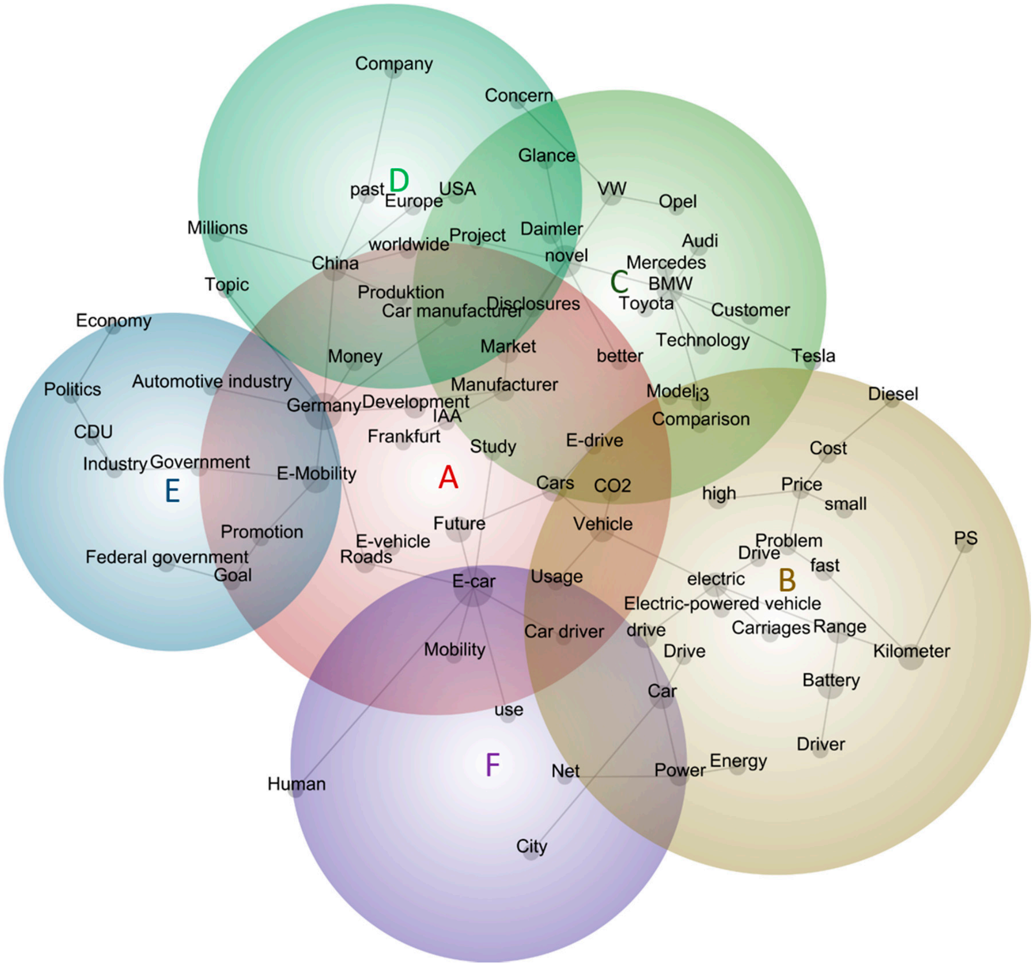

Figure 3. The overall concept map.

Considering these criteria, we have selected the news sites with the highest net reach in Germany [90]. The articles were manually downloaded as PDF files via the online archives of the news websites. To this end, we conducted a full-text search using the search term "Elektromobilität" (electric mobility). Our initial sample size consisted of 2054 documents. During an initial manual screening of the data, we noticed that we were not able to gather the articles from WELT in a processible format. Hence, we excluded these articles from the sample. Furthermore, we have removed articles which, although they have mentioned the term e-mobility, are only vaguely related to the topic. In the end, our adjusted database consisted of 1898 documents. The article length varies from short articles with only a few paragraphs to longer conductive articles with several pages (up to five). On average, an article consists of 56 sentences.

Third, in the data preparation phase, we applied Leximancer for various pre-processing tasks to improve the quality of our analyses. We used a predefined stop word list for German words, which was refined and modified in several iterations. In addition, we used various other functions of the software such as stemming, removal of HTML tags and URLs, and duplicate texts.

Fourth, while modeling, we performed a two-step analysis of our data set. First, we analyzed the entire corpus and visualized it by means of a concept map in order to get an overview of the topics discussed. To this end, we used Leximancer's linear topical clustering algorithm because it is more stable for highly networked entities as in our case [78]. Second, we focused on selected concepts that seemed relevant to us for the label development in CODIFeY. For this purpose, the Leximancer function "profiling" was applied. This function allowed us to examine texts in the spatial proximity of predefined concepts (in this paper, exemplified by the concepts CO_2 and battery; cf., Section 4) in order to gain a better understanding of the context in which they are discussed within the articles. For the analysis of these correlations, we used the Gaussian cluster algorithm of Leximancer and created concept clouds (cf., Figures 4 and 5) to display the results [91]. During the analysis, we found that the automatic recognition of concepts in the data did not work sufficiently well for our application scenario. As a result, concepts with identical or very similar meanings were treated separately. For example, four different concepts for batteries (battery, batteries, accumulator, accumulators) occurred. These issues may have been amplified by the fact that we have analyzed German texts. However, to improve the quality of results, we added manual coding to the automatic recognition of concepts.

Fifth, in the context of evaluation, we repeatedly discussed and reflected on interim results with fellow researchers in the CODIFeY project. In addition, we presented and applied our approach in three workshops with students and executives in order to uncover a potential for improvement and to demonstrate the practicability of our approach. Finally, we interpreted the results in the deployment phase, which is described in Section 4.

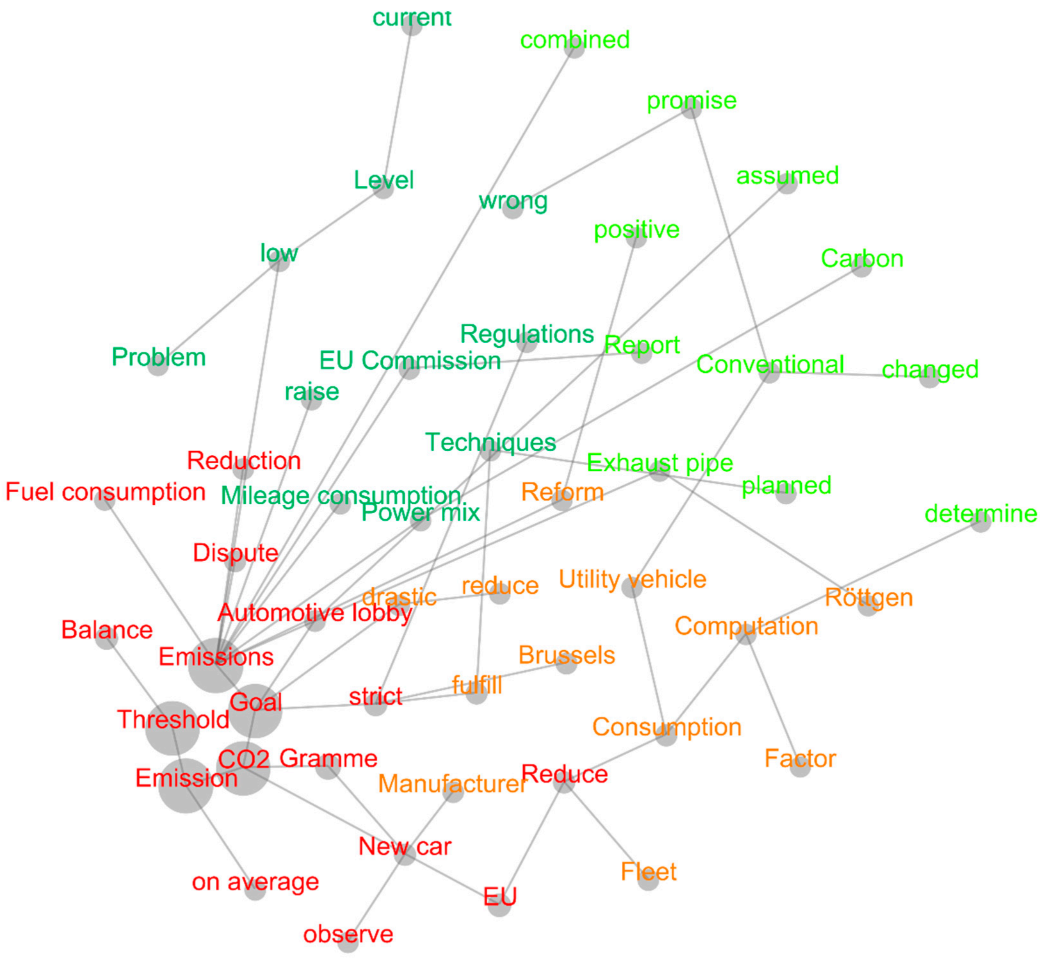

Figure 4. The semantic network of the CO_2 concept.

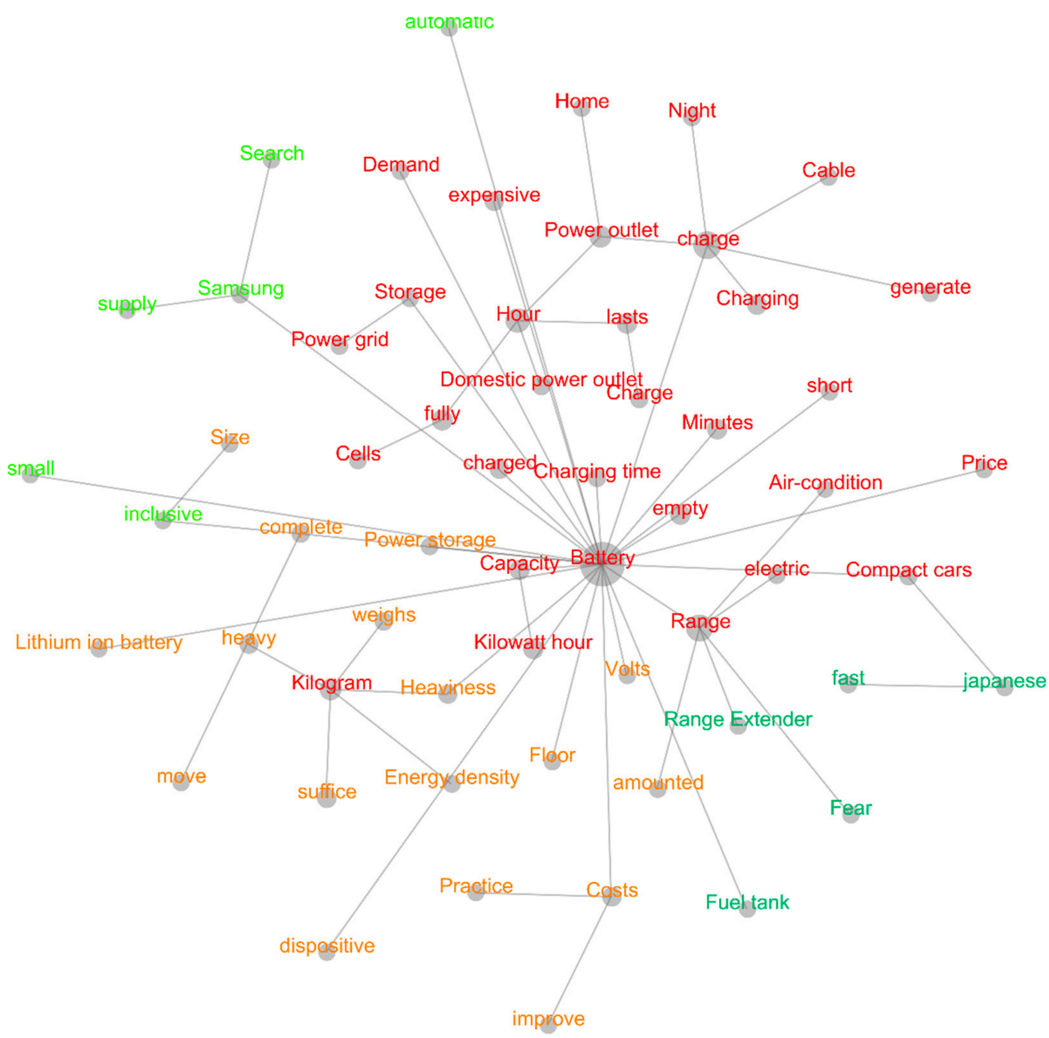

Figure 5. The semantic network of the battery concept.

4. Results

4.1. Findings from the Overall Discourse Analysis

This section presents the results from the TA processes, their interpretation and applicability in the innovation process for the sustainability labels. At the same time, this step represents stage (4) in the action research cycle: evaluation. Our first step in interpreting the TA results was to identify concepts and broader topic areas as well as their relationships to each other in the German discourse related to e-mobility. Figure 3 shows the overall concept map which results from our analysis of the text data. The concept map visualizes concepts as dots, where the size of these dots rises with increasing connectivity with other concepts on the map. Strong relationships between concepts are represented by edges, which leads to a network of related concepts. Concepts that occur frequently together in text sections are clustered in higher-level topic areas which are displayed as heat-mapped circles. The most relevant topic areas appear in red, the next one in orange and so on following the color circle. The following paragraphs describe the topic areas and the resulting recommendations for the sustainability labels in detail.

Electric mobility (A): This central topic area is connected to all other topic areas and hosts the most frequently discussed topics. Among these, automobile-related terms such as electric cars, automobiles, and electric vehicles can be found. Further central topics are Germany, the future, and industry-related subjects such as car manufacturers. This points to the major importance of the discussion about the future of the automobile sector in Germany. Those relations in the discourse can also give indications of the focus of sustainability labels. Hence, a focus on electric cars and their producers can be deduced from the discourse analysis.

Technology (B): The second most discussed thematic area hosts technology-related topics such as the battery, electric, energy, and drive. Furthermore, often addressed challenges and potentials in connection with the new technology can be found. Range, high speed, infrastructure, and battery, as well as monetary aspects such as price and costs, are associated with the topic problem. Moreover, drivers are often discussed in this context. On the other hand, potentials such as reducing CO_2 emissions, performance, and enjoyable driving experience are often mentioned. Accordingly, a focus on those technical components while addressing connected economic, ecological, and social challenges and opportunities can be reasonable.

Automobile manufactures (C): This thematic area includes diverse car manufacturers. Among these, mainly German companies such as VW, BMW, Mercedes, and AUDI are addressed. The only foreign producers often discussed are TESLA and Toyota. Furthermore, topics directly connected to the manufactures such as compact cars, technology, or electric drive are frequently mentioned. These results suggest considering cooperation with important manufactures for the label development.

Markets (D): This thematic area mainly addresses the global market for e-mobility. Topics such as worldwide scale, production, and businesses are discussed in the context of the leading markets of China, USA, and Europe. These results point out that sustainability labels for e-mobility should be developed for and distributed in those markets first. Interestingly, the topic of China is often mentioned in connection with the number one million which the German federal government was aiming for in terms of electric car ownership in Germany by 2020. This arguably reflects the fear of the German automotive industry and the government being overtaken by Chinese manufacturers.

Stakeholder (E): This cluster primarily hosts further stakeholders related to e-mobility. We identified broader terms such as politics, industry, and research as well as more specific terms such as SPD and CDU (important German parties), the federal government, and the automotive industry. Thereby, our results indicate close ties between politics, business, and research. Furthermore, related terms such as development, expansion, subsidies, and aims display how the mentioned stakeholders work together on the development of e-mobility in Germany. For example, money and subsidies are frequently discussed in the context of governmental and industrial collaboration in advancing electric mobility. For the development of sustainability labels for e-mobility, these results suggest considering cooperation with these stakeholders while also considering their respective ties and interactions.

Usage (F): This thematic area sums up topics related to the actual use of electric vehicles. The usage is particularly discussed in connection with urban areas. Furthermore, the issues of individual mobility and the electricity supply system are often mentioned in relation to the use of electric vehicles. For the development of the labels, it can, thus, be recommended to address the actual use of electric vehicles, especially in the urban context and to emphasize clean electric energy supply and individual mobility needs.

4.2. Findings from Zooming into Single Topics

To advance the interpretation for the development of sustainability labels in the field of e-mobility, we used the profiling function of Leximancer allowing a detailed analysis of every single term on the map in Figure 3. These zoom-ins also follow the heat map principle: the warmer the color of the term, the more often it was mentioned. In the following sections, we illustrate the example of zooming in and describing the topics of CO_2 and battery which we consider as highly relevant for the label development. Based on that, we make further recommendations for the sustainability labels.

CO_2 (cf., Figure 4): The most relevant terms in connection with CO_2 are limits, balance, European Union (EU), and aims. It becomes clear that the most important topic is the reduction of CO_2 emissions in accordance with the strict limits of the EU. In this context, politics-related terms such as Altmaier (German federal environment minister in 2012 and 2013), the EU Commission, Brussels, automotive lobby, and reforms are often coined. Furthermore, the comparison to diesel engines, fuel, and fuel consumption plays a major role in the discussion about the contribution of e-mobility regarding CO_2 savings. In this context, coal and energy mixes are often mentioned, reflecting the importance of the energy supply when charging electric vehicles. Moreover, the topics already indicate the diesel gate scandal which went public only at the end of 2015 and is, thus, only partially included in the data. In addition, automobile manufacturers and car fleets of companies are often discussed regarding CO_2 emission limits and reduction. These results indicate that sustainability labels for e-mobility should foster the reduction of CO_2 emissions, especially by promoting charging with renewable energy. Furthermore, particularly with regard to CO_2 limits, such labels should allow a comparison with vehicles powered by internal combustion engines and, thereby, emphasize the alternative which electric vehicles can represent within the car manufacturer's product portfolios and for car fleets of diverse companies.

Battery (cf., Figure 5): The most discussed terms related to battery focus on the charging process. Charging, charging time, range, charging stations, and sockets are often mentioned in this context. Moreover, challenges connected to the capacity such as energy density, fear, air conditioning, winter, weight, and low range are frequently discussed. Further challenges such as expensive acquisition costs and lifespan are also often mentioned. On the other hand, potentials such as recuperation by braking and energy storage as a buffer for the power grid are frequently discussed. In addition, technological aspects such as plug-in and range extender are often mentioned. For the label development, these results suggest specifically addressing the charging process and the mentioned challenges about the component battery. Additionally, these results suggest fostering the potential of applying batteries of electric cars as energy storage in the domestic context through bidirectional charging or as a stationary application after the battery has become too weak for the vehicle.

After the analysis of the overall map and the deeper analysis of relevant topics, it can be stated that the German e-mobility discourse has a very political character and focuses dominantly on electric cars, the challenges related to the battery and the charging process, as well as the automotive industry. Therefore, electric cars, their most discussed component, i.e., the battery, and charging processes can be important categories for sustainability labels. For the development of such labels, the automotive industry and the public sector represent important stakeholders. Furthermore, numerous technical aspects play important roles in the discourse, which could represent an obstacle for uninformed potential users. Consequently, a sustainability label addressing those aspects should also simplify these for potential customers. Additionally, science and politics are often mentioned in the discourse and should, therefore, be considered as important stakeholders for the label development.

4.3. Applicability in the Innovation Process for the Label Development

In the next step, we tested the results from the TA of broad discourse data for usability in the idea generation phase of the innovation process. In this phase, the resulting clusters and word occurrence supported the identification of important topics and stakeholders. Based on that, further stakeholders were invited to participate in the idea generation and the previously identified label categories were critically revised and thereby confirmed.

However, the structures that can be filtered from the concept maps and profiles were too general to support the idea generation phase with concrete ideas from silent stakeholders. Thus, we examined the applicability of the filtered structures in other phases and found that our TA results can best serve to support the orientation phase. In this phase, the structures filtered from the concept maps and profiles supplemented the previously made categorization of sustainability-related aspects of e-mobility with further topics and stakeholders. Particularly, the word occurrence served as an indicator of the relevance of certain aspects. We then used these findings for the label development. Furthermore, the mined data supported the identification of further opportunities for sustainability-oriented service innovations in the field of e-mobility. For example, based on the importance of the topic of batteries and its connection to environmental issues, we launched the idea generation for the further innovation challenge "A second life for electric car batteries".

Furthermore, we can derive implications about the efficiency and effectivity of the TA approach applied in CODIFeY. While the planning, data collection, execution, and interpretation of our TA approach took one month of working time for one person processing 1898 documents, a previously made manual collection and analysis of secondary data (cf., orientation phase in Section 3.2) took three months of working time for one person. Moreover, the manual coding only processed 43 relevant articles. By comparing the results of the manual processing with the outcomes of our TA approach, we evaluated the correctness of the identified topics and stakeholders. In doing so, we were able to validate the accuracy of our method. Thus, these results show that the structured screening with Leximancer can be faster and cheaper compared with a desktop research applying a manual evaluation while achieving similar results. More specifically, the topic modeling approach we conducted allows for the efficient evaluation of a vast amount of sources. Moreover, the fact that the amount of data proceeded with TA is almost arbitrarily scalable further underlines the efficiency of this approach. Furthermore, after testing our approach in different workshops with students and executives, we confirm the ease of use and practicability of our method.

Our results, thus, indicate that the TA of broad discourse data can particularly support the development of SOI in the very beginning of the of the innovation process: the orientation phase. The next section discusses the general applicability of our approach to foster OI processes for SOI.

5. Discussion

This section discusses the applicability of broad direct search data analyzed by TA to enrich OI processes. At the same time, it should represent stage (5) in the action research cycle (cf., Figure 2): learning.

By addressing the largely unexplored question of how the TA of broad direct search data can support OI for SOI, we propose one of the first approaches in developing a method for the efficient integration of external sources in OI processes through the application of TA. Our approach offers the possibility to capture a broad discourse and examine it from different perspectives at different levels of granularity. Considering the innovation process of SOI, we find that the TA of broad discourse data is best suited to support the orientation phase. In this phase, the mined text data can supplement the identification and analysis of opportunities for SOI by efficiently detecting sustainability-related topics and stakeholders of an innovation space (e.g., e-mobility). Moreover, the relevance of such aspects can be indicated through word occurrence. Thus, the TA of broad discourse data can enhance the efficient definition of the innovation space, the identification of concrete opportunities for SOI, and contribute to the preparation of the idea generation phase.

Furthermore, based on the experiences gained during the action research, we suggest applying different direct search methods combined with analytical methods in different phases along the innovation process of SOI (see Figure 6). These methods can then serve to complement OI approaches in the respective phase. Arguably, netnography can bring forth concrete ideas or feedback for a certain innovation because it aims to analyze the dialogues of potential customers or users [64]. Therefore, we propose the application of netnograhpy during the idea generation and management phase. In the case of SOI, however, this analysis should be widened to stakeholders potentially (negatively) affected by the innovations impacts [5], which requires consideration of additional sources and the processing of more data. Thus, netnography supported by data mining [25] can represent an efficient approach. More specifically, this could be realized by applying, for example, Kaiser's and Bodendorf's [26] opinion mining approach which is based on TA methods and a social network analysis.

Moreover, we recommend applying FLUID [27] to identify lead users efficiently. This has great potential to supplement indirect OI methods in the innovation phases of idea generation, idea selection and concept development, concept evaluation, and prototyping and testing. As it is highly relevant to generate solution-oriented knowledge in these phases [13], the efficiently identified lead users can then be invited to join indirect OI methods such as ideation contests or offline innovation workshops. Following the argument mentioned above, FLUID should also be widened to the identification of sustainability-relevant stakeholders in order to develop successful SOI. Synoptically, Figure 6 shows our proposed framework integrating the described indirect and direct search OI approaches combined with the discussed analytical methods along the innovation process for SOI. Building on that, the following section describes the theoretical and managerial implications as well as recommendations for future research.

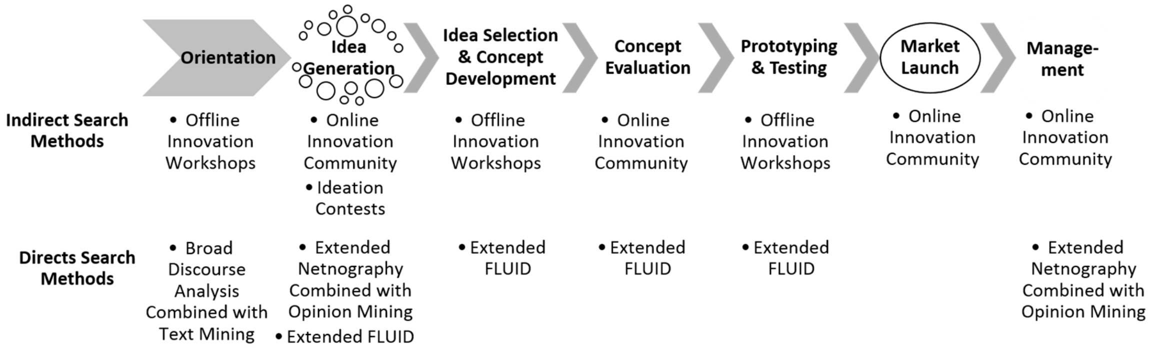

Figure 6. The open innovation methods and data mining support along the innovation process model following Reichwald and Piller [20], Paech [21], and Vahs and Brem [22], as well as building upon the results of our study.

6. Implications and Conclusions

By showing how TA of broad discourse data can support the early innovation phases of SOI, we expand the literature on opportunity identification [21] and analysis of sustainability aspects [74] in these phases. Furthermore, we add to the discussion of OI being an important instrument for the development of SOI [2,13,14,34].

Following Gregor's [23] taxonomy of theory types, our proposed framework contributes to the nascent theory for design and action in the field of OI for SOI. It presents prescriptive knowledge for planning and executing future inbound OI initiatives striving to give a voice to silent stakeholders. Besides, by introducing the framework, we add to the literature on direct OI search methods [7] as we link these with different data mining approaches to support indirect OI methods along the innovation process for SOI [21].

Moreover, our work is pioneering in its definition of the concept of silent stakeholders, relating this issue to SOI, and in its discussion of ways to identify them and their positions. In doing so, we add to the literature regarding direct and indirect stakeholders [16–19,92] and their participation in the creation of SOI [2,13]. Future research can use the concept of silent stakeholders to further investigate why certain actors are either not willing or able to participate in OI and how additional methods can capture the perspective of so-far silent stakeholders.

From a managerial perspective, TA, in the way we used it, can support the definition of the boundaries of the innovation space for SOI in which various sustainability-related topics, actors, and non-intended directional risks [21] are to be identified. Furthermore, we highlight ways to particularly support OI initiatives in the early innovation stages. For the development of successful SOI, this is of major importance as the majority of their future direct and indirect sustainability effects are pre-determined in the early innovation stages [42,93] from orientation to concept development. As central decisions on the profile of a new offering are being made, about 75–85% of the life-cycle costs are set within these phases [11,12]. Consequently, as these phases mark an important span to reduce risks and uncertainties concerning the market and technical [37] and sustainability issues [21], our data mining framework can pose an important tool to reduce risks in the development of SOI. More generally, we believe that our framework is appropriate to any innovation space that is publicly and extensively discussed. It enables practitioners to systematically disclose diverse viewpoints, fostering evidence-based decision making throughout the early stages of development.

Finally, by analyzing the limitations of our study, we derive recommendations for future studies in this field. First, considering the TA of broad discourse data, other relevant words could be considered as central terms of the word network (instead of e-mobility). Therefore, the identification of central terms is subjected to interpreter and selection bias. Furthermore, the database for the discourse relies on the usage of a single keyword ("Elektromobilität"). To capture more holistic e-mobility-related discourse data, other keywords may improve the database. Additionally, the stop word lists and clusters were created by experts and were therefore subjectively influenced. Such bias could be eliminated by the application of further TA operations (e.g., supervised machine learning).

From a methodological point of view, future research could analyze the same data with alternative methods, such as concept analysis, sentiment analytics, or further TA approaches. Furthermore, other databases and media such as social networks could be analyzed with regard to their usefulness as external sources for OI processes.

Another limitation lies in the analyzed news websites. On the one hand, these websites might offer a broad view of e-mobility. Given the existence of gate-keepers (in this case journalists), however, this form of public discourse might have its own selection-biases. As a result, it is possible that relevant silent stakeholders and their perspectives were excluded because of the filter function of the journalistic process. Even without such gate-keepers, certain stakeholder voices might be difficult to find in existing data sources as they do not equally participate in some discourses in the first place (such as in the case of elderly people and digital media formats). This shifts the focus towards the availability, diversity, and quality of the already existing data sources (e.g., data from social media) and towards the application of other methods of TA (e.g., concept extraction) to explore them. Thereby, existing direct search OI approaches (i.e., netnography, lead-user-identification) can represent important starting points for the application of analytical methods. However, future research is needed to test the applicability of mined data from such approaches throughout the innovation process. Particularly, the above-argued applicability of netnography supported by data mining and FLUID in certain phases of the innovation process for SOI should be tested, for example, in a more holistic action research.

Additionally, future research can refine the general idea of using TA for OI. From a conceptual perspective, a comparative framework could analyze the advantages and disadvantages of different text categories. Empirical research could explore how different real-life text categories yield different results with regard to the breadth and specificity of ideas for the OI processes. Coming back to the specific research question of this article, a next step to identify silent stakeholder perspectives could be to explore e-mobility-related social media where gatekeeper effects are less pronounced.

Notwithstanding these limitations, we are confident that our TA approach offers a fresh perspective for increasing the inclusivity, effectiveness, and efficiency of OI processes, particularly with regard to the complexity of SOI. SOI typically faces challenges such as unintended effects that can affect remote stakeholders outside the conventional innovation process. Exploring new ways in which to identify these silent stakeholders and their diverse needs is a worthwhile step in bringing to fruition the potential of OI for sustainable development.

Author Contributions: C.D., C.K., and P.W. conceived and designed the action research study; M.B. and B.D. were responsible for supervision; C.K. performed the text analytics operations and analyzed the data; P.W. wrote the paper. All authors contributed to the development of the manuscript.

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