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Software Supported Quality Management of Boundary Resources and Complementor Satisfaction

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Abstract. Fostering the provision of digital services, innovation platforms reorganize the value creation, enabling complementary partners to innovate through the utilization of the offered boundary resources (BR). However, the use of BR for ecosystem management can become a challenging task for the platform provider. For example, due to the large number of BRs and their simultaneous use by complementors, it is a challenge for the platform provider to monitor and improve the quality of the BRs simultaneously. Against this background, the paper presents a partial dissertation result, introducing a software prototype for collecting complementor feedback on BRs. This feedback is processed to improve the quality of BRs and monitor complementor satisfaction to facilitate the management of the BR ecosystem. The prototype was evaluated with representatives from 10 industrial and enterprise IoT platform companies, confirming its usefulness for platform ecosystem providers, which is why it qualifies for the prototype excellence track format.

Keywords: Boundary Resources, Quality Management, Complementor Satisfaction Monitoring, Ecosystem Management, Software Prototype.

1 Introduction

Software platforms with open interfaces bundle a modular architecture to integrate their offerings and a set of specific functionalities for complementary partners to innovate. Complying with the innovation platform concept, digital platforms offer a digital infrastructure for multilateral partners to collaborate on the provision of digital services and digitized products, enabling ecosystems [1, 2]. A successful platform business model includes the evolution of the platform core and requires an appropriate participation architecture to support the engagement of complementary third parties. Boundary Resources (BRs) offer a concrete approach to open the platform and enable value co-creation between the ecosystem participants [3, 4, 5].

Already researched BRs include technical (i.e., for communication with the platform core and development of complements) and non-technical resources to transfer knowledge and platform-related capabilities from the platform provider to complementary third parties, enabling the complement creation [6, 7]. Since complementors use BR to leverage industrial use cases, they evaluate their quality during the complement development. Consequently, after opening a platform, a

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platform provider launches and maintains BR for the ecosystem participants to keep them attractive since they serve as contact points with the complementors. In fact, prior research even recognized how BRs create value-based lock-ins or be used in opportunistic competitive activities [4, 8]. Since ecosystem participants perceive quality differences of the BR, which they use to create complements, the quality of BRs can be used in competition between platform providers [9, 10]. Competing platform ecosystems can use excellent BR quality to get a competitive advantage and engage valuable complementors because otherwise, those can multihome or abandon platform ecosystems due to insufficient quality of BR [9]. In theory, quality is considered an antecedent of satisfaction. Both variables correlate, so high quality can lead to high satisfaction, which in turn manifests itself in the continued use of information systems. It has been empirically proven that complementors can distinguish the quality of BR and provide feedback around BR quality. Hence, platform providers are advised to collect feedback systematically from complementors on the experienced BR quality and use it for quality improvement [9, 11, 12].

However, the continuous evolvement and the associated quality maintenance of BRs can be highly complex for platform providers. This complexity is fueled by the high numbers and the variety of existing and used BRs. BR quality management requires simultaneous monitoring and results in complex decision problems, which BRs should be qualitatively improved to maximize satisfaction. Despite the importance of BRs and the complexity of the BR maintenance, there is still no market-ready software support for platform companies to monitor the quality of BR. In practice, BRs are permanently used by platform providers in various domains such as the industrial internet of things (IIoT) but without adequate decision support to manage the BR quality. This paper introduces a prototypical implementation of a quality monitoring system for BRs. In the context of this work, the prototype represents a design artifact, according to Hevner et al. [13], which acts as an operational model of a software system that implements partial functions of a future full-fledged enterprise software system. The prototype enables the collection of feedback on the BR quality for the calculation of key performance indicators (KPIs) and their presentation in a dashboard, demonstrating the realization of the prior study results of the same research project [9] as application software, supporting quality improvement and further development of BRs. Such an application software could reduce the efforts of gathering complementor feedback and accelerate the quality improvement of BRs. In addition, the prototype fosters a productive enterprise use of BR quality management.

2 Ecosystem Management through Boundary Resources

Simultaneous management of multiple BRs can pose a severe challenge to ecosystem managers in orchestrating platform companies. Previous work found how numerous the BR offering of a platform provider can be [6, 9]. Accordingly, quality management poses a complex decision problem to monitor and optimally allocate a limited budget for the quality improvement of multiple BRs. The prototype relies on the empirical collection of concrete user feedback, utilizing the methodology used in satisfaction surveys, such as the critical incident technique (CIT), to precisely identify

and eliminate quality deficits in the design of BRs, which are important for the complementors [14]. At the same time, CIT feedback can be systematized by applying the Kano model to assess whether the quality improvement will increase the complementor satisfaction or merely help to avoid frustration [15, 16].

In previous studies, it was observed that complementors are generally willing to give feedback on the BRs used and judge perceived quality [9]. After all, complementors from the platform ecosystem can expect the platform quality to improve and thus either achieve better quality complements or implement them with less effort. The ecosystem management can use this feedback to implement quality management of BRs, fostering the overall ecosystem attractiveness through complementor satisfaction.

3 Prototype Presentation

During the conception of the prototype, related approaches that have already been implemented as enterprise software were studied. We identified computer-aided quality (CAQ) and application programming interface (API) management as appropriate to support the BR quality management. Computer-aided quality (CAQ) systems, for example, form a suitable conception basis for BR quality management, as they enable mapping measures for the fulfillment of quality management processes based on previously collected quality data. A modern CAQ system includes customizable workflows for controlling information, visualizing data, and calculating key figures [17]. However, the purpose of CAQ systems is to track physical components and are used in manufacturing. Additionally, the software industry offers commercial services for API management. APIs exceed the purely technical significance for API-providing companies and require a lifecycle-related form of management [18]. However, an API management service is only designed to support the management of a single BR type and neglects the existing variety of BRs in specific application domains and the interdependencies of different BR. In domains such as IIoT, other BRs such as SDKs or connectivity libraries are highly important to implement complements. API management services are not designed for the quality management of these BRs. [9, 19]. Hence, existing concepts do not sufficiently consider the construct of BRs in platform ecosystems, also neglecting the fact that complementors use numerous digital BRs that offer digital feedback opportunities. Although, there are digital communication channels such as support forums, commonly integrated into developer portals, allowing the collection of feedback from the complementary users of BRs on their quality. However, developer forums are predominantly used for feedback on technical BRs, while satisfaction-generating non-technical BRs [9] lack systems to gather feedback. Moreover, according to the current state of research, developer portals are still affected by information fragmentation [20, 21]. Thus, there may be different portals with fragmented forums. This circumstance additionally complicates the analysis of feedback on the quality of heterogeneous BR portfolios, highlighting the need for a system, which is (1) focused solely on BR, yet (2) can be flexibly adapted to the current BR portfolio and (3) can also utilize existing feedback channels.

From the user perspective, the functions of these system components can be described as user stories and assigned to the complementors and platform providers:

Table 1. Functionalities of the prototype from the user perspective

Stakeholder	User stories
Complementors	As a user of BR, complementary developers would like to provide feedback on BR to inform the platform provider about quality shortcomings and their current satisfaction levels
Platform provider	As a BR designer, the platform provider would like to receive feedback from BR users on the BR usage to analyze it using suitable analysis techniques and KPIs and improve the BR quality.
Platform provider	As a BR designer, the platform provider wants relevant information visually processed to get an overview of the current quality level of the BR and the satisfaction level of the complementors.
Platform provider	As a BR designer, the platform provider would like to see the feedback processed in real-time if possible and send reports to the departments involved in designing the specific BR, which require improvement.
Platform provider	As a BR designer, the platform provider would like to receive recommendations based on the collected BR user feedback.

Accordingly, while a platform provider is the primary user of the quality management system, sid complementors are critical because they use the BR and generate feedback. The prototype is a web application, which can be assessed via the following URL: https://br-satisfaction-management.de The landing page serves as an entry point to navigate to the three functional areas of the prototype: 1) Form for complementors; 2) Dashboard for platform providers; 3) Dynamic reports for platform providers. In the following, the Fundamental Modeling Concepts block diagram is used to demonstrate the intertwined functionalities of the prototype:

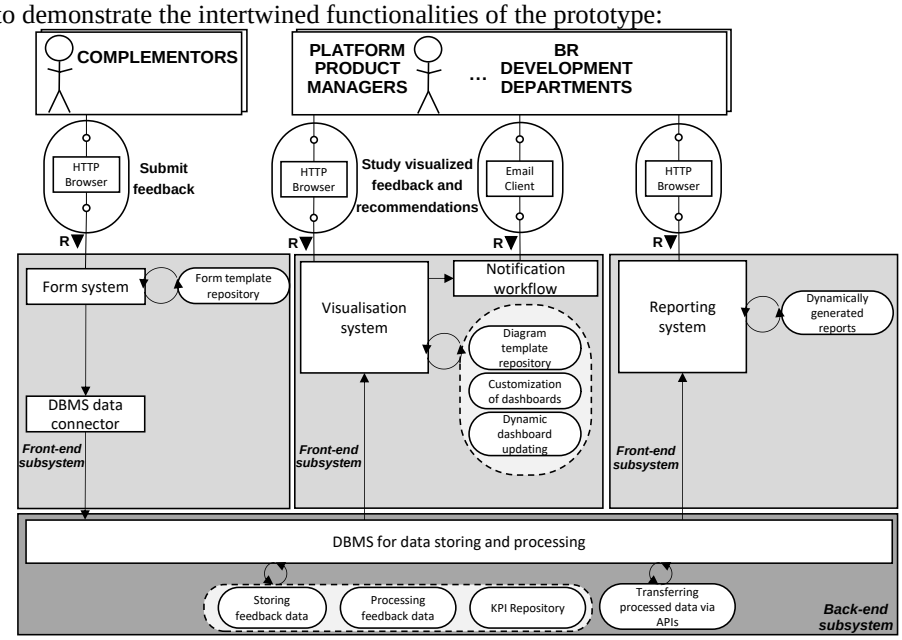

Figure 1. Conceptual design of the prototype

A form system acts as a front-end subsystem of the prototype and enables continuous capturing of feedback on the quality of BRs from the complementors, fulfilling the requirements of the first and second user stories. Complementors can provide their feedback on quality issues of BRs through critical incidents. Additionally, Likert-type scales are used for numerical self-assessment of the satisfaction level. The form is connected with a backend module capable of storing and processing the feedback data.

After the feedback submission, the data is sent to a database management system, and this subsystem is the core module of the prototype. As for the data processing, we implemented the Kano classification to be calculated based on the numbers and ratio of critical incidents, as described in [9]. Depending on the feedback on BRs, quality data can be heterogeneous and change with time due to a large number of BRs, their heterogeneous properties, and the constant introduction of new BRs in a platform's life cycle. Therefore, the form system and the data storing and processing subsystems must handle flexible data models for storing heterogeneous quality data, using them for analyses and monitoring.

The data storing and processing system can be linked to other subsystems. The processed quality data should be visualized so that the platform managers with a cross-cutting function can understand the feedback on BR quality and forward it to appropriate departments. A dashboard was created for the visualization of feedback data and calculated metrics in real-time. According to the definition of Few [22], dashboards display consolidated information needed to achieve required objectives on a single screen to be monitored by the user. Hence, the consolidation of feedback data in a dashboard enables immediate analyses. The prototype offers a bar chart to show the satisfaction potential of the different BRs according to the different Kano classes. The ring diagram processes the contact data and highlights which complementors report negative critical events and experience quality issues. An additional list displays the average satisfaction ratings for each complementor, representing self-stated satisfaction with the platform. This can be used for targeting dissatisfied complementors, prioritizing the quality issues they experience, and preventing multihoming. Another ring diagram gives an overview of the share of negative CIs for each BR. Lastly, another bar chart displays the distribution of positive and negative CIs for each BR. Additional notification workflows transfer snapshots of the dashboard in predefined time intervals via email to other departments, such as Research and Development (R&D) or different developing teams that are involved in the development of specific BRs. Accordingly, ecosystem managers and platform product managers are the primary stakeholders to drive coordinated evolvement of BRs, supported by the dashboard.

The last subsystem is a dynamic recommendation system, which automatically generates recommendations in line with the logic of the Kano model. The recommendations are derived dynamically from the gathered feedback data, based on the current classification of the BR according to Kano’s classification. Hence, the reports contain automated recommendations, so responsible stakeholders from the appropriate development or R&D departments can be informed in case of quality shortcomings.

4 Evaluation

The real-world value of the prototype was evaluated in moderated group discussions with representatives from different departments of 10 IIoT platform companies. Workshops aimed to obtain qualitative feedback from practitioners on the problem-solving capability of the prototype. During the workshops, the researcher demonstrated the functionalities of the prototype and explained the relationship between the presented submodules. The value was confirmed because, during the workshops, only one IIoT platform provider confirmed that it could automatically evaluate platform feedback from various sources (including support forums) using a system developed in-house. Functional suggestions for improvement included the request for extensive complementor segmentation, which is already partially implemented into the dashboard design. In general, however, the term "boundary resources" was criticized as being unknown in practice and requiring too much explanation before gathering feedback. Difficulties in understanding were suspected both with complementors and with the company's own sales department, which is in contact with complementors. Nevertheless, we have deliberately not replaced the term "boundary resources" to maintain scientific rigor and to carry the knowledge about the concept of boundary resources into practice.

5 Results and Outlook

The conducted work fits into the exploratory prototyping due to the objective of prototypical implementation. In particular, design decisions are evaluated and examined during the exploratory prototyping. The developed systems contain a reduced range of functionalities of a real system that can be used for a follow-up development of a market-ready platform ecosystem management software. A software system enabling the quality management of a holistic BR portfolio is expected to be superior compared to the market-ready approaches mentioned in section 3. In its current state, the prototype offers potential for future development. The prototype can be extended to include other metrics for evaluating the quality of BR or the satisfaction of complementors. Besides, functionalities for automated monitoring of API error codes or other crash reports can be collected and evaluated automatically. Developer portals and other feedback channels of a platform provider can be connected to track more quality issues by further development of the prototype. Text mining technologies can be applied to feedback data from developer forums or social media [23] to identify quality problems with the BRs discussed there more quickly. In addition, the interdependence of individual resources is not currently implemented in the recommendations of the reports or the dashboard. An overall BR-Quality-Index is also not calculated. Lastly, potential barriers to reporting feedback from complementary BR users have not been explored. This potential limitation requires both empirical research and enhancement of the prototype with reward mechanisms to improve the use of a feedback-based quality management system for BR by complementors in a platform ecosystem, as the current development state does not contain notification workflows for complementors compared to replied and closed threads in developer forums.

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