TRANSFORMING ORGANIZATIONAL RESOURCE INTO PLATFORM BOUNDARY RESOURCES

Research

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Abstract

The emergence of digital platforms shifts the locus of innovation from firms to ecosystems. This shift deprives product-developing firms of established control mechanisms and calls for new alternatives. Existing literature argues that platform owners have to empower ecosystems, while respecting the autonomy of members. This point to a contradiction; platform owners and third-party developers are interdependent, yet, at the same time, fundamentally detached. Contemporary research suggests that we may address this contradiction through the concept of boundary resources. Serving as the interface for arm's length relationships, boundary resources are shaped in the interplay between platform owners and application developer. However, we have found that they are also formed in a continuous negotiation with existing firm assets. Therefore, in this research we ask how product-developing firms transform internal resources into platform boundary resources. We conducted a case study of a digital platform initiative at Volvo Group, a global truck manufacturer. Drawing on the concept of tuning, we studied Volvo's practices in shaping boundary resources within and across multiple organizational and technological contexts. We found that resource transformation may leave firms in limbo; exposing an asset as a platform boundary resource tends to destroy its value as an internal organizational resource.

Keywords: firm resources, platform, boundary resources, transformation

1 Introduction

The ecosystem metaphor has proved a powerful rhetorical device for discussing innovation processes in the digital era. Practitioners as well as researchers frequently use the concept to underline that emerging innovation environments are substantially different from established and often taken-for-granted industrial practices. Digital innovation ecosystems are distributed (Yoo, Lyytinen, & Jr., 2008), self-organizing (Benkler, 2002), and open-ended (Avital & Te'eni, 2009). In such a context, innovation processes unfold in a non-linear manner (Y Yoo et al., 2010), resonating poorly with value chain strategy and waterfall models of product development. Therefore, when engaging in digital ecosystems incumbent firms find that existing command and control structures do not work since they simply have no legitimate authority over ecosystem stakeholders (Tiwana, 2013). Consequently, they cannot control the innovation process. Extant research argues that incumbent firms, rather than searching for new control mechanisms, should engage in innovation orchestration (Dhanaraj & Parkhe, 2006; Levén, Holmström, & Mathiassen, 2014). Such orchestration aims for defining the basic innovation architecture, which then becomes a platform for ecosystem members to build on through their own complementary innovations (Nambisan & Sawhney, 2011, p. 41). As platform owners they may shape and influence ecosystems (Schilling, 2005; Willianson & De Meyer, 2012), while respecting the autonomy of ecosystem members and without exercising explicit authority.

Research on digital platforms underline that such governance capability requires platform owners to empower the ecosystem's third-party developers. More precisely, they have to transfer design capability to those developers (Von Hippel & Katz, 2002). Therefore, rather than trying to figure out what specific end-user functions they would like to see developed, they need to carefully consider the platform's generic, core functionalities (Baldwin & Woodard, 2008; Henfridsson, Mathiassen, & Svahn, 2014). Properly designed a finite number of such digitally enabled platform resources may trigger an unbounded number of product variations and speciation (Gaskin et al., 2010; Yoo, 2013).

Recent research has conceptualized such platform resources as boundary resources to recognize that platform owners and third-party developers are interdependent, yet, at the same time, fundamentally detached. In practice, those boundary resources – tools, regulations, APIs[1], etc. – "serve as the interface for the arm's length relationship between the platform owner and the application developer" (Ghazawneh and Henfridsson 2013, p. 174). Existing research has explored how boundary resources are created, maintained, and how they evolve over time to stimulate ecosystem creativity, yet offer a mechanism for control (Barrett, Oborn, Orlikowski, & Yates, 2012; Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015). Specifically, it is argued that boundary resources are shaped through a continuous interplay between platform owners and third-party developers.

While existing research shed light on the benefits of open platforms (Benlian, Hilkert, & Hess, 2015; Ondrus, Gannamaneni, & Lyytinen, 2015)and emphasize that incumbent firms need to engage with external ecosystem (Selander, Henfridsson, & Svahn, 2013; Tiwana, 2015), our study of a truck manufacturer's struggling with a new digital platform suggests that this perspective on boundary resources is incomplete. Focusing on relationships among actors in the ecosystem and confirming existing research, we found that the interplay between platform owner and third-party developers indeed is reflected in boundary resource design. At the same time, our research suggests that existing organizational resources make up a primary raw material for platform design; boundary resources are shaped, not only through the interplay with external developers, but also in a continuous negotiation with internal organizational resources. Taking existing resources to the platform may create a market positioning that is distinct from rival firms'. In other words, such distinctive positioning (Cennamo & Santalo, 2013a) offers competitive advantage by shaping "a platform ecosystem that is different from

[1] Application Programming Interface

competitors' portfolios" (p. 1336). At the same time, incumbent organizations typically build competitive advantage by protecting organizational resources (Barney 1991; Penrose 1959; Wernerfeldt 1984). Making them publicly available in a digital platform may destroy such competitive advantage and prevent the organization of accumulating rents (Teece et al. 2007). Addressing this void, we explore how firms identify organizational resources, how they tackle unavoidable tensions between existing business models and upcoming revenue streams, and how they package them as platform boundary resources. With the objective to contribute to the emerging literature on boundary resources, we ask: *How do product-developing firms transform internal resources into platform boundary resources?*

2 Boundary Resources

Contemporary research on platform boundary resources can be traced back to a multi-disciplinary discourse of boundary objects. Boundary objects cut across multiple social settings. They are "plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites (Star & Griesemer, 1989, p. 393). Thereby, they are adaptable to different viewpoints, yet robust enough to maintain identity across them (p. 387). Innovation researchers have explored this property as a way to cope with knowledge boundaries, i.e. the tendency of knowledge in product development to make both a barrier to and a source of innovation (Carlile, 2002, p. 442). Boundary objects have also been studied in the context of design. It is argued that such design boundary objects (1) enable and connect design routines, (2) align stakeholder interests, and (3) identify and fulfill gaps in design knowledge (Bergman, Lyytinen, & Mark, 2007, p. 551). Consequently, they help represent, transform, mobilize, and legitimize design knowledge by facilitating shared understanding and promoting agreements about designs (Bergman et. al. 2007).

Platform researchers align with this reasoning as they argue that platform owners support third party development by transferring design capability to external developers through resources (Von Hippel and Katz 2002). These resources play a significant role in providing access to the platform's core functionalities and in the deployment of applications (Baldwin & Woodard, 2008; Henfridsson et al., 2014). Contemporary platform research is underlining that these platform resources are located at the borderline between the platform owners and external, independent ecosystems. Recognizing that such resources have to be explicitly designed to cut across multiple social settings and to be adaptable to different viewpoints researchers increasingly refer to them as platform boundary resources (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013; Yoo, Henfridsson, & Lyytinen, 2010).

According to Ghazawneh and Henfridsson (2013, p. 174) platform boundary resources are "software tools and regulations that serve as the interface for the arm's-length relationship between the platform owner and the application developer". Further, they view third-party applications as "executable pieces of software that are offered as applications, services, or systems to end-users of the platform" (p. 175). The literature categorizes boundary resources in different ways, including SDKs[2] and APIs, guidelines and documents, agreements and Intellectual Property (Bergman et al., 2007; Gawer, 2009; Ghazawneh & Henfridsson, 2013; Youngjin Yoo et al., 2010).

3 Resource Transformation

Properly designed a digital platform affords the emergence of an unbounded number of product variations and speciation based on a finite number of digitally enabled platform resources (Gaskin et al. 2010; Yoo 2013). These resources are shaped through a continuous interplay between platform owners and third-party developers (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013). However, in an attempt to extend the literature we focus our attention on how firms engage in the transformation of ex-

[2] Software Development Kit

isting organizational and technological resources into platforms resources. In doing so, we depart from the resource-based view of the firm (RBV) and its general assumption that competitive advantage primarily lies in the application of a bundle of valuable tangible or intangible resources at the firm's disposal (Barney 1991; Penrose 1959; Wernerfeldt 1984). To provide sustained competitive advantage resources should be designed so that they cannot be easily imitated nor substituted without great effort (Barney 1991, p117). As firms transform existing organizational resources into platform boundary resources they typically break with the RBV perspective on competitive advantage. While it offers competitive advantage through distinctive positioning in the ecosystem (Cennamo & Santalo, 2013a), it also exposes resources in public and prevents the organization from using it for accumulation of rents (Teece et al. 2007). Therefore, when firms engage in transformation of organizational resources, to design attractive platform boundary resources, they cause a clash between innovation regimes (Godoe, 2000). This clash is manifested as competing logics in organization, market dynamics, and architectural design (Svahn & Henfridsson, 2012).

With tensions and contradiction taking center stage, we have turned our attention to the work of Pickering (1993) and the his concept of *tuning*. His practice-oriented research departs from the interplay between human and material agency, powered by the dialectic process of resistance and accommodation. Barrett et al. (2012) have extended Pickering's concept of tuning into the context of digital innovation. According to them, digital innovation involves different, heterogeneous actors whose interests, values, norms, competencies, and practices may conflict with each other's. In other words, they argue that innovation is not a singular entity and actualization of digital innovation is neither inevitable nor necessarily associated with some predetermined outcomes.

The concept of tuning was successfully applied by Eaton et al. (2015) to conceptualized and describe the process by which boundary resources come into being and evolve in service systems. They argue that changes in boundary resources must be understood, not as a matter of creation by the firm that owns the infrastructure, but rather as collisions between and evolution of artifacts within and across multiple organizational and technological contexts (Boland et al., 2007). In what follows, we apply the tuning lens (Barrett et al., 2012; Eaton et al., 2015) to analyze the transformation of organizational resources into platform boundary resources in a product-developing firm. We have found this theoretical lens suitable for our study since it allows us to zoom in on tensions and contradictions inherent to digital innovation. By viewing the transformation of resources as a tuning process we concurrently focus on new boundary resources existing organizational resources.

4 Research Approach

To understand the dynamics of resource transformation we have conducted detailed case study research in a single setting (Yin, 2009). We made our case study at Volvo Group, a leading manufacturer of buses, trucks and construction equipment at the global market. Volvo has been experimenting with the effects of digitalization and connectivity through different research projects. This study was carried our as an integral part of one of those projects. The project was set up to address the contradictions between openness and control in the context of automotive infotainment. According to the project description it aimed for a new platform concept, offering independent developers "significant creative leeway and few constraints in designing applications", while meeting "highest safety standards". The overall purpose of the project was to "design, develop, and evaluate a *safe* connectivity platform concept, i.e., the overall philosophy and design of a set of resources with which to generate derivative infotainment services and applications that satisfy state-of-the-art safety standards". This involved difficult trade-offs, with potentially harmful consequences for the firms. As an example, strong voices argued that the driver distraction guideline from NHTSA[3] would be applicable to trucks. However,

[3] National Highway Traffic Safety Administration

this guideline was developed and tested for cars only, leaving many open questions for Volvo. It was therefore considered important to set up the project so that its members could experiment relatively freely, without risking company operations. Executing the project at safe distance from ordinary development allowed its members to engage in proper assess of the NHTSA guideline and contribute with new knowledge on driver distraction in the truck context. Volvo Group had the leading role in the project, but to build a creative team it also engaged senior engineers at Volvo Car Cooperation and a leading Swedish IT consultant firm.

Exploring different alternative strategies, the project team eventually decided to opt in for Google's Android platform. To be able to enter this existing ecosystem they had to extend the platform with automotive-specific resources. Our study reflects how Volvo Group engaged in transformation process of internal resources into such platform boundary resources. We had continuous access to the project and its members across a two-year period. This generated considerable amounts of data for in-depth empirical analysis. As a rationale for a single-case study design, we consider this project as a revelatory case, where we had the opportunity to access, observe and analyze a hard-to-access environment.

4.1 Data Collection & Analysis

This case study research is informed by empirical data gathered from several sources from fall 2013 until fall 2015. First, we collected data from biweekly project meetings where Volvo experts and senior engineers engaged in problem solving. Altogether, we have notes from 34 such meetings. Second, we participated in five workshops. These workshops focused on sharing the latest observed challenges and tensions in achieving the project goal with the team and discussion about possible solutions. All five workshops were recorded. Third, we used the project database as data source in our research. This database documented decisions, actions, and how actions were assigned to different teams or individuals. Altogether, the database contained 55 different actions and 150 decisions. Fourth, we conducted semi-structured interviews with 12 Volvo managers and senior experts, 7 third-party developers, and 17 alpha test teams. These interviews made a rich and extensive data source in that it provided in-detail reasoning behind actions and decisions. Finally, project reports made an important data source, offering us understanding of motivations and constraints.

Our data analysis departed from a review of the final project report. This review provided six early candidates of resources that Volvo initially used as its resources. We then used Atlas.ti to store and structure data, and to construct a timeline of actions and decisions across the project. Ten platform boundary resources were selected for this particular study to show the transformation process of those six internal resources. Three of these resources were developed in form of Application programming interface (API). Three other resources transformed as documents and guideline an others were developed in form of software development kits (SDKs). Given the initial resources, which have been used for transformation into boundary resources as well as the process timeline, we tried to visualize our findings into numbers of episodes. Initially it seemed to us that the resources as the start points of transformation process can be divided into two types: publically accessible or proprietary resources. However further analysis, convinced us that dividing the public accessible resources were addressing two different motivations for transformation. As this change resonates with types of transformed boundary resources quite well, in final decision we decided to have three episodes.

5 Results

In 2013 Volvo Group initiated its platform project and articulated an objective to stimulate safe development of in-car infotainment applications. Putting creativity and innovation center stage, a key challenge would be how to engage third-party developers. These developers would typically be unexperienced in designing for the automotive context and have little understanding of the specific requirements for visual distraction while driving. They would also be out of range in the sense that Volvo would have little influence over how developers actually worked. This caused a paradox; Volvo had to concurrently provide third-party developers creative leeway and control their applications for driving safety. The automaker understood it had to find new ways for guiding external developers, rather than controlling them. The project made an exploration of how to empower external developers in their design work, without compromising safety.

In this experimental platform project, Volvo took on the tricky task of figuring out what platform boundary resource would be valuable for external developers in designing and developing infotainment applications, safe enough to be operated while driving. They also had to figure out how to realize those resources, using existing assets and knowledge. Overall, Volvo Group transformed internal resources into platform boundary resources in three distinct areas. The resources were designed to:

- Guide development practices for generation of applications with limited driver distraction.
- Support developer self-assessment of applications.
- Stimulate applications with relevance for a driving context.

5.1 Guiding Development for Driving Safety

Seeking inspiration for how to guide third-party developers, safety experts at Volvo started to review, explore and compare different automotive guidelines for designing in-vehicle Human-Machine Interface (HMI). Altogether, they reviewed guidelines from five well-known authorities: NHTSA, JAMA[4], ESOP[5], AAM[6] and ISO[7]. The documents were categorized into two types: driver distraction guideline and test procedure documents. The documents from ESOP, JAMA and NHTSA became Volvo's were the main references for understanding driver distraction. As a safety expert in Volvo argued *"Those are guidelines for safety basically, [e.g. addressing] how to use a nomadic device or any other portable technology in a truck in a safe way."* Reading these documents could give developers an understanding of Volvo's expectations. On the other hand, as argued by a human factor specialist, *"these guidelines were too specific, too detailed, and [therefore] not so useful for software developers."* Recognizing this contradiction, the team engaged various safety-oriented specialists at Volvo to summarize the key concepts of these documents.

"We have reviewed all of them and took out the ones [key concepts] that we thought were specifically important and of course referred to them and we made our own compilation."

This new document resulted in a compressed version of the ESOP, JAMA and NHTSA driver distraction guidelines, including prioritized information and excluding what was less important to developers.

As a basis for a test procedure guideline the safety experts selected NHTSA's suggested method for measuring safe interaction. This method was originally developed for cars and not for trucks, making it questioned at Volvo Group. Although not formally adopted by Volvo Group, the project team considered it attractive since it was simple to express and explain. Further, in contrast to many other solutions it could be realized as a practically feasible test. Evaluating this test in an experimental project would make a valuable contribution in itself. The performance test criteria was expressed as:

"85% of individual glance durations should not exceed 2 seconds. Mean of individual glance durations should not exceed 2 seconds, Task completion should not require more than 12 seconds of total glance time at display and controls (for 85% of sample)."

Applications complying with these criteria would – in this particular project – be considered safe from the perspective of visual interaction.

[4] Japanese Automobile Manufacturers Association
[5] European Statement of Principles
[6] Alliance of Automobile Manufactures
[7] International Organization of Standardization

The project now had transformed original resources into a compressed and adapted design recommendation. However, as described by a human factor specialist, this document was written by automotive people and with the applications, rather than development context in mind. Therefore, to make third-party developers accept and adopt the recommendation, the team engaged in further transformation:

"We want to be sure that software developers understand how we want them to understand. That's why we basically transformed them [design recommendations] for an easier to understand language and classified them and categorized them differently, like providing screen shots, tables and so on.

This transformation resulted in a 12 pages document, called safe connectivity recommendation. Paying particular attention to the distanced relation to third-party developers the project team had high expectations on it. However, interviews with randomly selected third-party developers suggested that such a document – although tailored to the target group – might not reach through. One developer explained that *"as a freelancer I will not spend so much time to read a written document. Instead of that, I prefer to watch a video tutorial or something like that."* Project team members had a hard time accepting this feedback from real developers. As illustrated by a safety expert, they resisted further transformation and argued that these external developers simply were not capable of making such judgments:

"They cannot make judgments because they are not safety experts. […] the information [the content of the safe connectivity recommendation] is already decided!"

However, with some distance to the confrontation with external developers, Volvo started to take these concerns seriously. At the end of the project 172 bachelor students were selected as alpha testers. In a programming course, they were assigned to develop safe applications based on Volvo's platform. With previous comments in mind, the project team crafted a lecture from the safe connectivity recommendation. This lecture was designed to raise awareness about driver distraction and its consequences through real cases, supported by damages statistics, facts, etc. This lecture did not just offer an alternative channel for communicating directly with developers on how to use platform boundary resources, it also opened up for informal discussions and learning directly from developers.

5.2 Supporting Self-Assessment

To identify proper test methods for external application development the project team took inspiration from NHTSA and ISO. The overall idea was to identify acceptance criteria to be applied by developers before final release. NHTSA's suggestion was based on a driving simulation environment and the use of eye tracking technology to measure driver distraction. Requiring such complex and expensive infrastructure, this method was considered unrealistic by Volvo. ISO suggested a method based on a so-called occlusion test. It involved occlusion goggles to block interaction and thereby enforce certain use pattern. While this method was applicable internally at Volvo, reliance on occlusion goggles made it complicated for external developers.

With this barrier in mind, a senior expert in human-machine interaction (HMI) outlined a way to transform ISO's test method into a simple tool for developers. He called it a 'metronome app':

A simpler version of this [occlusion test method] is to measure total task completion time at the same time as glances are controlled by a metronome, set at 1.5s on/off road. This may be easier.

The metronome beeps could be adjusted in accordance with the glance duration mentioned in NHTSA acceptance criteria. Developers could then test the effects of switching attention between the application and the driving task, as suggested by the metronome. As described by a project team member, however, the initial evaluation of the metronome app was not very promising: *"We tested the metronome with an app and found it very difficult to sync our sight with the beeps. We tend to anticipate the beeps instead of waiting for the beeps before looking at the screen or looking back at the road."*

While the metronome implementation failed, Volvo kept looking upon the occlusion method as the most promising way of measuring driver distraction. In the autumn 2013 the team developed an application called the Occlusion App 1.0. This application did not require occlusion goggles for test, but running in parallel with the test object, it simply blocked the device screen, as specified in the NHTSA acceptance criteria. This afforded developers to assess their applications using any standard Android platform. When the screen was on the user could interact with the screen for 2 seconds and when the screen was off they could not. If the total interaction time for completion of a specific task exceeded 12 seconds the application did not meet NHTSA acceptance criteria. However, according to NHTSA the tester should be able to interact with application even when Occlusion app blocks the screen. Consequently, when releasing the next version of the Occlusion app (2.0), this problem was resolved.

Concerns about the occlusion app made the project team return to the idea of using eye-tracking devices in a driving simulation environment. This was a proven test method, where Volvo had significant internal experience and plenty of existing technology. Would it, after all, be possible to transform these internal resources into a practically feasible test for external developers?

Volvo Group used driving simulators since it was a less expensive way of studying driver behavior, compared to real world driving studies. However, third-party developers could not easily get access to driving simulation stations. Trying to resolve this, the project team decided to use an open source driving simulator software called TORCS[8]. This software was able to simulate vehicle data signals, to be used when testing third-party applications. Still, the eye tracker posed a problem. Trying to be creative, the team identified smartphone cameras as a potential solution, but that would require Volvo to develop an eye-tracking software. Addressing this issue, they focused attention on the Open CV[9] Eye tracker and decided to adapt this open source solution to fit the TORCS driving simulator.

Although the occlusion app and simulation-based tests would afford developers to assess how their applications caused driver distraction, the project team realized that real-world tests would remain important. How could Volvo support developers in testing applications on real end-users? Over the years, the automaker had developed and formalized best practices for how to set up valid and reliable tests, involving end-users. This best practice, materialized as an internal document, provided recommendations on sample size, gender balance, age of test subjects, and number of tests to be performed. To guide developers in setting up this kind of tests, the project team transformed the best practice document into a development tool – the Test Leader App. This new tool could be used during development and was capable to monitor, moderate and record different test results. The project team expected that this tool would make developers capable to self-assess their work in relation to NHTSA acceptance criteria as well as the ISO test method.

5.3 Stimulating Development for Driving Context

The platform project was initiated with an ambition to draw a balance between safety issues, on the one hand, and creative and innovation, on the other. Gradually, the project team realized they had focused most attention on pushing safety aspects forward. They had to direct more attention to the question of empowering third-party developers. After all, stimulating innovative development for the driving context was an important part of the project.

Over the years, Volvo had spent a lot of time and resources to collect data about customers. This data was synthesized into Business Portfolios Analyses. These analyses made fictional cases, describing hypothetical customers of a given age, sex, income, market profile, and profession. Thus, the Business Portfolios Analyses made tools for exploring customer needs and identify key areas of improvements.

As argued by a senior engineer, the Business Portfolio Analyses could help developers "*put themselves into the knee of end-users to understand what their needs are.*" They could make a great re-

[8] The Open Race Car Simulator
[9] Open Source Computer Visioning

source for stimulating more valuable and useful applications. However, Volvo viewed these resources as company confidential and a source of competitive advantage. Trying to balance this contradiction, the project team selected a specific part of the Business Portfolio Analyses and started to transform it by scaling it down. They created a persona, giving developers basic information such as age, sex, type of truck, logistics company profile, work routines, and driver preferences for services. The project team realized that more personas would further help developers, but given the firm's resistance to reveal its Business Portfolio Analyses the team decided explore this resource, before introducing more.

While the persona would support third-party developers in understanding customers, the project team realized they had little understanding of developers and their needs. To support and encourage developer creativity Volvo had to understand them better. Therefore, the team developed 10 scenarios, described as 'user stories'. Each scenario represented an interpretation of specific developer demands. As an example, one of the scenarios focused on *"access to vehicle data to create more value for the end user of the application"*. This scenario directed the teams' attention to vehicle data and issues of enabling such data for developers. Traditional solutions for getting access to vehicle data were based dedicated device to be connected to the vehicle via a cable. This would make a barrier for developers and the team, therefore, decided to package a set of signals as an API to support developer access.

Experimenting with a vehicle data API the project team realized that it was hard for them to predict what data signals would be most valuable for external developers. Thinking about what signals could constitute a vehicle data API the team started to assess a possible collaboration with another initiative – Automotive Grade Android (AGA). This project also developed an android-based digital platform for the automotive industry, but with a software engineering focus on APIs and SDKs. After several meetings with the AGA project team, Volvo saw an opportunity in the fact that AGA developed an "AGA's Vehicle API giving possibility for App developers to access vehicle data". The team decided to join forces with AGA. When starting to think about the organizational interventions associated with the inclusion of AGA resources, the team identified a need to complement and extend the resources provided by AGA. Volvo's global application SDK coordinator argued: *"the choice of going with Automotive Grade Android allowed us to focus more on the other user stories"*.

One of the other scenarios identified a need for vehicle signals that could reveal driver distraction: *"As a developer I want notifications from the vehicle that are of interest from a safety perspective so that I can show different views depending on situation"*. Referring to the NHTSA driver distraction guideline, AGA considered 'driving' vs. 'stand still' as the two main driving modes. Based on these two modes the so-called Distraction Level API was designed to afford developers degradation of application functionality, based on driving modes. However, this solution relied on a definition of driving modes, which was a matter of debate in the team. In other words, the team was seeking for a solution that was not tied to discrete distraction levels. Posing an alternative to the Distraction Level API, the team then developed the Safety API. This API relied on a so-called workload assessor, estimating the workload from various internal signals. This afforded a more nuanced solution, where the platform could define what interaction modalities such as images, videos, text and sounds to use in a given situation. While satisfied with this new platform resource, the team could see that its complexity might create a barrier to adoption and developed a complementary resource; the Safety API Tutorial. Essentially, this resource was a video clip, demonstrating how to work with the API.

Figure 1 provides a holistic view of how Volvo transformed internal resources into boundary resources. The graph presents platform boundary resources, such as documents, SDK and API. It also includes intermediate resources, engaged in the transformation process. In this graph, parallelograms represent technical documents, diamonds are APIs, rectangles are SDKs and triangles are educational materials.

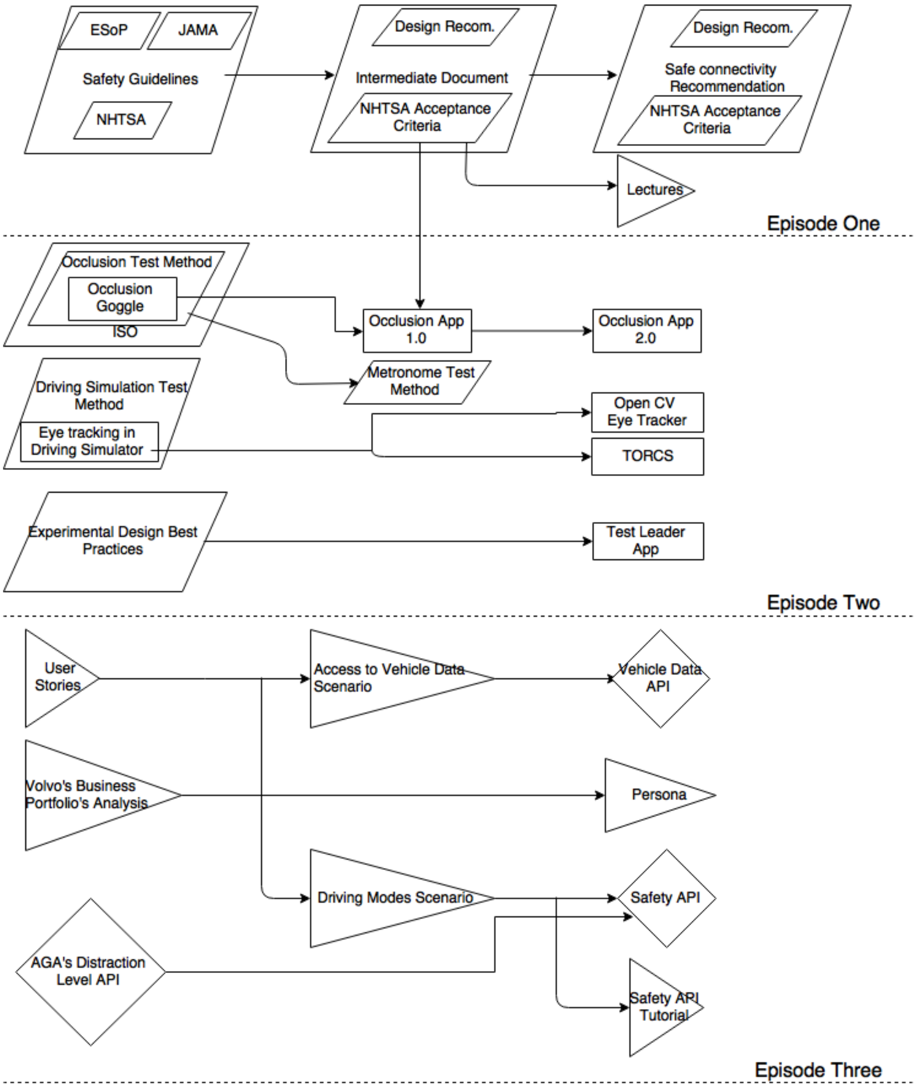

Figure 1. Holistic view of resource transformation process

6 Discussion

Analyzing the transformation of organizational resources into boundary resources, we identified three main areas where Volvo took action; the Volvo project team tried to guide development practices for generation of safe infotainment applications; they wanted to support developers for self-assessment of applications; they tried to stimulate applications with relevance for a driving context. Synthesizing these episodes, we found that Volvo initially approached the issue of boundary resource design from a strictly internal perspective. For example, when the project team first tried to assess and compare different automotive guidelines for HMI design, the discussion was centered on driver distraction measurements, but without considering how such measurements would play out among external developers. The idea that external developer might view driver distraction differently was foreign to the team. Therefore, the design of boundary resources was primarily view as a way to enable existing and well-proved knowledge for external developers. The transformation of internal resources into platform boundary resources was, at first, exclusively colored by Volvo's frames of references, without recognizing a need to shift identity (Tripsas, 2009) or culture (Lucas & Goh, 2009).

The development of the safe connectivity recommendation marks a shift in mindset, where the project team started to recognize that external development takes place in a different context. Boundary resources that make perfect sense to an automotive engineer, might actually be disregarded by an Android developer. Now, team members invested more time in trying to understand external developers. Rather than just enforcing Volvo's knowledge they tried to identify gaps in design knowledge and use existing organizational and technological resources to fill these gaps. The transformation of organizational resource into platform boundary resources was not anymore viewed as a unilateral activity, but involved mutual interaction. Boundary resources were critical to this interaction by "facilitating shared understanding and promoting agreements about designs." (Bergman et. al. 2007, p. 551).

As the project team gradually focused more attention on the stimulation of novel applications, we noted a another shift in mindset; the project team did not just recognize that boundary resources had to be shaped with developers in the loop, but it tried to explicitly understand what these resources would allow developers to do. The work with the vehicle API, as an example, illustrates how Volvo tried to identify potential resources for transformation and then explored what these resources could afford (Leonardi, 2011) in application development. As the project team learned about affordances, they also tried to find ways of increasing developers' capability to understand and apply affordances. Put differently, they searched for core functionality that could empower developers in application development.

Our case study of resource transformation at Volvo Group offers several important learnings. First, it emphasizes that platform designers have to recognize that people interact with objects only after they understand what it is good for and what it can affords them (Treem and Leonardi 2012). Therefore, the transformation of internal resources into platform boundary resources have to be guided by continuous exploration and articulation of resulting affordances. As described by existing research, platform owners cannot do this by themselves. Instead, platform boundary resources are shaped collaboratively, in a continuous interaction between platform owners and external developers (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013). However, while confirming previous research, our study also indicate that the emergence of platform boundary resources cannot be fully understood by studying the interplay between platform owners and external developers. It is important to also recognize that existing organizational resources often make up the primary raw material for platform design. That means, platform boundary resources are shaped, not only through the interplay with external developers, but also in a continuous negotiation with internal firm resources.

Transforming existing firm resources for inclusion with a digital platform may offer substantial advantages. For example, it can open up for a market positioning that is distinct from rival firms'. In other words, such distinctive positioning (Cennamo & Santalo, 2013b) may offer competitive advantage by shaping "a platform ecosystem that is different from competitors' portfolios" (p. 1336). At the same time, the transformation of internal resources triggers competing concerns (Svahn et al. forthcoming), as platform thinking clashes into existing practices. Traditionally, incumbent organizations build competitive advantage by protecting organizational resources (Barney, 1991; Penrose, 1959; Wernerfelt, 1984). Making resources publicly available, by including them in a digital platform, may destroy such competitive advantage and prevent the organization of accumulating rents (Teece, 1993). Our study suggests that such tensions are more the rule than the exception when firms seek to transform organizational resources into platform boundary resources. Sooner or later, they end up having to ask themselves whether to keep a resource as an asset for competitive advantage in the existing market or to expose it to external developers for building competitive advantage in an upcoming market.

We recognize that our research has limitations. First, since this is a single case study it is important to be aware of the specific context at Volvo Group. Second, the studied platform was developed in an experimental project and was never used in Volvo's ordinary products. However, we look upon the student evaluation as an authentic event, providing reasonably accurate results for us to draw conclusions. Finally, we could have focused more attention, earlier in the study, on the tensions and contradictions powering resource transformation.

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