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Reallocating Uncertainty in Incumbent Firms through Digital Platforms: The Case of Google's Automotive Ecosystem Involvement

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Abstract

This research examines how incumbent firms decide on the degree of involvement of technology players in their digital strategies, by integrating insights from digital innovation and digital platform research. We conducted an embedded case study on the adoption of Google's Android Automotive OS and Google Automotive Services by the automotive industry, using semi-structured interviews with industry experts and senior decision-makers. We build on affordance-actualization theory to develop a grounded model of uncertainty reallocation consisting of five aggregate dimensions: (1) external digital platform by tech firm, (2) incumbent firm and its goals, (3) uncertainty tradeoffs and affordance of reallocation, (4) strategic actions by incumbent firm, and (5) short- and long-term outcomes. Our results provide valuable insights into the selection of non-binary platform strategies and the effects of various levels of technology firm involvement. This addition to the knowledge base of the information systems discipline provides practical guidance for incumbent firms navigating digital transformation.

Keywords: Digital platforms, Digital innovation, Incumbent firms, Uncertainty reallocation

Introduction

The automotive industry is undergoing a significant transformation due to digital technologies that challenge original equipment manufacturers (OEMs) (Bohnsack et al., 2021; Svahn et al., 2017). By 2030, modern OEMs aim to generate up to 50% of their profits from recurring digital revenue streams (Römer et al., 2022). Yet, many are still struggling to adopt a digital-first approach, vital for realizing software-defined vehicles (Dremel et al., 2017; Svahn et al., 2017). Cars are evolving from status symbols to "smartphones on wheels" (Hanelt et al., 2015; Kaiser et al., 2018), with infotainment systems playing a central role (Weiss et al., 2021). With up to 40% of drivers considering switching brands for superior digital services such as integrated navigation and entertainment features (Heineke et al., 2020), tech players are in a favorable position. They leverage their smartphone expertise, using infotainment as a medium to occupy the digital interface between the driver and the vehicle (Schreieck et al., 2022; Weiss et al., 2021). For example, Google not only attracts drivers with its navigation application, Google Maps, but offers an operating system (OS) for entire infotainment suites (Legenvre et al., 2022). This growing proficiency of tech players in automotive dynamics could relegate OEMs to mere hardware producers, reshaping the industry value chain.

An incumbent firm is defined as a well-established firm with a significant market share in its industry, often with long-standing customer relationships and operational processes (Porter, 1985). Most incumbent firms must revise their business strategies to remain competitive in the digital age, which is currently dominated by tech players (Hermes et al., 2021; Sebastian et al., 2017). Incumbents, which have years of experience enhancing their pipeline business models, need to broaden their traditional value-creation logic to include digital platforms (Marheine et al., 2021; Van Alstyne et al., 2016). However, the pursuit of digital innovation brings unique challenges, such as lack of expertise, surging costs, and changing customer expectations (Gao et al., 2022; Oberländer et al., 2021; Sterk et al., 2022). Previous studies have examined how incumbent firms transition to the platform economy and the required changes to benefit from platform economics (Sandberg et al., 2020; Sebastian et al., 2017; Svahn et al., 2017). However, they have usually assumed that incumbents have only two alternatives for platform strategizing: building or joining (Cusumano et al., 2019; Hein et al., 2020). They overlooked the potential to collaborate, assemble, configure, or contribute to open-source, white-label, or tech firm-provided platforms (Hermes et al., 2021). Our objective is to explore the non-binary elements in platform strategy and the impacts of varying levels of tech firm involvement. We ask: *How and why do incumbent firms decide on a certain level of tech player involvement in their digital strategy?*

We conduct an embedded case study (Yin, 2014) focusing on Google's Android Automotive OS (AAOS) and its underlying Google Automotive Services (GAS) as the sole locus of our research. Our research is based on semi-structured interviews with industry experts and senior decision-makers knowledgeable about Google's digital platforms and their adoption by incumbent OEMs, as well as publicly available information published from the AAOS inception in May 2017 through April 2023. In the process, we find three distinct digital strategies that incumbent OEMs can adopt to integrate Google's offerings. Through grounded-theory-based interpretive data analysis (Gioia et al., 2013), we identified uncertainty reallocation as a core construct and derived five aggregate dimensions that represent the building blocks of a grounded model—(1) external digital platform by tech firm, (2) incumbent firm and its goals, (3) uncertainty tradeoffs and affordance of reallocation, (4) strategic actions by incumbent firm, and (5) short- and long-term outcomes.

The remainder of this paper is organized as follows: First, we outline the theoretical foundations of uncertainty in digital innovation processes and boundary resources in digital platforms. Next, we outline the research method of our case study, followed by the analytical results. Finally, we present a grounded model of uncertainty reallocation through digital platforms, discuss the implications of our research, and provide a brief conclusion on its limitations and further research opportunities.

Theoretical Foundations

Uncertainty in Digital Innovation Processes

The digital era introduces numerous uncertainties for incumbent firms (Salmela et al., 2022; Svahn et al., 2017) as they navigate a volatile, uncertain, complex, and ambiguous (VUCA) environment while redefining their organizational identity and purpose (Wessel et al., 2021). Uncertainty, defined as *"a potential deficiency in any phase or activity of the process, which can be characterized as not definite, not known, or not reliable"* (Kreye et al., 2012, p. 683), or simply, a *"lack of understanding"* (Kreye et al., 2012; Ramirez Hernandez & Kreye, 2021), leads decision makers to have low confidence in predicting future outcomes resulting from their decisions (Erkoyuncu et al., 2013; Ramirez Hernandez & Kreye, 2021). Unlike risk, which is defined as a measurable unknown, uncertainty cannot be assigned a probability (Jalonen, 2012).

Uncertainty management throughout the innovation process has been studied in service management and new product development (Ramirez Hernandez & Kreye, 2021). However, recent research emphasizes its importance also in digital innovation processes in the context of Information Systems (IS) (Poeppelbuss et al., 2022). These processes involve decisions under highly variable and uncertain future states, influencing perceptions of strategic options for structuring, developing, using, and deploying IT artifacts (Kohli & Melville, 2019; Nambisan, 2017; Nylén & Holmström, 2015). Factors contributing to increased uncertainty include rapid technological developments, evolving customer demands, internal challenges in understanding the affordances of digital technologies, determining the level of collaboration with suppliers and partners, and assessing whether investments in digital innovation will yield the required returns for all actors involved in the ecosystem (Nambisan, 2017; Poeppelbuss et al., 2022; Svahn et al., 2017).

We adopt a multidimensional conceptualization of uncertainty (Poeppelbuss et al., 2022; Ramirez Hernandez & Kreye, 2021), while recognizing the interrelated nature of these dimensions (O'Connor & Rice, 2013). Ramirez Hernandez and Kreye (2021) distinguish between the unpredictability of the external environment *(environmental uncertainty)*, the lack of experience with the technologies the organization intends to adopt and employ *(technical uncertainty)*, the organizational dynamics throughout the change process *(organizational uncertainty)*, the adequacy of financial, technical, and human resources *(resource uncertainty),* and the inability to predict and explain the actions of external related actors *(relational uncertainty)*. This distinction allows us to delineate the different sources of uncertainty in our study.

Existing research suggests strategies for managing uncertainty by reducing it at its source or coping with it by minimizing its impact (Poeppelbuss et al., 2022; Simangunsong et al., 2012). Organizations may also engage in *uncertainty reallocation* by shifting criticality between uncertainty types (Poeppelbuss et al., 2022; Ramirez Hernandez & Kreye, 2021). For instance, Poeppelbuss et al. (2022) empirically show how participation in multi-actor innovation settings can reduce technical and resource uncertainty while increasing relational uncertainty. In this context, our study explores how external digital platforms, such as Google's automotive platforms AAOS and GAS, enable incumbents to reallocate uncertainties and how they determine strategic actions to actualize and exploit these affordances.

Affordances of Boundary Resources in Digital Platforms

We define a digital platform as *"a set of digital resources—including services and content—that enable value-creating interactions between external producers and consumers"* (Constantinides et al., 2018, p.381). Digital platforms can provide technological affordances, which refer to *"what one individual or organization with particular capabilities and purposes can or cannot do with a technology"* (Majchrzak & Markus, 2013, p. 832). To provide new affordances, digital platforms must possess inherent flexibility, enabling them to be reconfigured as needed (Hein, Setzke, et al., 2019; Yoo et al., 2010). In addition, the architecture of digital platforms is characterized by a high degree of modularity, facilitating the integration of new modules without jeopardizing the entire system (Tiwana et al., 2010).

To design for such affordances, platform owners use boundary resources that enable complementors to develop products or services on the digital platform (Eaton et al., 2015; Ghazawneh & Henfridsson, 2013; Hein, Setzke, et al., 2019). Boundary resources can be software tools or rules that *"serve as the interface for the arm's-length relationship between the platform owner and the application developer"* (Ghazawneh & Henfridsson, 2013, p. 174). The concept of boundary resources can be understood as a theoretical device (Ghazawneh & Henfridsson, 2013) for digital platform owners to balance the tension between retaining platform control and stimulating the generativity of third-party developers (Tilson et al., 2010). These resources include technical and social elements, such as application programming interfaces (APIs), and regulations, incentives, and guidelines, respectively (Aanestad et al., 2019).

Prior research has mainly focused on the boundary resources of digital smartphone platforms (Eaton et al., 2015; Karhu et al., 2018, 2020). For instance, Eaton et al. (2015) explain how boundary resources in Apple's iOS platform change through distributed tuning. This process triggers cascade of adaptations and rejections in a network of diverse actors and artifacts. Karhu et al. (2018) study Google's Android mobile platform and identify four functions of boundary resources: defining openness, facilitating, loosening couplings, and capturing value. Besides research on purely digital ecosystems, research has addressed boundary resources in Internet of Things (IoT)-based digital platforms (Hein, Weking, et al., 2019; Petrik et al., 2021; Petrik & Herzwurm, 2020). Our study integrates these research directions through a case study of Google's automotive platforms, AAOS and GAS, focusing on software-defined vehicles as complex IoT devices. Specifically, we examine the affordances of boundary resources within AAOS and GAS to understand how platform owners facilitate generativity for OEMs and third-party developers while retaining control.

Research Method

We use an embedded single-case study approach (Yin, 2014) to und how incumbent firms adapt their digital strategies in terms of engaging with technology firms in response to them introducing digital platforms to the market. This section details our case selection, data collection, and data analysis.

Case Selection. We employ a revelatory single case strategy (Yin, 2014), which includes multiple subunits of analysis and allows for variation across them to examine previously inaccessible dynamics of a phenomenon (Yin, 2014). We chose the automotive industry and Google's AAOS along with its underlying GAS features, such as Google Maps, Google Assistant, and Google Play Store as our case. Our selection was motivated by the significant IT-driven innovation in the automotive sector, and Google's central role through AAOS. Unlike alternatives such as Android Auto or Apple CarPlay, AAOS is specifically designed for direct in-vehicle integration, allowing enhanced interaction with vehicle systems. Due to the increasing partnerships between OEMs and Google, our study focuses mainly on the extent of Google's access to vehicle functions and data (e.g., AAOS with/without GAS). As embedded subunits within this case, we analyze the strategic positioning of different incumbent firms regarding Google's AAOS and GAS solutions over time. Following a sampling logic that emphasizes subunit diversity (Yin, 2014), we identified three distinct OEM actualization strategies by analyzing their strategic actions from 2017 to 2023, and used these as the basis for abstracting knowledge across multiple embedded units of analysis. Figure 1 shows a timeline of the evolution of Google's AAOS and GAS offerings, along with the OEMs' strategic positioning.

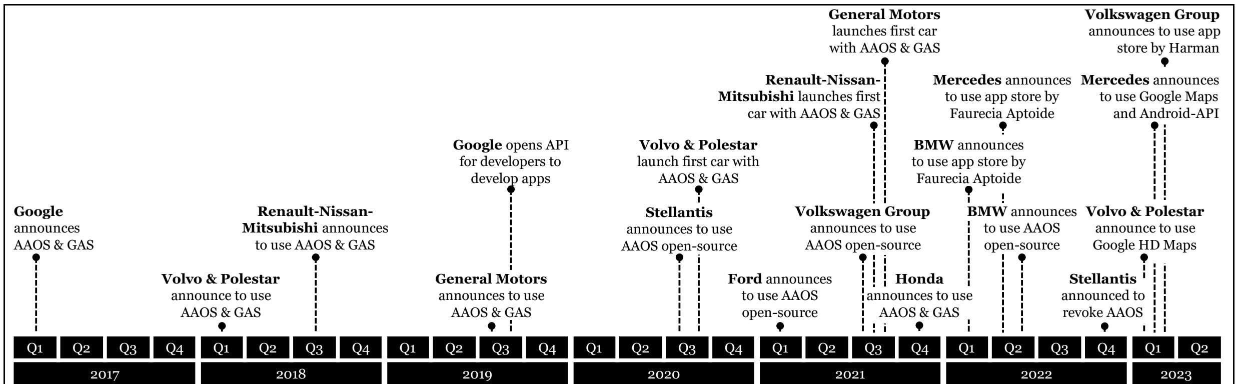


Figure 1. Case timeline of AAOS and GAS development and adoption by OEMs

Data Collection. Our primary data sources were interviews and archival documents, providing a multi-faceted view of our case (Yin, 2014). Between June 2021 and April 2023, we interviewed 17 industry experts and senior decision-makers actively involved in incumbent firms. These interviewees held pivotal roles in understanding Google's automotive offerings (i.e., AAOS and GAS) and their adoption by automotive OEMs (see Table 1). The timing of the interviews coincided with significant developments and announcements in the automotive industry related to Google's offerings. Additionally, our secondary data source's timeframe, spanning May 2017 to April 2023, provides a broader historical context prior to the primary data collection period. Using both convenience and theoretical sampling, we initially reached out to existing contracts in the automotive industry and subsequently acquired additional interviewees to provide depth on specific emerging aspects as the study progressed (Bryman, 2016). Participants were selected based on their professional roles, ranging from technical experts to strategic decision-makers, to ensure an encompassing perspective on our topic. While a wider pool of potential participants was initially identified, practical constraints such as availability and sensitivity of the topic determined the final set of interviewees. While the perspectives of car users were not considered central to the decision-making of incumbent firms, we recognize their potential value in future studies that seek a broader understanding.

The semi-structured interviews, averaging 53 minutes, were structured around open-ended questions on pre-defined topics (e.g., value-capturing strategy, data sovereignty, or scalability), conducted by two authors, and their transcripts were analyzed using MAXQDA software. Our secondary data included 67 publicly available archival documents, such as articles, strategy update reports, and press releases, focusing on OEM's strategic activities related to Google's AAOS and GAS between May 2017 and April 2023. By analyzing this data, we identified 19 strategic activities by either Google or the OEMs (see Figure 1). OEMs that planned to integrate AAOS or GAS in some way include BMW Group, Ford, General Motors, Honda, Renault-Nissan-Mitsubishi, Mercedes-Benz, Volkswagen Group, Stellantis, Volvo, and Polestar.

Data Analysis. Following established procedures for inductive data analysis (Gioia, 2021; Gioia et al., 2013), our analysis began with two authors independently reviewing interview transcripts and documents.

During this phase, descriptive open and in-vivo codes were assigned to relevant segments to capture a range of insights related to our research question. To ensure the reliability of our coding, both authors met regularly to discuss discrepancies and arrive at a shared interpretation. This iterative approach fostered a higher level of inter-coder reliability and ensured the robustness of the concepts and themes derived. Supported by initial memos (e.g., preliminary diagrams), these team discussions helped reassemble the data by aggregating clusters of descriptive codes into 46 informant-centered first-order concepts that served as inferential and explanatory codes that highlighted explanatory patterns in the data. In the second-order analysis, we further condensed related first-order concepts into 17 more research-centered second-order themes. Finally, we distilled the second-order themes into five aggregated dimensions and developed a grounded model. In the latter analytical steps, we the applied affordance-actualization theory (Strong et al., 2014) as a theoretical lens to explain the conceptual relationships among the constructs.

Industry Sector	Company	Role of Interviewee (Years of Tenure)	Length
Car Manufacturer	OEMCorp1	Product Owner App Store (6)	72 min
		Android Automotive Developer (6)	46 min
	OEMCorp2	Lead Android Automotive Developer (8)	45 min
	OEMCorp3	Senior Project Manager Vehicle Platform (6)	67 min
		Project Manager Automotive Software (11)	68 min
	OEMCorp4	Product Manager Digital Services (5)	59 min
	OEMCorp5	Company Builder Automotive (6)	61 min
	OEMCorp6	CEO/CTO Digital Innovation Unit (20)	66 min
Tier-1 Supplier	SupplierCorp1	Senior Android Automotive Developer (5)	51 min
		Senior Vice President Engineering (24)	41 min
		Product Lead Software-Defined Vehicle (8)	27 min
		Product Manager Infotainment (8)	42 min
		Business Owner Android Automotive (24)	46 min
	SupplierCorp2	Director Navigation Software (13)	58 min
Consulting	ConsultingCorp1	Strategy Consultant Automotive (20)	44 min
	ConsultingCorp2	Strategy Consultant Automotive (4)	44 min
Applied Research	ResearchCorp	Senior Automotive Software Architect (8)	62 min

Table 1. Overview of Interviewees

Insights from Google's Automotive Ecosystem Involvement

In this section, we present analytical insights into how and why incumbent firms reallocate uncertainty by deciding on the level of tech player involvement in their digital strategy. The focus of our embedded case study is Google's automotive platform offering (i.e., AAOS and GAS), as Google currently holds the predominant position in infotainment and operating systems, forcing traditional OEMs to reconsider their digital strategy. We first describe the affordances of uncertainty reallocation by incumbent firms (i.e., carmakers) via the utilization of a tech firm's (i.e., Google) external platform and then present findings regarding the actualization strategies taken by incumbent firms.

Affordance of Uncertainty Reallocation

External Digital Platform by Tech Firm

The influx of tech players into the automotive industry has resulted in a more fragmented competitive landscape. They provide external digital platforms to penetrate the market for certain areas of the technology stack, as observed with Google's operating system (AAOS) and the accompanying service offerings (GAS). Boundary resources play a crucial role and are an indispensable tool for platform owners to implement digital platform strategies. In the context of Google's digital in-vehicle platform, we identified boundary resources used to pursue four strategies—scale, capture value, standardize, and facilitate. In the following, we elaborate on the boundary resources associated with Google's AAOS or GAS (see Figure 2).

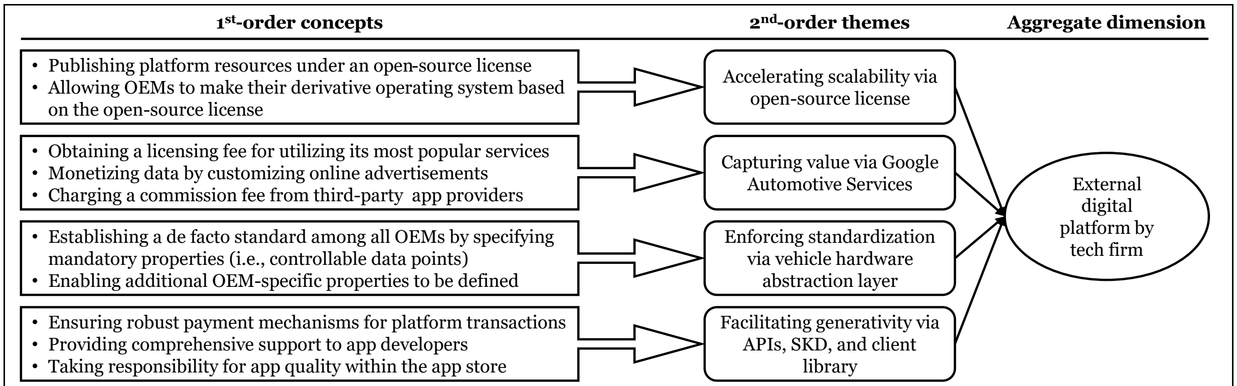


Figure 2. Data Structure for "External Digital Platform by Tech Firm"

Accelerating scalability via open-source license. Analogous to its smartphone OS, Google has released AAOS under an open-source license so that OEMs can install AAOS in their cars without involving Google and without entering into a contractual relationship with Google to make their derivatives of the OS. The Product Lead of SupplierCorp2's software-defined vehicle program pointed out the distinction between a "true" open-source approach like Linux and having *"a commercially interested firm like Google as the shepherd of the open-source project."* In the end, AAOS *itself is always "just an enabler for Google, but it does not generate any monetary gains,"* as ResearchCorp's Senior Software Architect added. From a strategic perspective, the open-source license encourages as many OEMs as possible to integrate AAOS to scale the ecosystem quickly. ConsultingCorp1's Strategy Consultant summarized this aspect as follows:

> *"Android Automotive open-source is Google's brilliant idea to make carmakers dependent without directly charging licensing fees. [...] Some OEMs are afraid to work directly with Google due to the licensing costs and dependency. However, some of them are being convinced because it is possible to use AAOS open-source, which seems like Linux. This is the Trojan horse that OEMs fall for because they don't have to pay licensing fees."* (Strategy Consultant, ConsultingCorp1).

Capturing value via Google Automotive Services. While AAOS itself is open-source, Google has developed value-adding software artifacts called Google Automotive Services (GAS) that interact with the OS, including Google Maps, Google Assistant, and the Google Play Store. To use GAS, implementing OEMs must enter into a licensing agreement and share proprietary data with Google. According to ResearchCorp's Software Architect, *"Google's focus is not on acquiring in-vehicle data. From a marketing standpoint, the user is a more appealing target than the vehicle itself." Thus,* Google's primary scaling mechanism depends on gaining access to user data in order to extract patterns to develop customized online advertising, and improve the quality of applications such as Google Maps. Google's third monetization mechanism is its Play Store, which is mandatory for OEMs using GAS and charges a commission fee for third-party applications hosted there. The Product Owner of OEMCorp1's app store stressed the analogy to the smartphone world:

> *"The most exciting thing, from my point of view, is the business model. Who will earn money with digital products in the vehicle in the future? If you look at how things have worked in the mobile phone world, third-party app developers are the only ones earning money directly from digital products. But who is the only one who gets a revenue share? It's the two big stores, Apple and Google. The Play Store is one of three apps that come with GAS. And that means that the likelihood that you as an automotive OEM can still earn money with digital products in the car afterwards will be diminished."* (Product Owner App Store, OEMCorp1).

Enforcing standardization via vehicle hardware abstraction layer. Regardless of whether an OEM chooses the open-source option or licenses AAOS, the most important requirement for integrating Android into their cars is the implementation of the vehicle hardware abstraction layer (VHAL). The VHAL extends the original Android framework for the automotive context and defines properties, such as powertrain-related data, that must be supported by all OEMs implementing AAOS. Google enables OEMs to extend the VHAL and integrate custom, manufacturer-specific properties, giving them control and data sovereignty over the vehicle data sent to Google. However, according to analysis by ConsultingCorp1's Strategy Consultant, the authority ultimately remains with Google, as market demand for advanced applications will force OEMs to share specific vehicle data items with Google and third-party developers:

> *"The belief that the OEM has full control over the VHAL and data is a widespread misconception. In reality, the OEM can only define supported data, and this poses a challenge as developers are hesitant to build applications for a platform that is not based on a common foundation of supported data and functionality. The platform business operates within a merciless economy of scale, and without external developer support, the OEM's capacity to build customer relationships is severely limited. […] This lack of scale and content will cause the standard to fail, as it will not be able to secure a customer base."* (Strategy Consultant, ConsultingCorp1).

Facilitating generativity via APIs, SKD, and client library. The success of Google's expansive digital ecosystem can be attributed to its robust third-party developer community, which delivers a diverse set of third-party apps available to end users. Implementing GAS comes with APIs and a software development kit (SDK) that facilitates app development while guaranteeing a robust payment infrastructure for all platform transactions through the Google Play Store. GAS provides extensive support for app developers, including various resources such as tools, test suits, documentation, and collaborative events (e.g., developer conferences). In addition, AAOS provides a client library called Google Play Services, which facilitates frequent updates to developer APIs independently of OEMs. Finally, with its established control mechanisms, Google takes responsibility for excluding undesirable or malicious apps, relieving the OEM of the burden of ensuring the app quality in the store. SupplierCorp1's AAOS Business Owner summarized the similarities and differences to a Linux-based OS for developers as follows:

> *"The bottom part of Android and the Linux system is similar because it's a Linux kernel with certain similarities, but the architecture of Android is different, for example, because of the virtual machine and the high-level APIs, which are mainly for third-party developers to develop apps […]. They just promote it as an app development environment. The documentation for AAOS is not extensive for OEMs; it's mostly for app development. […] The whole architecture and the setup for Android is just to promote third-party apps."* (Business Owner Android Automotive, SupplierCorp1).

Incumbent Firm and Its Goals

The ongoing digital transformation is turning cars from status symbols into rolling computing platforms. This paradigm shift has pushed OEM to re-evaluate their strategic goals, forcing them to make crucial decisions about their future service offering and digital business models to remain their competitive edge in the market. By implementing an appropriate digital strategy, OEMs can retain control of their businesses, avoid commoditization by tech players, continue providing high-quality services to end customers, and tap into recurring digital revenue streams. We found that OEMs have formulated four overarching goals concerning their infotainment offering, which we discuss below (see Figure 3).

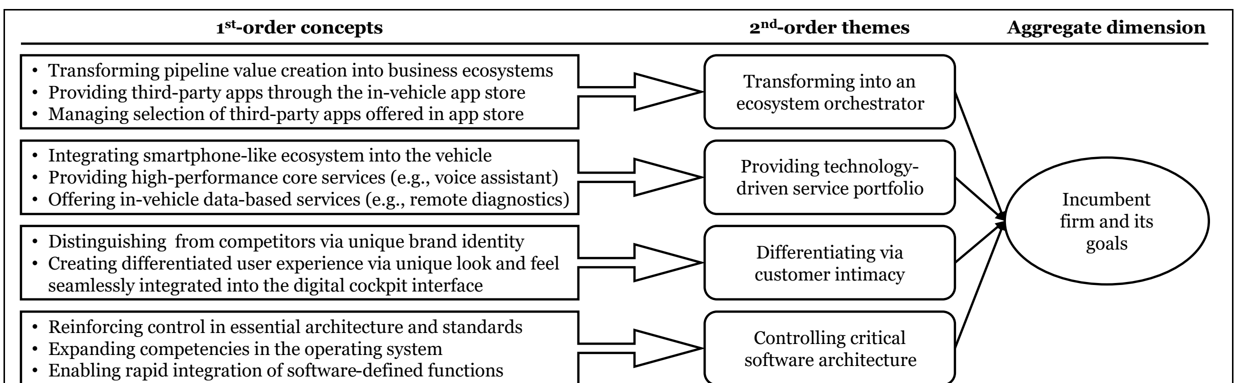


Figure 3. Data Structure for "Incumbent Firm and Its Goals"

Transforming into an ecosystem orchestrator. OEMs want to move from selling physical cars within a linear value chain to orchestrating service-oriented business ecosystems. Due to the complex nature of software-defined vehicles, they rely on third-party developers to expand their application offerings while maintaining quality standards and managing costs efficiently. Implementing in-vehicle app stores not only enhances the driving experience but also provides an opportunity to earn a significant revenue share from third-party apps. The ecosystem orchestrator takes on the role of a gatekeeper, controlling the selection of third-party apps and determining which are ultimately offered in the app store. The Product Owner of OEMCorp1's app store emphasized the difference between the OEMs' existing business models and the coveted role of an ecosystem orchestrator:

> *"Today, we don't have a platform business model, which means we don't build a two-sided marketplace but sell products in the pipeline value creation, where we end up enriching the product more and more through suppliers and sell it once to the customers. In the future, we want to build a platform ecosystem where third-party developers develop apps for us. As a store provider, we can set certain rules, such as what is allowed and what is prohibited. We can also ensure that these rules are adhered to, and we can earn money with [the app store]. But as of today, no one makes money with apps in cars."* (Product Owner App Store, OEMCorp1).

Providing technology-driven service portfolio. An additional goal of incumbent firms is to provide a value-adding digital app portfolio to meet increasing end user expectations. This includes the integration of the user's other digital ecosystems, such as music streaming, into the vehicle, which has become standard practice. Moreover, OEMs try to improve the performance of other in-vehicle services and reduce the dependencies on smartphone mirroring, with navigation systems and voice assistants being the most prominent. For instance, map application providers *have the power to influence the driver with targeted and prominently placed points of interest. With the vast* amounts of in-vehicle data generated by sensors and software, OEMs are looking to create analytical insights about the vehicle, the driver, and their environment, enabling data-driven business models in areas such as insurance, after-sales, and fleet management. *Appropriately, the Product Owner of* OEMCorp1*'s app store drew an analogy to the smartphone and confirmed the significant potential underlying digital in-vehicle services:*

> *"Is there even a market for digital products in cars or not? Nobody can say, but I believe there is. [...] But in 2005, very few people would have said that many billions of Euros would be turned over in a quarter via an app store that runs on a mobile phone. And if you look at the possibilities, a smartphone offers only a fraction of the interfaces and sensors or data that a car theoretically has. If you take that as a measure of the potential for innovation, the business potential for digital automotive products is enormous."* (Product Owner App Store, OEMCorp1).

Differentiating via customer intimacy. As a third goal, OEMs seek to differentiate themselves through unique brand identity and direct interaction with the end user via the digital cockpit. Control of the digital interface, and therefore customer interaction, allows for a differentiated user experience and improved customer value. In particular, premium carmakers strive to deliver rich digital experiences seamlessly integrated with their overall brand identity and familiar aesthetics, such as intuitive touchscreens. However, OEMs must retain control over the user touchpoint and central data to generate and capitalize on increased satisfaction via brand-exclusive onboard experience. SupplierCorp2's Director Navigation Software affirmed:

> *"Today, it's all about software and the experience you create for your customers, but also the relationship you build with them. If the big screen in your car belongs to a third party [...] and they own the direct relationship with the consumer, what is left for the OEM? How can they differentiate themselves? How are they going to create and monetize value-added services on that platform in the future? [...] This is not about the operating system, but what they build on top of it, like their own applications or ecosystem to keep that direct relationship with the consumer and collect and use data to improve and monetize their products."* (Director Navigation Software, SupplierCorp2).

Controlling critical software architecture. Finally, OEMs aim to strengthen their control over key architectures and standards by expanding capabilities in OS and middleware. Both serve as critical vehicle components that enable carmakers to integrate essential software-defined features into the vehicles rapidly. These functionalities include remotely integrating additional battery power or activating seat heating features through over-the-air updates. However, while OEMs are eager to expand their in-house software stack development to avoid external dependencies, lack of expertise, escalating costs, and lack of economies of scale are putting pressure on them to partner with large tech companies. ResearchCorp's Automotive Software Architect added specific reasons for the strong emphasis on in-house development by OEMs:

> *"It can be more efficient and cost-effective for the OEM to develop a custom proprietary operating system. For example, AAOS requires a lot of heavy hardware. [...] Additionally, allowing external tech players to take responsibility for the further development of the operating system poses significant risks for the OEM. [...] Utilizing a third-party operating system entails a potential loss of control over data, as the vendor may try to get as deep into the vehicle as possible."* (Senior Automotive Software Architect, ResearchCorp).

Uncertainty Tradeoffs and Affordance of Reallocation

The rise of digital platforms such as AAOS and GAS presents a significant potential to reduce uncertainty for legacy carmakers. However, these also increase uncertainty compared to established pre-digital strategies. In sum, external platforms may not necessarily reduce uncertainties but offer the potential to reallocate them, requiring incumbents to balance multiple tradeoffs, as illustrated below (see Figure 4).

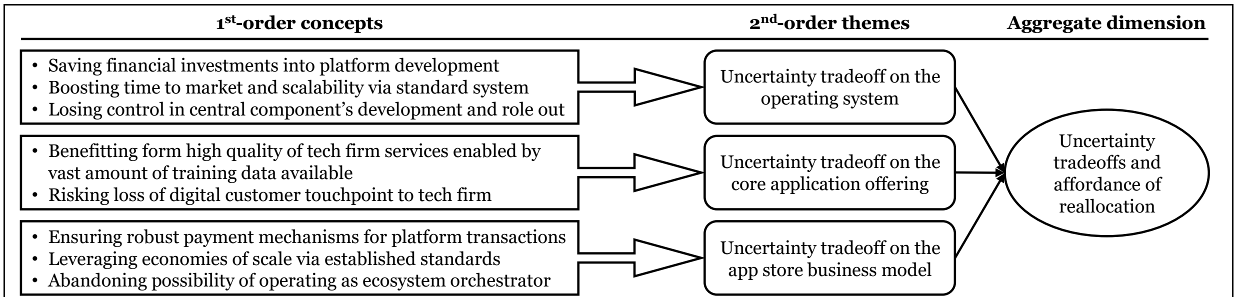


Figure 4. Data Structure for "Uncertainty Tradeoffs and Affordance of Reallocation"

Uncertainty tradeoff on the operating system. Whether to implement AAOS or build a proprietary OS is a key consideration for OEMs. Using an external platform such as AAOS provides significant financial benefits by reducing the need for continuous system updates with each new generation of hardware. Developing and maintaining in-house technology stacks requires a large financial investment, including the cost of hiring software developers with the necessary skills. Also, integrating mature off-the-shelf solutions such as AAOS can improve time-to-market and scalability, especially in the low-volume luxury segment. On the other hand, Google's control over the AAOS system raises uncertainties, even without the use of GAS. Since AAOS is likely to become a standard feature in many cars, Google's role as the provider of AAOS would give them considerable power. They could cease releasing open-source versions of AAOS and offer new versions under license agreements that require GAS or let the VHAL specifications force OEMs to share critical vehicle data. A Company Builder from OEMCorp5 commented on this tradeoff as follows:

> *"Implementing AAOS entails considerable uncertainty to OEMs, as it may result in a loss of control over user data, user behavior, and system usage information. On the other hand, it must be acknowledged that the automotive industry has yet failed to develop a stable operating system. In this regard, I believe it is necessary to strike a balance. While this approach may present challenges, I believe that the benefits of integrating a trusted and well-established operating system outweigh the potential drawbacks associated with data business, information loss, and usage profiling."* (Company Builder Automotive, OEMCorp5).

Uncertainty tradeoff on the core application offering. The next critical strategic decision for OEMs is whether to use GAS or develop and integrate comparable solutions. Google's advantage lies in its vast training data from widespread smartphone use, which makes it difficult to develop navigation services with comparable real-time geo-information as Google Maps or similar voice recognition capabilities as Google Assistant. Moreover, many drivers currently use Google Maps via their smartphone's projection mode and may demand a built-in version, exposing OEMs with alternative solutions to the threat of losing customers. Despite the potential benefits, there are downsides to implementing GAS for OEMs, including losing their digital customer touchpoints and user interactions to Google or limited visibility into data exchange. Finally, GAS offers limited customization of the infotainment system's user interface, resulting in a reduced impact on brand identity and customer experience. The impact of this uncertainty factor varies depending on the OEM's target audience, as explained by OEMCorp1's Product Owner App Store:

> *"An important aspect that OEMs must weigh up is the issue of user experience, user interface, and differentiation. When using GAS, they have limited control over the user interface and experience compared to building on plain Android open-source. However, this is not a general argument for or against GAS; not all OEMs see differentiation in user experience and interface design as a competitive differentiator, especially volume OEMs with lower-priced vehicles who place less emphasis on these aspects."* (Product Owner App Store, OEMCorp1).

Uncertainty tradeoff on the app store business model. When deciding on GAS, carmakers must consider that it includes the integration of the Google Play Store as the in-car app store. Using GAS reduces OEMs' technical uncertainty by ensuring robust payment mechanisms for all transactions and quality control for third-party apps. Also, adherence to established standards can reduce the OEM's potential threat of limited app developer engagement and failure to achieve economies of scale. As a result, experts suggest that the Google Play Store could outpace proprietary alternatives in terms of app quantity, as it facilitates third-party app development through specific boundary resources (i.e., SDK, APIs, and client library). However, embedding the Play Store increases OEMs' uncertainty about its business model, as it prevents them from pursuing the goal of becoming an ecosystem orchestrator by delegating control over third-party app selection, user engagement, app sales tracking, and revenue sharing to Google. SupplierCorp1's Business Owner AAOS stressed the strategic options OEMs have regarding in-car app stores:

> *"There was a time when every major manufacturer was trying to develop their own app store. [...] And how many apps did they have in there? Negligible. That approach has failed. In the second wave, a few manufacturers started using the Google Play Store instead. However, what are the others doing? They are looking for third-party app stores, ideally working with other OEMs to hopefully reach a critical mass of customers and ensure the marketplace's sustainability and profitability."* (Business Owner Android Automotive, SupplierCorp1).

Strategic Actualization Process

Strategic Actions by Incumbent Firm

When integrating Google into an OEM's in-vehicle offering, three actualization strategies have emerged that involve the uncertainty tradeoffs discussed (see Figure 5). To illustrate the actions taken for each strategy, we supplement the description of each type with a corresponding real-world example in the form of a case vignette, also visualizing which architecture components come from Google (grey) and which come from the OEM. (white) (see Vignette 1-3).

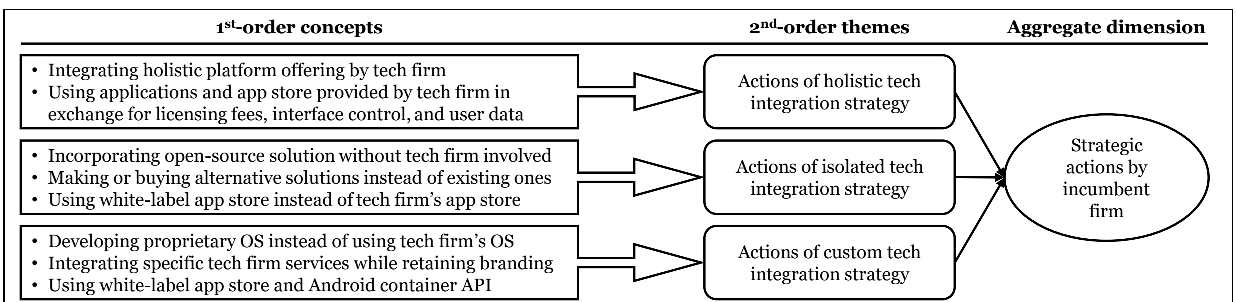
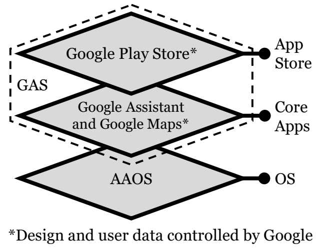


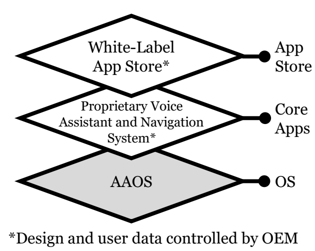
Figure 5. Data Structure for "Strategic Actions by Incumbent Firm"



Swedish carmaker Volvo Cars and its subsidiary Polestar, both owned by Chinese carmaker Geely, have been offering cars with built-in AAOS since 2020. Volvo is fully committed to the partnership resulting in all new cars featuring the whole infotainment system supplied by Google, including the pre-installed GAS. Thereby, Volvo or Polestar car drivers are prompted to link their Google accounts. Furthermore, Google and Volvo are taking their partnership to the next level with the integration of "HD Maps," where Google Maps will use additional car sensor data in real-time to provide highly detailed and up-to-date road information.

Vignette 1. Illustrating "Holistic Tech Integration" via Volvo's Google Built-In Approach

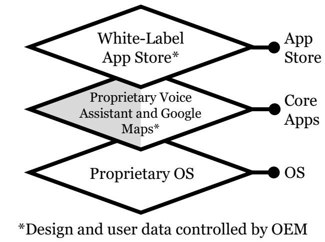
Actions of holistic tech integration strategy. This strategy involves the comprehensive integration of the tech firm's digital platform offerings, in our case both the AAOS and GAS platforms (see Vignette 1: Volvo's Google built-in approach). OEMs that adopt this strategy benefit from a rapid go-to-market, allowing them to focus on their existing core competencies. Regular over-the-air updates of the AAOS base architecture provided by Google ensure a continuous update of the OS and the pre-installed GAS provide the OEM with an attractive service offering in exchange for licensing fees and dedicated vehicle data, reducing the OEM's software development effort to a minimum. With this strategy, OEMs offer their end-users a seamless experience that they are familiar with from their smartphones, including Google ID login, the established Android look and feel, and popular Google applications. Google takes care of the app store, security, and support for app developers, while the OEM takes the role of a complementor, allowing the tech firm to orchestrate the digital ecosystem, including shaping ecosystem policies and receiving revenue shares from third-party apps.



Starting in 2023, the BMW Group will be the first German carmaker to launch an infotainment system based on the open-source variant of AAOS, called BMW OS 9. This approach excludes permanently installed GAS applications (e.g., Google Maps), as BMW wants to retain independence in these areas. BMW also does not use the Google Play Store and instead tries to build up its own Android-based commercial ecosystem supported by selected suppliers. Here, BMW integrates Faurecia Aptoide's white-label app store, with BMW developing the user interface to preserve its brand-specific design and experience.

Vignette 2. Illustrating "Isolated Tech Integration" via BMW's Open-Source Approach

Actions of isolated tech integration strategy. The second strategy adopted by OEMs is to integrate the open-source versions of a digital platform (e.g., AAOS), but not to use proprietary platforms and services (e.g., GAS) in order to avoid becoming too dependent on the external platform providers (e.g., through contractual agreements or payment obligations with Google) (see Vignette 2: BMW's open-source approach). In pursuing this strategy, OEMs need to find alternatives to proprietary services. For example, for in-car navigation systems and voice assistants, OEMs can either rely on their existing service offerings or choose between the traditional make or buy binary. For the app store, most OEMs adopting this strategy procure an Android-based white-label app store from a software vendor to retain the benefits for app developers while outsourcing the app store development effort and retaining platform control. Compared to the first strategy, the OEM replaces Google as the orchestrator, gaining the authority to set app store rules and earn revenue share from third-party applications. The look and feel of the infotainment system and data sovereignty remain with the OEM using open-source and white-label solutions.



Mercedes-Benz took a unique approach to its software strategy in 2023. Instead of choosing an off-the-shelf operating system like AAOS, the firm developed a proprietary infotainment system called MB.OS. This choice was made to retain control over customer relationships and data privacy, and to integrate exclusive car functions. Mercedes is using Faurecia Aptoide's white-label app store, but has also formed a strategic, long-term alliance with Google to be the first OEM building its own branded navigation system using in-car data and Google Maps navigation features.

Vignette 3. Illustrating "Custom Tech Integration" via Mercedes' Exclusive Approach

Actions of custom tech integration strategy. Apart from the two strategies of using open-source platforms such as AAOS with or without proprietary platforms and services (here: GAS), Mercedes-Benz has exemplified in our case a so far unique third strategy (see Vignette 3: Mercedes' exclusive approach), which relies on a proprietary OS without the tech firm's involvement to retain full control over the base-layer of software architecture and overall integration. Although GAS is not involved, this strategy includes the integration of certain Google services in exchange for licensing fees. For example, the OEM integrates Google Maps, which includes rich location details and real-time and predictive traffic information. Under this strategy, the OEM integrates specific Google services while maintaining its own brand and design, and retaining sovereignty over user data. For the app store, the OEM also takes on the role of the platform owner and uses a white-label solution for the app store. In the case of Mercedes, in order to provide a functional app store despite the absence of AAOS, a container API is integrated to run Android apps.

Short- and Long-Term Outcomes

The commitment of incumbent OEMs to an actualization strategy, characterized by their degree of tech firm integration, ultimately leads to different short- and long-term outcomes. In this subsection, we analyze the (anticipated) outcomes for each of the specified strategies (see Figure 6).

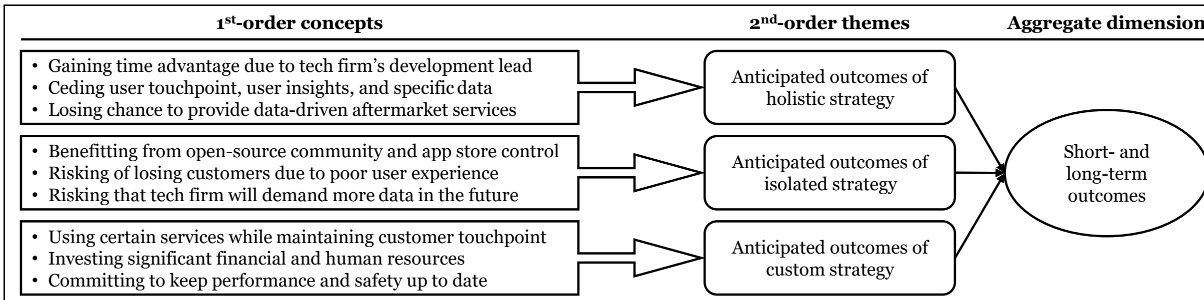


Figure 6. Data Structure for "Short- and Long-Term Outcomes"

Anticipated outcomes of holistic strategy. The holistic tech integration strategy offers early adopters in the short term a state-of-the-art infotainment system with high recognition value (e.g., due to the popularity of Android in the smartphone sector) and a time advantage over other OEMs, since white-label app store providers have to follow Google's Android development. This time advantage is reinforced by close collaboration with the tech partner, allowing the OEM to be the first to release new services, such as in our case the next-level navigation feature "HD Maps". However, OEMs cede the direct touchpoint with the end user, along with valuable insights into user engagement with the infotainment system and specific vehicle data, to Google. In the long run, this approach results in the OEM losing critical infotainment capabilities and the ability to provide data-driven aftermarket services to various end users (consumer, business, and government), including the domains of fleet management, driving analytics, and location-based services. OEMCorp3's Automotive Software Project Manager highlighted this aspect as follows:

> *"Google's data capabilities enable it to offer unique vehicle data-based services that OEMs currently lack the competence to provide. As a result, OEMs may transform into pure chassis suppliers, leaving Google to derive services and business models from the data. In the past, car ownership*

> *was a simple process with limited customer interaction. Now, customers can pay for additional vehicle functions and personalize their vehicles. Aftersales, for example, is the absolute cash cow of the automotive industry and involves continuous customer support and the exploration of new sales channels. By handling this over to tech players, OEMs will lose vital monetization channels."* (Project Manager Automotive Software, OEMCorp3).

Anticipated outcomes of isolated strategy. The OEM's short-term outcome of pursuing the isolated tech integration strategy is to initiate a stable and scalable OS based on the established open-source standards (here: AAOS), which, due to its open-source nature, is constantly being supplemented by a vast developer community. In addition, this approach allows for the creation of a proprietary ecosystem that is mostly independent of the tech firm and gives OEMs control over key differentiators and business model elements, including data ownership, user interface, and app store orchestration. However, OEMs must find competitive alternative solutions with equivalent performance to the tech firm's service suite (here: GAS) to avoid customer churn due to a potentially inferior user experience compared to the tech firm's mature digital offerings. Moreover, the long-term viability of working with white-label app store providers as a genuine alternative to the Google Play Store remains unclear. This approach can only succeed if the adaptation effort for third-party developers to place their apps in multiple Android-based app stores remains manageable, and the tech firm continues to provide the necessary boundary resources (e.g., Google's APIs). Finally, a Company Builder Automotive from OEMCorp5 stressed that a possible long-term outcome could be Google using its position of power to gain more access to vehicle data in the future:

> *"In the future, Google may try to get access to as much car sensor data as possible. For years I've been discussing using all powers of persuasion that we as an OEM can tap into insanely cool data, whether it's from the camera, temperature, or light sensors. Conversely, Google has seen through this potential of moving sensor stations [i.e., cars] for years because they collect everything that isn't nailed down with their smartphones. Google may exploit this lock-in effect to get access to more vehicle sensor data. I have no idea how the OEMs are going to fight this."* (Company Builder Automotive, OEMCorp5).

Anticipated outcomes of custom strategy. OEMs that negotiate individual deals with a tech firm reap the immediate benefits of both strategies discussed so far: leveraging powerful services like Google Maps, while retaining customer touchpoints, including brand, design, and data sovereignty. The app store-related outcomes are similar to the second strategy because of the same white-label approach. However, the peculiarity of this strategy of not using open-source standards such as AAOS and instead developing a proprietary system result in a high short-term financial expenditure, but also has two critical long-term consequences. On the one hand, this approach is primarily characterized by the fact that a significant part of the base system is programmed in-house, thus retaining important software competencies and central control (e.g., over vehicle data) over the OS. On the other hand, the OEM is responsible for maintaining and evolving the system, including performance and security updates, over multiple generations of vehicles. Because of the latter, industry experts, including the Senior Project Manager Vehicle Platform from OEMCorp3, are skeptical about the long-term viability of a proprietary OS:

> *"No [OEM] can avoid Android in the long run. Simply for one reason: it has proven itself! There are two big options when it comes to touchscreen devices, user interface frameworks, operating systems, and development environments: iOS and Android. Show me another framework, another SDK that I can use today, where I can get a good look and feel and user experience. [...] It's not an option anymore to develop it in-house."* (Senior Project Manager Vehicle Platform, OEMCorp3).

Discussion and Conclusion

A Grounded Model of Uncertainty Reallocation in Incumbent Firms

We set out to explore how and why incumbent firms decide on a certain level of tech player involvement in their digital strategy. We apply affordance-actualization theory as a theoretical lens to develop a grounded model of uncertainty reallocation in incumbent firms (see Figure 7). In doing so, we combine the insights gained so far using the five inductively derived aggregate dimensions as building blocks of the model—(1) external digital platform by tech firm, (2) incumbent firm and its goals, (3) uncertainty tradeoffs and affordance of reallocation, (4) strategic actions by incumbent firm, and (5) short- and long-term outcomes.

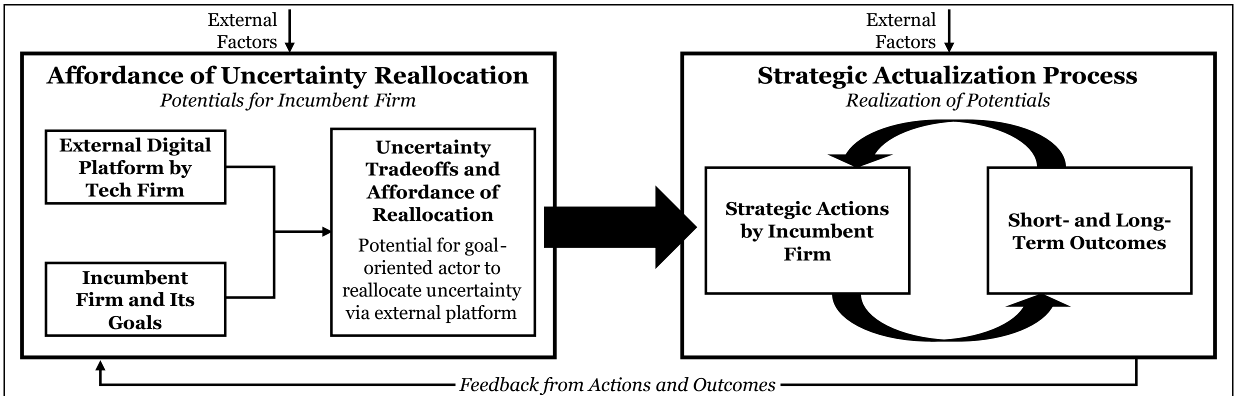


Figure 7. Grounded Model of Uncertainty Reallocation in Incumbent Firms

By offering a digital platform, tech firms aim to dominate and control specific technology areas in traditional markets, creating an attractive platform offering for incumbent manufacturers and third-party service providers while maintaining platform control through boundary resources (Ghazawneh & Henfridsson, 2013). At the same time, incumbent firms are reevaluating their strategic goals in the face of ongoing digital transformation, forcing them to make critical decisions about investments in technology development and their intended digital portfolio in the future. The combination of these two aspects, leads to uncertainty tradeoffs between different dimensions (e.g., technical, resource, and relational uncertainty), but the means offered by the external platform also provide the affordance to reallocate uncertainty between these dimensions. Given these different sources of uncertainty, incumbent firms must critically weigh their strategic goals, capabilities, and constraints to decide whether to engage with a tech firm's digital platforms. With the construct of "uncertainty reallocation" at the center of our model, we emphasize that external digital platforms do not necessarily reduce uncertainty but provide the potential to reallocate it, requiring incumbents to make a variety of tradeoffs.

On the right side, we illustrate how incumbent firms choose specific strategic actions after perceiving the affordance of uncertainty reallocation. Their chosen strategy influences their role in the ecosystem and their future business model. For example, incumbents that opt for holistic integration of the external digital platform typically adopt rather a contributor role, giving up customer touchpoints and access to user data. Conversely, the openness of a digital platform may allow incumbents to create platform derivatives and act as orchestrators. Depending on the strategy, short- and long-term outcomes will result, allowing incumbent firms to immediately and iteratively evaluate and adjust their actions and, in the long run, also adjust their strategic goals based on the fit between intended goals and the feedback from actions and outcomes. Finally, although outside the scope of our empirical study, the entire process is also subject to external factors such as political, economic, or technological changes in the incumbent's environment.

Implications, Limitations, and Future Research

Our analytical findings contribute empirical insights into the growing involvement of tech firms in established industries and provides insights into the decision-making of incumbent firms in this context. Thus, our findings have **theoretical implications**. First, through the application of affordance-actualization theory (Strong et al., 2014), we can theoretically grasp the phenomenon of uncertainty reallocation in long-standing business ecosystems (e.g., Poeppelbuss et al., 2022; Ramirez Hernandez & Kreye, 2021). The affordance of uncertainty reallocation arises from the interaction between incumbent firms and an external digital platform offered by a tech firm. Collaborating with the tech firms enables incumbent firms to meet their strategic goals, but also exposes them to the risk of being locked into using the external platform's boundary resources (Ghazawneh & Henfridsson, 2013). Furthermore, our research adds to the current understanding of digital platform affordances (e.g., Beverungen et al., 2021; Hein et al., 2020; Hein, Setzke, et al., 2019) by introducing the reallocation of uncertainty as a core construct when incumbent firms respond to external digital platform proposals. We provide empirical evidence that while incumbent automotive firms share some goals and contextual factors, properties such as resource availability, customer segments, and organizational structures individually determine the potential of external platforms to reallocate uncertainty. This also has implications for recent adaptations of the uncertainty construct in multi-actor digital innovation settings (e.g., Poeppelbuss et al., 2022). It highlights the heterogeneity of affordances for uncertainty reallocation when firms face similar external offers, and underscores the socio-technical nature of uncertainty reallocation processes in a digital innovation context. Finally, the case of the automotive industry illustrates how the uncertainty surrounding digital transformation in incumbent firms presents a negative socio-technical antecedent, constraining organizations from realizing shared and collective affordances for leveraging the smart products properties in multi-actor settings (Heinz et al., 2022; Herterich et al., 2023).

Our study also has **managerial implications**. Our findings provide a benchmarking tool for evaluating strategies relative to the embedded subunits in our case study, illustrating the range of strategic options that automotive OEMs can pursue using Google's digital offerings. For instance, adopting Google's full suite of tools through the holistic strategy secures a time advantage, but may result in giving up control over user touchpoints and data, potentially leading to a missed opportunity to offer data-driven aftermarket services independently. The other two approaches, which use Google's suite to a lesser extent, have more flexibility and monetization potential. However, the isolated strategy risks losing customers who may find the user experience lacking, and the custom strategy requires sizable financial and human resources. Nevertheless, it remains uncertain whether establishing an ecosystem around their proprietary (white-labeled) app store is viable, given digital platform principles such as network effects, scalability, and lock-in effects. We show that incumbents must compromise on their ambitious goals to remain competitive, and that there is no universal strategy for involving tech players. Rather, incumbents should carefully assess which technology and business control points in the ecosystem they need to own, depending on their internal capabilities and goals. Decision-makers in other industries can benefit from studying the advanced car industry's use of industrial IoT frameworks to better understand their role in their own ecosystem, and to assess the future capabilities they will need. This requires careful consideration of which aspects should be developed in-house, through collaboration with traditional suppliers, or by partnering with dominant tech companies.

Our study has **limitations** that point to areas for **future research**. Although we engaged extensively with industry experts both inside and outside of OEMs, we faced constraints in obtaining interviewees due to the ongoing strategic exploration of OEMs. To gain a more complete understanding of the organizational dynamics that affect the sensemaking process described by our theoretical model, our research could be complemented by in-depth case studies of organizations. Our exploration of this emerging phenomenon can provide valuable initial observations and insights for such studies, which should include multiple informants per case and observe the organizations over a longer period of time. Second, limiting our analysis to Google's AAOS and GAS may restrict the applicability of our conclusions (Yin, 2014). It is important to note that our findings are not exhaustive and may not apply to every incumbent firm seeking to integrate external digital platforms. We see great potential in adapting our theoretical model by conducting similar studies in different industry contexts (e.g., manufacturing, agriculture, or smart home platforms) to increase the applicability of our results. Finally, our study focuses on Google's AAOS and GAS in the Western market, so our findings may not be readily transferable to regions with limited access to Google services. Future research could examine partnerships with tech players from regions like China, given the recent shifts in market share in the automotive industry and beyond.

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