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Experiences with Product Development Methodology in the Public-Private Research Campus Mobility2Grid

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Abstract

Product development practices have become an essential element for organisational competitiveness and success of the enterprises' innovation. Manufacturers and researchers need to work together and therefore focus on improving effectiveness to develop products at lower costs, with newer technology and more customer-focused. Research Campus Mobility2Grid as a large public-private research project has thus developed a methodology that specifically addresses this problem of product development and exploitation of research results. The methodology refers to different levels of abstraction. It comprises as main elements a cross-sectional work package in the superordinate project structure and distribution of work packages among the participating organizations (i.e. universities, research institutes, industry), the foundation of a dedicated spin-off, and innovation workshops for product development. This paper aims to explore how different types of ideas and projects are evaluated and selected in the context of the development of complex technological products. The implementation was accompanied by a qualitative research approach, workshops and observations that have been carried out with the cooperation of different companies. These elements of the methodology will enhance decision-making before finalizing market-ready products. A case example from the living lab of the European Energy Forum (EUREF) Campus in Berlin is presented to demonstrate the application of the proposed methodology. In the Research Campus Mobility2Grid companies from the energy and mobility sector as well as research institutes were participating. A spin-off was founded for the purpose to support the success of product development as well as the management of the project activities on one mutual campus. The result of this paper presents useful guidelines for research and development projects to support effective methodological ap- proaches and efficient assessment dimensions in related decision-making.

Keywords: Product Development, Public-Private Partnership, University-Industry-Collaboration, Exploitation, Living Lab

Introduction

Companies motivation to enter public-private partnership research projects are linked to expectations regarding achievement of economic exploitable research results [1]. The activities of public research organizations in these projects are also likely to be evaluated by the applicability of the results in the affiliate product development. To meet these requirements a product development methodology was implemented in the public-private Research Campus Mobility2Grid (M2G). This paper presents the methodology and evaluates it with qualitative methods.

M2G is part of the Research Campus Initiative funded by the Federal Ministry of Education and Research in Germany within the framework of the German High-Tech Strategy. The Research Campuses are designed to translate research findings into new products more quickly and to accelerate the development of innovative processes and services [2]. Public research and private market organizations can participate in the campus. The Research Campuses function as living labs. Key elements of their structure are joint location, common research and innovation agenda, long term funding, and own contributions in addition to the funding. M2G contributed to the initiative goals by establishing a cross-sectional work package. The package aims at integration of research results in mutual product development processes and strengthening inter-project collaboration of 18 funded and overall 35 participating partners.
Collaborative research projects such as M2G face special project management challenges. These include heterogeneous partners focused on individual goals, high demands on creativity, and innovation pressure. To ensure that cooperation takes place, the project design should include coordinating activities and rooms for cooperation [3]. Fernandes et al. [4] propose and evaluate the program stakeholders view of a program and project management approach to manage such projects on the general project management level. Principles for evaluating interdisciplinary research projects and management interventions to link the process of interdisciplinary research are proposed by Bark et al. [5]. Fernandes et al. [6] discuss essential project management practices for collaborative university-industry research and development projects.
The introduction of a cross-sectional work package for product development within the M2G project corresponds to the formal project management requirements, which are crucial to the project success. Project partner activity in product development was supported within and outside the activities of the work package in M2G. Within the work package, the methodology was developed to support and encourage partners to develop research results into products. As a process with different elements the methodology consisted of innovation workshops with active product idea inquiry and further individual support. In these workshops Business Model Canvas [7] and Business Model Navigator [8] methods were used. Outside the work package the corporate spin-off inno2grid was accessible to every M2G project partner as a catalyst to turn research findings into products and bring them to market. Corporate spin-offs will support product development especially when an early stage of innovation is given [9].

This paper presents some of the products together with the process of the methodology, which led to this development within M2G during a five year period (2016-2020). Section 2 explains and provides theoretical background to the methodology of a coordinated product development within M2G. Workshops results as well as examples of products are presented in this section. The overall process is evaluated in a qualitative manner by providing the lessons learned in Section 3. Section 4 includes a conclusion as well as an outlook to the second funding phase of M2G in the years 2021-2026.

Product Development Methodology

The combination of research and commercialization efforts are important to establish competitiveness within a science-based industry, e.g. electronics, software, or biotechnology. In this context, technology transfer from research to product development is a paramount process of innovation. M2G is the structural element of the methodology to incorporate research and commercialization through joint product development activities. The concept of a living lab is introduced in the context of the EUREF Campus as a central area of activity of M2G. Leminen [10] identifies three major characteristics for a living lab. First, the active collaboration of all stakeholders in innovation activities; second, stakeholders from companies, public agencies, universities, and users form public-private-people-partnerships (4P); third, a common spatial location. Baedeker et al. [11] argue that living labs support the development of sustainable products and services as a user-centered method. Thereby, co-creation is stimulated which helps a company to better understand customer needs, and hence, reduces risks and time to market new products or services as well as improves return on investments [12]. The principal of living labs is incorporated into the overall project structure of M2G and the definition of work packages. The methodology in this context consists of the following three main elements. First, as a facilitator of collaborative activities, a cross-sectional work package is set up to insti- tutionalize product development. In doing so, exploitation of technological knowledge obtained within various work packages is stimulated. Second, to operationally initiate, manage, and support product development activities within the cross-sectional work package a corporate spin-off was founded. Third, within the cross-sectional work package, several workshops were conducted under the regime of the spin-off employing different techniques to generate ideas, evaluate market potentials, and create business models.

1.1 Cross-sectional Work Package for Exploration and Exploitation

M2G focuses on the three major topics Mobility, Energy, and Communication. Seven work packages can be distinguished i.e. (1) Acceptance and Participation, (2) Smart Grid Infrastructures, (3) Interconnected e-Mobility, (4) Bus and Commercial Transportation, (5) Education and Knowledge Transfer, and (6) Digital Spaces. The cross-sectional work package (7) Operation and Commercialization was designed to provide superordinate support for the other work packages, to encourage their cooperation and collaboration [13], to combine research results, and introduce commercialization. This organizational management approach can foster co-

production of value within university-industry research projects [14]. In accordance with [15], cross-sectional work package (7) is set as a platform to support joint sense-making, learning as well as open discussion and trust. It is defined as a project-internal incubator, which methodically works out the ideal exploitation strategy for suitable results to maximise the output of M2G in the form of actual innovations on the market and thus the overall economic benefit of the funding. Figure 1 illustrates the topics and work packages of M2G.

The set up of M2G as depicted in Figure 1 can generally be described by the notion of exploration and exploitation in organizational learning. In this context organizational learning is understood as a process of improving actions through better knowledge and understanding [16]. Exploration is understood as search, variation, risk taking, experimentation, play, flexibility, discovery, or innovation. Exploitation refers to terms such as refinement, choice, production, efficiency, selection,implementation, or execution [17]. Organizations that predominantlyrely on exploration rather than exploitation tend to experience high costs of experimentation and little benefits from commercialization. Organizations with a focus on exploitation rather than exploration may produce strong path dependencies which tend to stabilize in suboptimal equi-

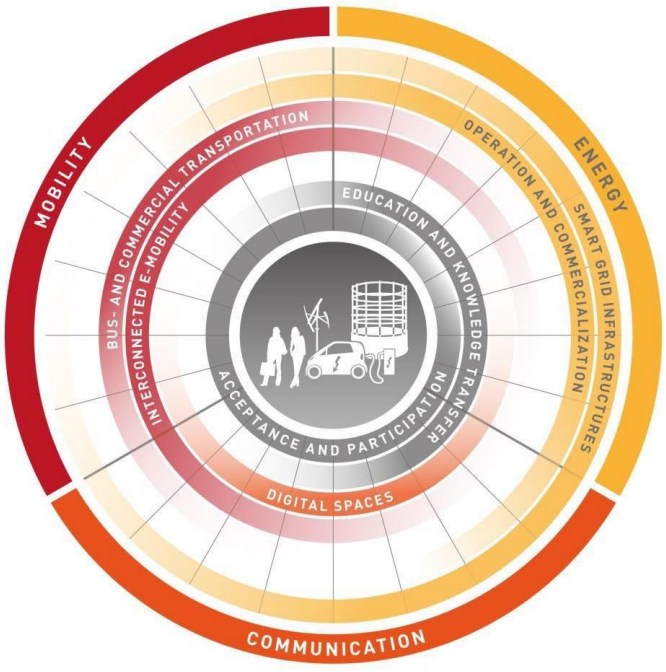

Figure 1: Topic fields and work packages of Mobility2Grid

libria lacking new ideas and technology developments [17]. Organizations whose activities are typically more exploratory are universities or public research institutes, whereas exploitation rather takes place in private companies [18]. This may be due to higher inherent uncertainties of returns on investments in exploration compared to exploitation [17]. However,

both exploration and exploitation can be seen as intertwined processes, exploitation requires prior exploration and causes new exploration [19]. The ability to find the right balance between exploration and exploitation is crucial for an organization's survival and prosperity in a competitive environ- ment [17]. A university-industry collaboration can provide for this purpose [20]. Considering a living lab, the balance of exploration and exploitation can be seen as equal [21].

This advantage comes into play in M2G. Its design as a living lab institutionalizes the balance of exploration and exploitation at EUREF Campus and by the different work packages. Work packages (1) to (6) have a stronger focus on exploration, work package (7) emphasizes exploitation. This trend is reflected by the responsibility of each individual work package: (1) to (6) are led by academic institutions, (7) is led by a private company. However, competencies of the heterogeneous partners are fragmented. Different types of organizations unite different types of knowledge. In addition, due to the relatively large number of the different subject matters in the work packages, knowledge is dispersed within the joint project. To avoid silo knowledge within the respective work packages and to provide for appropriate balance between exploration and exploitation, work package (7) employs a cross-sectional approach to facilitate interaction and knowledge transfer among the work packages. Sirén et al. [22] stress the importance to institutionalize the knowledge obtained from exploratory and exploitative activities. This amplifies the role of work package (7) within M2G given that knowledge transfer is a major factor for the commercialization of research through product development and thus a driver for innovation [23]. An organization's ability to absorb scientific and technological knowledge and thus to enable organizational learning is important in this context [24]. The ability of a company to capture outside knowledge can be seen as a function of prior related knowledge e.g. basic skills, a common language, or knowledge about relevant scientific or technological developments [25]. Sirén et al. [22] refer this ability to strategic learning as a specific type of organizational learning i.e. the 'ability to recognize the value of new information, assimilate it, and apply it to commercial ends.' Here, strategic learning is given a mediating role between exploration and exploitation strategies within a company which encourages its economic perfor- mance. A major factor to support this ability is proximity–in particular geographical proximity, interpersonal relationships and intensive communication–of academic researchers and compa- nies in science-based industries as it enhances the ability of knowledge transfer and thus product development [20]. Therefore, an inherent part of work package (7) is to support proximity of work package (1) to (6) e.g. by staging joint activities such as workshops.

1.2 Corporate Spin-off Role

In the context of exploration and exploitation, spin-offs typically follow the pattern of commercially exploiting technological knowledge from prior exploration activities within the parent organization [26]. Parent organizations may be private businesses or universities. Following Velde et al. [27], a corporate spin-off is a separate legal entity that is concentrated around activities that were originally developed in a larger parent firm. The entity is concentrated around a new business with the purpose to develop and market new products or services based upon a proprietary technology or skill. A university (or public research) spin-off can be defined as a 'new company founded to exploit a piece of intellectual property created in an academic institution' [28].

Within M2G, private businesses and public research institutes form alliances by collaborating together on joint research and development activities. In doing so, all participants set up an ecosystem for exploration and exploitation of academic and corporate knowledge and competencies for the purpose of innovation and competitive advantages. Thus, for a private company it is a strategic decision to participate in such a joint project. This is especially true for science-based industries as collaboration and alliances are considered to be an important factor for a firm's innovation performance [9]. Spin-offs may support an organizational framework for innovation in this context. As a consequence, the formation of a spin-off is as well a strategic decision as it can elevate the innovation performance of the parent company. With regard to research and development, a spin-off may be seen as a methodological approach to facilitate flexibility, speed, entrepreneurship, and co-operation in the innovation process [29]. In the context of living labs, small companies e.g. spin-offs in contrast to large enterprises may support user-centered product development efforts as they are perceived to be more agile and less tied to current markets and established practices [12]. For the future economic success of the innovative activities the technological environment i.e. the technological knowledge base in which a start-up is spun off by the parent organization is paramount [26].

The foundation of the corporate spin-off inno2grid by the parent companies Schneider Electric and Deutsche Bahn Energie within M2G showcases this methodology. The heritage of inno2grid lies is the research institute InnoZ i.e. personnel was taken over as well as parts of the functions were transferred to inno2grid. Therefore, inno2grid can be seen as a hybrid between research and corporate spin-off. Its institutional anchoring, the spatial location on the EUREF Campus, and the industrial parent companies represent a technological environment in which academic knowledge, financial resources, and technical expertise is combined. Inno2grid was embedded as a central player within work package (7) to support exploitation of research results by organizing knowledge transfer and fostering product development. On this basis inno2grid meets the requirements for a successful exploitation of technological knowledge created within the ecosystem of M2G and commercialization of innovative products.

1.3 Innovation Workshops, Examples, and Results

The process of product development management within M2G began with a systematical inquiries for product ideas in the work packages. A questionnaire was filled to every work package coordinator. Later in the project the query of product ideas was made by interviews between the product development work package (7) and work package coordinators (1) to (6).
Innovation workshops to develop business models for product ideas followed the inquiries. Two methods were used in these workshops i.e. Business Model Canvas and Business Model Naviga- tor to visualise and structure a business model for a product idea. In the workshop the product idea business model is described in nine dimensions, see Figure 2, in accordance with Business Model Canvas. Business Model Navigator introduces 55 business model patterns to answer at least two of the four questions defining a business model [8]:

1. Who are our customers? 2.What do we promise them? 3.How do we produce the service?
4.How do we achieve value for the service?

During these workshops suitable business model patterns for the product ideas are selected. Business model patterns from the two categories defining the companies mission statement and revenue streams are discussed. An example of using the Business Model Navigator is given by Laurischkat et al. [30]. The authors use the navigator to define business models for electric mobility that have a customer centred view on value propositions.
The Six Steps Moderation method according to Seifert et al. [31] was used in a workshop with all participants of M2G. The workshop goal was to sum up developed products and ideas, and to gather development ideas for the second funding phase of M2G. This method was used as it allows gathering, prioritizing, and further processing of ideas from all workshop participants. Further support of product development was conducted through individual activities. For example, the research results which were developed to a product by a project partner were integrated into an existing product of another partner. Or, partners participated in the further process as feedback giving customers.

In the research project, various workshops were carried out in the field of education up to the development and operation of the electrical systems in a smart grid. The aim of these workshops is to develop business ideas and to check their market capabilities. The results of workshops that were carried out to support the development of two product areas are explained here as examples.
In the first example, the work group of work package (5) Education and Knowledge Transfer developed and tested further training courses to ensure the transfer of knowledge and offer them to interested user groups. The idea was visualized using the Business Model Canvas as depicted in Figure 2 and evaluated for economic feasibility.
For this purpose, key factors of the business model were discussed in the workshop and added to the canvas. After completing the canvas, fields of action and resources became visible. The aim of the advanced training modules was the exchange of theoretical and practical knowledge about the connection of energy and mobility transition. The six advanced training modules were designed for this purpose: M2G basics, renewable energies and smart grids, battery systems, electric vehicles, energy and charging infrastructure and innovative business

models. Compa- nies of different sizes were able to book the modules independently from each other and use the advanced training formats to find out about current research results in the respective field.

<table>
<tr>
<td rowspan="2">Key partner

-Berlin Agency for Electromobility (eMo)
-inno2grid (i2g)
-M2G as new speakers
-TU Campus EUREF
-TU Berlin ScienceMarketing (TUBS)</td>
<td>Key activities

-New speakers
-Marketing
-New contents</td>
<td rowspan="2">Value proposition

Customer-oriented (individual)
-With M2G focus
-Demonstration of current research results in the areas of energy and mobility transition</td>
<td>Customer relations

-Personal</td>
<td rowspan="2">Customer types

-Niche market
-SME to large companies
-Middle management
-Energy consultant</td>
</tr>
<tr>
<td>Key resources

-Speakers
-Rooms: Zero emission energy and Mobility Base (ZeeMo.Base)
-Financial Resources for Marketing</td>
<td>Distribution and communication channels

-Website
-eMo and M2G network
-Trade fairs (flyers)
-German Energy Agency (dema)
-Berlin Energy Consultants Network (B-EN)</td>
</tr>
<tr>
<td colspan="3">Costs

-Speakers (travel expenses, accommodation)
-Marketing
-Rent</td>
<td colspan="2">Revenue sources

-Fixed price per module (2h or 4h)?
-Fixed price per participant/day?</td>
</tr>
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Figure 2: Business Model Canvas for the exploitation idea *Target Group-Oriented Continuing Education Formats*

In the second example, another M2G idea was an application that helps the operators of areas e.g. residential or commercial to manage visitor and tenant data as well as charging infrastructure. Various workshops were held to develop a business model for this idea and to look at different business model patterns and take a closer look at their advantages and disadvantages in relation to the implementation of the app.
Through these workshops it became clear that the main task of the application *Campus-Navi* remains navigation on campus. However, with additional information on menus in various restaurants on campus or the occupancy of parking spaces and charging stations, the customer receives additional offers for the basic navigation package. Also part of the Campus-Navi is to display the current share of locally generated renewable energy in the total electricity consumption on the EUREF Campus. This should enable environmentally conscious charging as possible. Environmentally conscious visitors can better decide when they want to charge their e-vehicle based on the proportion of green electricity in the Micro Smart Gird at the EUREF Campus. Furthermore, current energy

consumption and associated average CO2 emissions of buildings of the EUREF Campus are shown. The second part of the workshop dealt with var- ious business models for generating cash flows. The paying customers should be site operators and local companies. The site operator pays for a package of different service levels. All basic functions are included in the basic package. Support with rental management is only included in the package for a higher payment level. Companies on campus can buy various packages from the site operator. The price of these packages depends on the services included. Another topic discussed in the workshops was how to improve the application from the customer's per- spective (see Figure 3). The following functions have been proposed for the Search and Find area. The application should make it possible to easily find current events on the Campus. For this purpose, a route function, supported by images and information about various buildings, is to be provided, which is also linked to an event. During an event, visitors can park and charge their cars. An integrated function of the application is to record the route to the charging stations that are unoccupied during the appointment. It was also suggested that visitors read

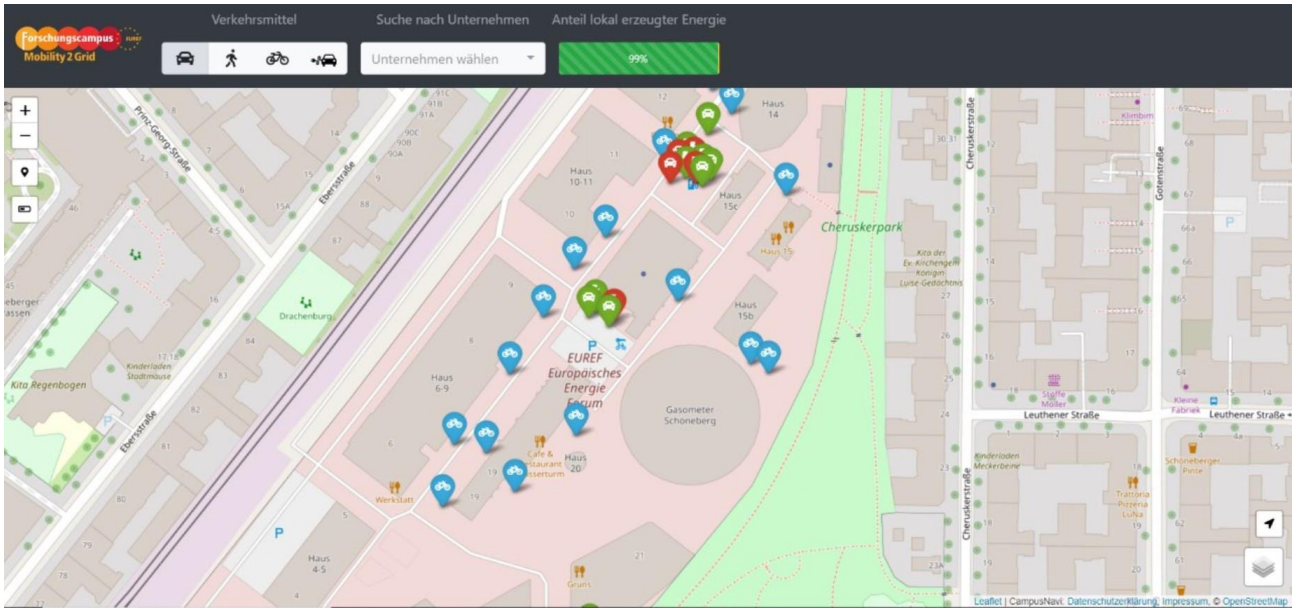

Figure 3: Sample presentation of the Campus Navigation Platform

the current electricity mix and price and use this to decide whether they would like to charge their cars. Figure 3 shows an example of the Campus Navigation.

In cooperation with DB Connect and inno2grid, an e-vehicle sharing solution for employees at the EUREF Campus was developed and tested within a year. This platform was used to digitally book two e-vehicles at the site, organise carpooling, and view public transport connections. The employee receives information such as the location, number, and availability of the vehicles as well as its charging status.

A qualitative survey has been conducted with some employees in order to better understand their needs and identify potential improvements of the processes and the product. This phase was conducted to explore and learn more about the main challenges that the employees face in their daily trips. The openness of interviewees enabled the identification of some new and unexpected issues, characteristics, and factors.
On the basis of evaluation processes and workshops, valuable improvements in the area of corporate car sharing could be implemented. The employees' requirements were featured and converted into enhanced and concrete aspects for a better operating efficiency. This implies creating a user interface, where all information is handled through the mobile platform to address the need of the employees and are responsive to user actions. The platform has built functions and contains several layouts that allow the interaction of the user in real time. This significantly increased the use and satisfaction with the sharing service.

Methodology Retrospect

This section includes the evaluation of the methodologies described in Section 2. The evaluation is based on the results of a qualitative survey and takes into account the observations made during the project.
The results show, that the methodology used by inno2grid proved to be suitable for successfully supporting the research activities in a holistic manner by developing innovative products and integrated solutions. The methodology enabled smooth cooperation between the partners, coordination of the activities and successful product development, and contributed to the achievement of the research objectives. The success of M2G in general and inno2grid in particular is reflected by the national and international interest. More than 11,350 visitors were received on the EUREF Campus during the period of 2015 to 2020. Inno2grid took charge of many guided tours outside the funded activities on campus. In addition to European visitor groups from politics, industry, education, and science, international delegations from countries such as China, India, and Ghana were also present. Prototypes and fully developed and displayed products made a significant contribution to exploitation, e.g. to stimulate further technology development or the acquisition of customers.
However, the results of the qualitative survey also show, that project partners in M2G found it difficult and not useful at first to receive support from a cross-sectional work package and the spin-off inno2grid for their individual activities. However, the methodological approach convinced the partners in the course of the project. It helped as project participants with responsibilities reaching into every aspect of the project to establish good relationships with the project partners. This increased the willingness to accept the offers of general support.

Conducting workshops proved itself as a good instrument to discuss ideas with several partners previously unknown to each other. Workshops were a key element to inspire participants to further explore new ideas, or may illustrate and promote process development practices. It is a suitable way to teach hands-on skills to the attendees as it offers an opportunity to try out recent methods and fail in a safe environment. Workshops were applied to opt for an immersive and collaborative environment as well as strive to stay proactive about idea generation. Workshops employed different methods that

disturb and challenge the participants' thoughts in order to raise reflection and innovation. Workshops using the Business Model Canvas and Business Model Navigator methods were highly suitable for developing new ideas. The Business Model Canvas defines the business model in detailed aspects. The Business Model Navigator addressed the strategy to follow with the product when looking at the mission statement patterns. The revenue stream patterns provided new ideas for the revenue stream design, such as the guaranteed availability pattern [8]. Further development of ideas required a wider choice of methods. The methods chosen lacked the economic aspects of the business model.

Joint product development and research result exploitation had to be encouraged actively even in the case of a joint project as M2G. This active part required a motivation to promote the collaboration, which had to be separated from content under consideration. This requires an independent funding of the work package. As the partners acting in the work package received a project and company funding, the topics to be examined more closely were chosen influenced by the companies interests.

Conclusion

A methodology that incorporates innovative assessment during the early stages of product development is presented in this paper. The methodology was part of the private-public partnership research project Mobility2Grid. It suggests a superordinate project structure with a cross-sectional work package, incorporates corporate spin-off roles, and proposes innovation workshops for ideation and business model creation in order to enhance product development. Research results with potential for product development were gathered. Then, initial specifications were determined with the help of workshops and conducted interviews.

The methodology confirms that product developers need to maintain a level of vagueness during the early stages of product development, and as a result, the methodology defers dealing with the specifics of design to later stages, namely during the detail design phase. Establishing a central work package responsible for the product development process encouraged the partners to think in the direction of exploitation additionally to the exploration taking place in the research project. However, the partners initially faced several difficulties in communication, motivation, and disengagement of the product development activities from internal development. Utilization of product development methods helped to transfer research results into products.

Future work could extend the proposed methodology to link it to a technical and engineering design phase. This may include procedures to develop product features with respect to tangible and intangible needs.

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