

Path Creation in Digital Innovation: A Multi-Layered Dialectics Perspective

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Abstract

We extend the path creation literature by developing a dialectic perspective of its multi-layered nature. In particular, our perspective focuses on the process by which designers shift their attention across different layers of digital innovation in the pursuit of a particular innovation path. To better understand path creation in digital innovation, we draw on a six-year in-depth field study of designers at CarCorp and its owner, GlobalCarCorp. Because of the reciprocal nature of path creation and path dependency, the design agency of CarCorp's path creators is embroiled in tensions and contradictions. The reciprocity of dominant, emergent, and residual design structures serves as an underlying generative force for breaking away from the current innovation path of the studied automaker.

Keywords: digital innovation, design, dialectics, path creation, path dependency, product innovation

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INTRODUCTION

On January 3, 2009, the New York Times featured the Op-Ed article “four ways for Detroit to save itself,” advocating a case for adopting digital technology to make cars safer, cheaper, cleaner, and more convenient (Thrun and Levandowski 2009). Encouraging Detroit to break from its traditional path, the article echoes the widely held conviction that a new innovation path is essential to rescuing the troubled auto industry.

The suggestion that such a radical turn could be accomplished “without too much trouble,” however, appears to be too optimistic. Our six-year study of innovation at CarCorp and its parent company, GlobalCarCorp¹, suggests that digital innovation is a long and arduous process that cuts across multiple layers of path creating design activities. Extending the path creation literature, our research explicates digital innovation at CarCorp as a multi-layered process enacted by designers within and across layers of dependencies in the microstructure of car design. Throughout this paper, digital innovation refers to the embedding of digital computer and communication technology into a traditionally non-digital product.

In the organization literature, the idea of path creation has emerged as a powerful theoretical perspective for conceptualizing innovation (Boland et al. 2007, Garud and Karnøe 2001). Viewing innovation as an ongoing agency embedded in sociotechnical structures (Garud and Karnøe 2003, Garud et al. 2008), Garud and Karnøe’s (2001) original notion of path creation was developed in response to the economic theory of path dependency (Arthur 1989, David 1985). While path dependency analysis focuses on innovation as an outcome of complex interactions among seemingly minor and random events, thus placing human agency backstage, the path creation perspective highlights the central role of designers and entrepreneurs in mindfully deviating from the existing path and creating an alternative future (Garud and Karnøe 2001, Stack and Gartland 2003). Embedded in the institutional order established over time, technology designers “shape emerging institutions and transform existing ones despite the complexities and path dependences that are involved” (Garud et al. 2008, p. 957).

The original idea of path creation focused on single entrepreneurs and their path creating activities (Garud and Karnøe 2001). Recently, scholars have recognized the significance of multiple and distributed actors, each contributing to the production of a new path (Boland et al. 2007, Garud and Karnøe 2003). For instance, Boland et al. (2007) explored the cascading nature of multiple and intersecting path creations among heterogeneous actors. Their work expands the path creation perspective by placing an entrepreneur’s path creation activities in a larger sociotechnical context, thus noting that an entrepreneur’s deviation often collides and interferes with other paths, resulting in unpredictable wakes of innovation.

In this paper, we further contribute to this stream of literature by noting the multi-layered nature of innovation paths. If Boland et al. (2007) take a step back from a single entrepreneur in order to ‘zoom out’ to see multiple paths forming a complex form of wakes, we take a step closer to ‘zoom in’ on the dynamics and structure of a single path. In so doing, we observe how a particular innovation path that CarCorp created in fact consisted of multiple layers that were threaded. As a single thread is seldom a straight line but rather is made up of multiple and interwoven fibers, we propose that an innovation path within a firm consists of multiple intertwined layers. Without heeding closely to the multi-layered nature of path creation, one may mistakenly assume that changes in just one layer (e.g., inventing a new design by adopting new digital technologies in cars) will be sufficient for forging a new path.

¹ GlobalCarCorp is a pseudonym for one of the big three American automakers.

We synthesize two theoretical perspectives in developing a process model for understanding path creation in digital innovation. First, we draw on extant design literature (Baldwin and Clark 2000, Hirschheim et al. 1995, Yoo et al. 2006) that identifies the material, cognitive and organizational aspects as the three layers of design. Second, we use a dialectical view of organization (Benson 1977, Seo and Creed 2002, Williams 1980) to conceptualize the design process as design agency, involving active and selective negotiation and re-negotiation of the dominant sociotechnical reality in view of contradictions and tensions within and across layers of digital innovation. Essentially, the research question addressed in this paper is: *what is the multi-layered process by which designers create new paths during digital innovation?*

To better understand layers of path creation, we conducted a 6-year longitudinal study of car infotainment solutions at CarCorp and its owner GlobalCarCorp and observed how a new innovation path was created over time. Struggling with realizing the vision of the “connected car,” CarCorp designers actively introduced changes in the material layer of the infotainment innovation, only later to discover that new structures were needed in the cognitive and organizational layers as well. Each such discovery involved contradictions between the established innovation path, colored by CarCorp’s manufacturing origin, and the path created by infotainment designers pertaining to digital technology.

In the remainder of the paper, we first outline a review of the path creation literature. We then present our theoretical framework that draws a synthesis of design literature and a dialectic view of organization. Next, we present the research methodology, followed by a presentation of our longitudinal case study of CarCorp’s path creation in the car infotainment area. Sensitizing the case study with the theoretical framework outlined, we develop a dialectic process model of path creation in digital innovation. We conclude our paper by discussing the implications of our process model for innovation theory and practice.

PATH CREATION

Path creation analysis focuses on the role of agency in creating new trajectories in innovation (Garud and Karnøe 2001, 2003). Such analysis also recognizes that new paths are never created in a vacuum, isolated from existing sociotechnical arrangements (Hanseth 2000). In this regard, path creation is an idea that presupposes the existence of path dependency (Arthur 1989, David 1985). As implied in Garud and Karnøe’s (2001) original definition, there exists a mutual interdependence between path creation and path dependency (Stack and Gartland 2003) that manifests the classical duality of structure (Garud et al. 2008, Giddens 1984). Garud and Karnøe (2003) further note that the term ‘path’ suggests “that the accumulation of inputs at any point in the development of a technology is as much a position that actors have reached as it is one that they may depart from” (p. 281).

The reciprocal nature of path creation and path dependency is reflected in actors’ ongoing enactment of existing structures. Drawing on such structures as resources in the innovation process, designers can at the same time deviate mindfully from them in seeking the envisioned change (Feldman and Pentland 2003, Garud and Karnøe 2001). Designers can therefore be regarded as embedded agents who generate new paths as a step-by-step process over time (Garud and Karnøe 2001, 2003).

There is a paucity of research that closely examines the underlying generative process of path creation. Viewing technology entrepreneurship as a collective enterprise involving distributed competences (Tsoukas 1996), Garud and Karnøe (2003) describe path creation as a

process that involves multiple actors. On the basis of evidence from the wind power market, they explain how multiple actors deploying modest resources can co-shape a successful innovation path. Boland et al. (2007) further extend this analysis by showing how wakes of innovation are occasioned when heterogeneous actors' paths collide. To date, however, the literature offers little explanation of the internal dynamics of path creation by which a group of designers or entrepreneurs break away from its past. In particular, little is known about what happens when designers who used to design non-digital products try to break away from the existing path and create a new digital path. We suggest that such path creation involves the shifting of attention across different layers of established material, cognitive and organizational structures over time. The next section outlines a theoretical perspective that offers a basis for understanding such shifts of attention in the path creation process of specific groups of designers.

TOWARDS A MULTI-LAYERED PERSPECTIVE

This section presents the basis of the proposed multi-layered path creation perspective that amalgamates the literature on design structure (Baldwin and Clark 2000, Hirschheim et al. 1995, Yoo et al. 2006) and a dialectical view of organization (Benson 1977, Seo and Creed 2002, Williams 1980). While the layers of design structure provide a conceptual tool for exploring different layers of innovation design, the dialectical view facilitates analysis of the tensions between path creation and path dependence that are evoked in design agency while helping us understand the dynamics of change.

Layers of Design Structure

Innovation involves not only the creation of artifacts with new material properties but also the modification of the existing cognitive model of the product and the organizational structure of design tasks and responsibilities. For example, in the area of software development, the importance of mutual interdependency across actual software code as well as a logical design that defines high-level requirements and functionalities and the composition of the project team are well documented (Brooks 1995, Hirschheim et al. 1995). Similarly, in the context of architectural design, Yoo et al. (2006) observe the reciprocal relationship between architectural design and project team structure. In the context of new product development, scholars have noted the importance of cognitive structures (Barr et al. 1992, Galunic and Rodan 1998) and organizing structures (Foote et al. 2001, Galbraith 2002, Sawhney et al. 2004) in supporting the development of new products and services. Baldwin and Clark (2000) also advance an evolutionary account of innovation design in which they articulate the interrelationship across physical product, conceptual design structure, and the task structure in organizing resources.

Collectively, the extant literature on innovation design suggests that there are three broad layers of structure that need to be interrelated during innovation design: the material, cognitive and organizational layers. We refer to this concept as layers of design structure in this paper. The material layer refers to the tangible instantiation of a particular design. The artifact can be seen, heard, touched, and used; it performs a set of specific functions that create value for its user. Second, in order to produce the artifact, designers need to configure design elements in a specific way. The cognitive layer is a logical design of the artifact that represents the mental schema which underpins the structure and functions of the artifact that is being designed. For instance, it specifies the hierarchical relationship and interdependences among design elements. The final layer of structure, the organizational layer, specifies activities performed by various

designers and their interrelationships. It describes the design process and links design activities with particular units of organizations.

Path Creation Dialectics

In order to explore multi-layered path creation as a process involving human agency, we adopt a dialectical view of institutional organization (Benson 1977, Seo and Creed 2002, Williams 1980). This view implies a model of an organization as a social entity that is always in a state of becoming (Benson 1977, Weick 2004, Yoo et al. 2006), yet is at the same time embedded in a larger sociotechnical system that constrains its design choices. Over time, repeated patterns of interactions and interdependence between firms and units within them create powerful networks of institutional forces (Hargadon and Douglas 2001; Powell 1991). Firms are therefore locked-in and path-dependent (Arthur 1989, Bassanini and Dosi 2001, David 1985), sometimes falling into competency traps (Levitt and March 1988). Thus, any organization engaged in innovation needs to overcome such path dependence in order to transcend its present socio-technical configurations. Dialectics offers a perspective for understanding the process by which firms break away from the powerful and systemic force of path dependencies (Boland et al. 2007; Garud et al. 2008; March 1991).

Using the dialectical view, we conceptualize designers in organizations as agents who are situated in contradictory and multiple layers of material, cognitive, and organizational structures. While designers are constrained by the dominant design and other sociotechnical configurations that limit their design options, they actively and artfully exploit contradictions in these different layers of structures in order to seek an alternative future. The dialectical view suggests that “the future is not necessarily a project of the present order; rather, the future is full of possibilities and one of them has to be made” (Benson 1977, p. 18). Therefore, at the core of a dialectical view is the tension between the familiar path dependencies and the unfamiliar and uncertain projected innovation paths. This tension constitutes a force that propels willful and competent human entrepreneurship toward new designs.

A key aspect of dialectics is captured by the notion of contradiction (Poole and Van de Ven 1989; Seo and Creed 2002). Seemingly stable and coherent relationships between different layers in sociotechnical structures are only temporary and arbitrary patterns (Benson 1977, Weick 1979, Williams 1977). While a detailed analysis of contradictions is beyond the scope of this paper (Seo and Creed 2002), we suggest the multi-layered nature of innovation design as an important source of contradictions in digital innovation. As layers of material, cognitive, and organizational structures are embedded in wider sociotechnical contexts that follow idiosyncratic evolutionary patterns, seemingly coherent and stable relationships across these structural layers can be disrupted by inconsistencies and incompatibilities related to changes in any one of these layers over time. Contradictions are therefore the source of a mindset shift, from an unreflective and passive mode to a reflective and active one among designers (Seo and Creed 2002).

While contradictions are a source of change, the actual temporal and historical movements between different states can be seen as a dynamic and complex negotiation and re-negotiation among dominant, emergent and residual structures (Williams 1977, 1980). According to Williams (1980), dominant structures are central and effective systems of meanings and values that are “organized and lived” (p. 38). Therefore, it gives a sense of reality and finality to individuals. However, dominant structures are not static. On the contrary, they are continually shaped and adjusted through a process of selective incorporation of residual and emergent structures. Residual structures are the still-practiced residue of previous social

formations (e.g., in a society, it could be certain religious practices, rural community, and monarchy) that is retained in order to make sense of the current dominant structures. Emergent structures, on the other hand, are the new meanings, values, and practices that are continually being created, some of which are selectively incorporated into the current dominant structures (Williams 1980). Thus, contradictions do not produce momentous and discontinuous shifts. Instead, changes take place through the continual and selective integration of residual and emergent structures into the current dominant structures.

Finally, the selective incorporation of residual and emergent structures into the dominant structures takes place through design agency (Benson 1977, Giddens 1984, Seo and Creed 2002). It involves “the free and creative reconstruction of [sociotechnical] arrangements on the basis of a reasoned analysis of both the limits and the potentials of present [sociotechnical] forms” (Benson 1977, p. 5)². Thus, design agency also involves the active moment of drawing on alternative sociotechnical resources and logic found in surrounding environments.

With this theoretical perspective as a sensitizing device, we now turn our attention to a longitudinal case study of path creation in the automotive industry. We begin with an outline of the research methodology, followed by the case study.

RESEARCH SETTING AND METHODS

CarCorp is a manufacturing firm that produces, markets, and sells around 125,000 cars per year primarily in Europe and the U.S. CarCorp is a fully owned subsidiary of GlobalCarCorp, which is a major global vehicle manufacturer. The number of employees at the main production plant of CarCorp was 4,500 in 2007. Concurrent with GlobalCarCorp’s attempts to streamline their global business, which includes many other brands in addition to CarCorp, business functions are now tightly integrated with GlobalCarCorp’s global organization. While many areas of R&D have been re-located within the global firm to avoid redundancy, car infotainment – which is the empirical focus of this paper – is one R&D area for which CarCorp has been attributed significant global responsibility.

The research approach taken is process-oriented and focuses on the interplay among actors, context, and technology (Langley 1999, Markus and Robey 1988). The primary source of our research is a longitudinal study (Pettigrew 1990) conducted at CarCorp over a six-year period (2002-2008). During these years, we have participated as academic researchers in a number of R&D projects in the car infotainment area. In this regard, we have chosen to plunge ourselves “deeply into the processes themselves, collecting fine-grained qualitative data – often, but not always in real time – and attempting to extract theory from the ground up” (Langley 1999, p. 691). A recurring theme in these projects has been digital convergence and the need for a new path for car infotainment and telematics. Because this theme was incepted at CarCorp before we started our field studies, we also made an effort to collect data from the preceding period (1996-2002).

According to Yin (2009, p. 48-49), a single case study can be useful when the purposes of the study are revelatory and longitudinal in nature. In our case study of CarCorp, we sought: (a) to examine dependencies in different layers of innovation design; and (b) to analyze the pattern of path creation within and across these layers over time. Using a single case, we sought to

² In his original definition, Benson (1977) only mentions *social arrangements* and *social forms*. In order to emphasize the sociotechnical nature of digital innovations, however, we replaced the concept social with sociotechnical.

firmly trace events, activities, and choices ordered over time in order to build a process theory (Langley 1999). This manifests an understanding of “process as developmental event sequence” (Van de Ven 1992). In view of the four families of process theories outlined by Van de Ven (1992), we develop a dialectic process theory because of its appreciation of colliding events, forces, and contradictory values in organizational life (see also Poole and Van de Ven 1989). In particular, this dialectic orientation resonated well with our ambition to extend insights documented in the path creation literature regarding different actors’ colliding paths (Boland et al. 2007). Such collision is likely to manifest itself in contradictory ways for designers forming their own innovation path over time.

Our field study included multiple data collection methods including interviewing, participant observation, and project document analysis. Using Walsham’s (2006) distinction between styles of researcher involvement, we were “involved researchers.” Across the various R&D projects, involvement has varied between participant observation and action research, suggesting a relatively high degree of engagement (Nandhakumar and Jones 1997). The main advantage of involved research is that extended engagement with actors enables researchers to acquire an in-depth understanding of the practices and problems of the world (Van de Ven 2007). The other side of the coin is that researchers risk becoming “socialized to the views of the people in the field and lose(s) the benefit of a fresh outlook on the situation” (Walsham 2006, p. 322). As it was the first and the third authors who were directly involved in the data collection, the second author provided an outside view of the material and its interpretation.

One important source of data is interviews. All in all, 73 semi-structured interviews have been conducted over a six-year period. All interviews were tape-recorded and almost all were transcribed verbatim, producing more than 1,000 pages of transcribed interview material. Interviews have primarily been conducted with CarCorp and GlobalCarCorp engineers and managers working with car infotainment across several aspects of the business including applications, platforms, and software architecture. Among the 73 interviews, 55 were with CarCorp/GlobalCarCorp personnel, with some respondents being interviewed several times over the years. This was particularly true for a number of engineers, referred to as designers in this paper, who were deeply engaged in R&D projects in the car infotainment area. Because this core group of designers has participated throughout the entire process, typically in different organizational roles over time, they play a major role in this case story. In addition, 18 people outside CarCorp and GlobalCarCorp are included in the interview study. These respondents, who work as automotive suppliers, competitors, consultancy organizations, mobile device manufacturers, and mobile network operators, were all engaged in infotainment projects together with CarCorp.

Participant observation is another important source of data. Over the years, we have participated in over 50 meetings related to four main R&D projects in the infotainment area. In addition to these formal meetings, we have conducted frequent visits at various sites of CarCorp and GlobalCarCorp, both in Europe and North America. Lastly, the study includes a significant volume of archival data including reports, strategies, and sales forecasts. While many of these documents could not be used directly in this research because of their confidentiality, the material has served to corroborate interpretations made throughout the data analysis process.

Following the suggestions of Charmaz (2006) and Miles and Huberman (1994), we repeatedly read and coded the data to identify the key themes from major events, activities, and technology choices that emerged over time. Our strategy for theorizing using the process data can be described as a temporal bracketing strategy, i.e., a type of temporal decomposition

intended for structuring the process analysis (Langley 1999). As Langley notes, such a strategy is especially useful for incorporating multidirectional causality into the theorization. It allowed us to organize the data chronologically and across different layers of structures. We then analyzed the relationship among key concepts, which led to a theoretical understanding of the interrelatedness among these concepts and their evolution over time.

Throughout the study, we organized many workshops to validate intermediate understandings and to communicate the initial analysis findings back to CarCorp managers and engineers. The latter aspect is an important element in pursuing engaged scholarship (Van de Ven 2007).

PATH CREATION WITH DIGITAL TECHNOLOGY AT CARCORP

Some twelve years ago, a design group at CarCorp began exploring the opportunity to connect the car to external networks and devices in the infotainment³ domain. Recognizing the ongoing digitization of the car, designers envisioned that novel information and entertainment services could be offered to customers.

In what follows, we present events, activities, and decisions of this design group's efforts to implement the vision of "Car Connectivity" at CarCorp. Along with it, we also present the design group's own reflections over the changes in its identity and emphasis over time. We begin with the background to these efforts, followed by a detailed description of three phases of the designers' path creation.

Car Connectivity at CarCorp

In the late 90s, the embedded phone was one of the most important infotainment products at CarCorp, sold as an option in high-end car models. Consistent with the rest of the car design, the architecture of the embedded phone followed the conventional modular design. Different components of the system were integrated by CarCorp in a modular fashion. A typical embedded phone system included amplifier, antenna, dial pad, displays, microphone, telecommunication unit (e.g., a GSM-module), loudspeaker system, and steering wheel controls. While the responsibility for integrating the main modules (e.g., amplifier and telecommunication module) was sourced to first tier suppliers, CarCorp was in control of the product design and offer. This control was manifested in the specification of requirements on the system's functionality as a whole, as well as on the interfaces between subsystems. Over time, however, the embedded phone became a commercial disappointment for CarCorp. It simply failed to keep up with the explosive growth and rapid developments in mobile telecommunications.

In response to the commercial failure of the embedded phone solution, CarCorp sought out different designs, and nomadic device solutions (NDS) emerged as an increasingly important alternative to CarCorp's innovation efforts in the infotainment area. The main difference between the embedded phone and NDS is that the latter relies on a distributed telecommunication module. That is, instead of embedding a telecommunication module in the car, NDS include a gateway that interconnects an external mobile device with the in-car system.

³ Car infotainment refers to information and entertainment features for drivers and/or passengers. This product segment ranges from basic products such as CD-players and FM/AM radio tuners to more high-end ones such as embedded telephone systems, navigation, and rear-seat entertainment systems. Car infotainment has become increasingly important since infotainment has had a relatively high profit margin compared to other product segments in the automotive industry, especially when sold as options or accessories. Given that GlobalCarCorp made an overall loss the last couple of years, the significant profit made on infotainment is indicative of this fact.

In short, the system uses the driver's (or a passenger's) mobile handset as a telecommunication module. Even though the initial technological difference between the embedded phone and NDS may appear to be innocuous and even trivial, over time, the designers' struggle with NDS brought fundamental changes in CarCorp's overall infotainment innovation strategy. What we document below is the on-going struggle that they endured over that period of time.

Phase 1, 1996-2005: Tensions at the Material Layer

The Nokia Project

In 1996, CarCorp designers initiated an NDS development project with Nokia. The idea was to produce, market, and sell a solution that was compatible with a specific Nokia digital mobile phone. Since the firm's primary strategic infotainment focus was the embedded phone, the project was sanctioned by management as a possible alternative for low-end cars.

For the designers, however, NDS was something more. Compared to the embedded phone, they viewed NDS as a new technical solution that would increase customer convenience by establishing interoperability between the car and cell phones. In order to enable such interoperability, designers collaborated with Nokia engineers to create a cradle-based solution for docking the cell phone in the car. The cradle interconnected the Nokia device to in-car resources, including the audio system, control buttons, power supply, and external antenna. The application relied on AT commands⁴ for controlling the communication between the gateway in the car and the Nokia handset. Figure 1 depicts a simplified version of the NDS architecture with an emphasis on the interfaces between the vehicle and the Nokia device. In line with the designers' intention to increase customer convenience, the material structure of the NDS solution was significantly different from the traditional embedded phone. Rather than defining interface requirements that would be sourced to a tier-one supplier, requirements were adapted to interconnect the off-the-shelf Nokia device.

However, the project turned out to be a failure in that no commercial product was ever launched. Nokia changed the specifications of the compatible phone model even before CarCorp had a chance to include the solution in any vehicle roll-out plan. Reflecting on the early attempts, the CarCorp project manager noted:

The problem was that they [Nokia] changed their interface specifications on several occasions, which made it impossible to put a product on the market. They did not do this in order to create problems for us. Their market is just so much bigger and they wanted to keep their competitive edge in relation to Ericsson and Motorola.

The Nokia project gave the design group at CarCorp early experience in working with consumer electronics firms. Unlike traditional automotive suppliers, Nokia was not dependent on cooperation with CarCorp. Following its own innovation path, the cell phone was a stand-alone product with a much higher sales volume, making its role as a component in CarCorp's solution marginal to Nokia. In this regard, CarCorp designers learned that the instability of the proprietary hardware-based interfaces (e.g., cradles) made the traditional product control strategy virtually impossible. An infotainment designer recalled:

⁴ AT is a telephone network modem standard based on a solution developed by Hayes Communications. It is part of the GSM standard.

All the time, we were running for developing the right cradles timely, and because devices come and go rapidly and that tools had to be developed for producing the cradles that fitted the specific device, we couldn't keep up. Because it wasn't core competence, it was really difficult...

CarCorp designers noted that consumer electronics had a much shorter product life cycle and development time horizon. While CarCorp's development time horizon spanned at least 3-4 years, anything beyond 18 months was considered an eternity for Nokia. Such temporal differences, manifested in the material layer of the design, made it difficult for designers at CarCorp and Nokia to collaborate with the objective of designing stable interfaces between cell phones and cars.

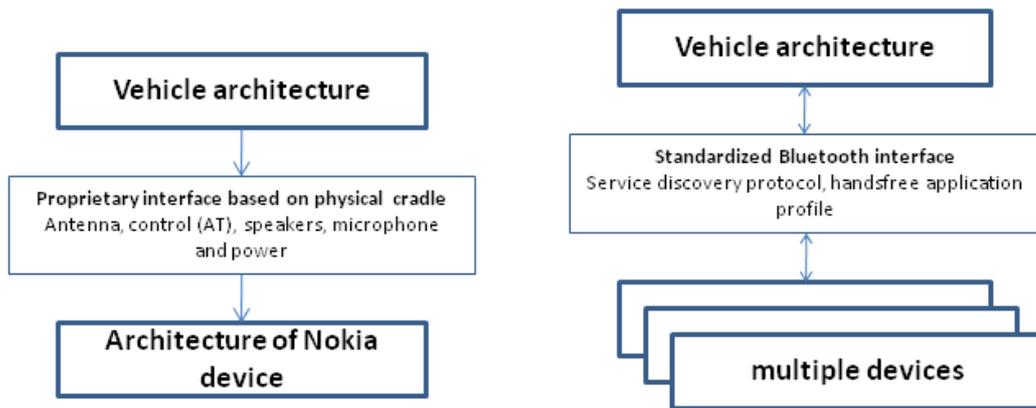


Figure 1: NDS Architecture, Nokia Project **Figure 2:** NDS Architecture, Bluetooth Project

The Bluetooth Project

After the early failure, it took some years before the design group picked up the NDS idea again. The designers were discouraged by the fact that there was no technical solution to the interface problems encountered in the first NDS effort. In 2002, however, the NDS designers decided to adopt a new emerging wireless technology standard, the Bluetooth protocol, to overcome previous problems with proprietary cradle-based interfaces. As an infotainment designer recalled: “it [Bluetooth] gave new life and hope in light of our mechanical concerns.” CarCorp’s infotainment product manager at the time commented:

Now [2002], the technology is in place. We have overcome the barriers associated with proprietary standards in mechanics, electronics, buses, and so on. General standards such as the Bluetooth protocol now exist, making us believe that this will actually work, also beyond a particular phone model's life-cycle.

Beyond having the technology in place, the Bluetooth project was driven by ideas about ubiquitous access to information. As noted by an infotainment designer, who later would become the most dedicated proponent of the new infotainment path:

A CarCorp customer has a life outside the car too. It is important to think about this [infotainment] from the customer's point of view: “these are my tools, my personal choices that I make to increase convenience in all situations. They should work together.” If you have chosen a CarCorp car, chosen a personal handset, chosen a PC at work, then you must be able to get these devices to work together.

Pointing to the promise of the Bluetooth standard, CarCorp designers managed to initiate a number of new R&D projects related to Bluetooth-enabled NDS. Rather than developing a proprietary solution based on the traditional automotive technologies, the rationale was now to concentrate on a standard widely used in consumer electronics. Contrary to established practice, CarCorp relinquished its control over an essential component (the cell phone) of the solution, as well as the communication interface, by implanting a device-independent solution (see Figure 2). The focus on the communication interface rendered new forms of design practices that were specific to technologies within the realm of consumer electronics and telecommunication. To this end, CarCorp invited global mobile operators and systems integrators with Bluetooth technology competence to participate in R&D projects.

Stimulated by their regained confidence, designers generated and explored more than 20 different use cases based on the Bluetooth standard. Still working in the material layer with fundamentally the same cognitive and organizational layers of design structure, a comprehensive prototype for supporting hands-free use of cell phones was developed and later evaluated and verified in actual car use. The solution was implemented on the basis of the service discovery protocol and the handsfree profile of Bluetooth. Demonstrating the solution to top management at both CarCorp and GlobalCarCorp, designers managed to get the specifications included in vehicle rollout plans.

However, a significant problem with the new design was that CarCorp designers only managed to make it compliant with a limited range of mobile devices. Because the Bluetooth protocols were interpreted differently by mobile device manufacturers, unanticipated interoperability problems emerged for CarCorp when commercializing the solution. While Bluetooth core protocols were stable and generally implemented in a consistent manner, the application profiles (e.g., the hands-free and address book profiles) were difficult to handle relative to multitudes of devices. An infotainment manager ironically reflected upon the unanticipated problems:

We thought so [that Bluetooth could handle interoperability problems]. Bluetooth got a huge backlash though. If you were an early adopter you run into troubles. CarCorp was a really early adopter [of Bluetooth] in automotive.[...] Standard proved not to be standard. There was a very complex relationship between devices over brands and models, which made the process rather hazardous.

In view of the steady stream of new devices, the Bluetooth-based solution proved inflexible. Since it only supported a handful of devices, the system needed to be updated for each new model year and it was difficult to keep pace when drawing on traditional infotainment testing and verification practices. At its core, the designers felt trapped in the contradiction at the material layer between two parallel and incompatible technological paradigms. Designers at CarCorp realized that they had to broaden their scope outside the traditional artifact focus to eventually realize their design vision.

Phase 2, 2006 – 2007: From Product to Platform

CarCorp now faced increased competition from the consumer electronics industry. The rapid consumer uptake of cell phones, portable music players, and navigation devices in combination with significant improvements in the functionality, price, and portability of such devices created significant competitive pressure on the car infotainment market. Still, the NDS

design group felt that the threat posed to core infotainment applications was not broadly acknowledged at GlobalCarCorp. The project manager of the early Nokia project commented:

We are a couple of people who think that this [selling embedded navigation and cd-changers] will not be possible in the future. Except from a particular customer group, top-end customers, who don't care but tick all available options when buying a car, no customer will select embedded navigation. [...] When you have navigation in your pocket, why have an embedded navigation system in the car? You will not have a cd-changer in the car AND a mp3-player in your pocket. We believe that this type of car equipment won't be there in the future, that the market will disappear for us.

Reflecting upon this conviction, the manager further noted:

Now, I should not presume that this is GlobalCarCorp's official stance. I get a lot of shit for saying this, especially from our marketing people [...] they don't believe in this, they don't think it is reasonable to think like this. They still believe that it is going to be possible to sell embedded navigation in large volumes, and that it still will be possible to sell CD changers.

As illustrated above, there still existed a gap between the designers' view and the mainstream CarCorp and GlobalCarCorp employee. Yet, the NDS design group was slowly gaining attention in wider circles of the organization. In proposing a new NDS project in 2006, they managed to convince the global infotainment manager of GlobalCarCorp, based at the Detroit headquarters, to serve as the chairman of the steering committee. This was important to sanction the project more broadly within GlobalCarCorp. The global infotainment manager underlined his support of the project:

With regard to a number of functional areas, this project is incredibly important. It is the only current activity in infotainment that is forward-looking. [...] The commercial potential is huge.

However, knowing the NDS design group's point of view, he still highlighted that NDS was only a complement to the embedded agenda:

The infotainment market is not threatened. There are some people pretending it is. We are selling more navigation systems than ever before and we are going sell even more next year.

Inspired by the attention received from Detroit, the designers were carefully reviewing their previous efforts in thinking about the direction of the new project. The Nokia project showed that when innovation paths collide, the mobile device manufacturer will prioritize whatever sells more cell phones. The Bluetooth experience showed that CarCorp could not keep the pace with the steady stream of new mobile devices introduced on the market. In view of the disappointments that emerged when working within the material layer, designers turned their attention to the cognitive layer in order to reframe the design problem. Rather than developing an in-house product, they realized the need of infotainment platform designs that relied on technologies used by application developers in the consumer electronics and mobile services domains. In this way, they tried to overcome the fundamental contradiction they faced at the material layer due to the differences in product life-cycles.

The idea of devising a platform for an open NDS design therefore became the mantra of the new project. This broader scope, beyond specific functionality such as handsfree or navigation, was facilitated by GlobalCarCorp's decision to make CarCorp one of two main centers for infotainment R&D. The former manager of the Nokia project was appointed to

manage the project. With respect to the support of management, he reflected upon current systems and the road ahead:

They [our systems] are very inflexible. If you want to put something into production, it takes three years, almost regardless of what it is. So, if we could get away from hardware solutions, we might address the problem of long lead times for introducing new functionality in the car. [...] The hardware used should remain the same over time, while the software modules should enable the adaptation needed.[...] We are envisioning a design that boosts the car's capacity to handle the digital world. The solution must enable us to follow the technical development in telecommunications during both the construction and production time of the car, which taken together is around 7 years.

These words of the project manager revealed a radical re-orientation of the mental model that had dominated CarCorp designers. Rather than holding on to the automotive design tradition, he envisioned a car architecture that would be malleable and subject to environmental changes. Much effort was therefore invested in decreasing the differences of the in-car platform and outside technological paradigms. This shift involved considering technologies from consumer electronics and telecommunications. For instance, designers spend a considerable amount of time assessing Java-enabled technology and the promise of the Digital Living Network Alliance (DLNA)⁵ technologies. Drawing on lessons learned in the Nokia and Bluetooth projects, however, this assessment was oriented towards the prosperity of these technologies rather than their technical fit with in-car technologies.

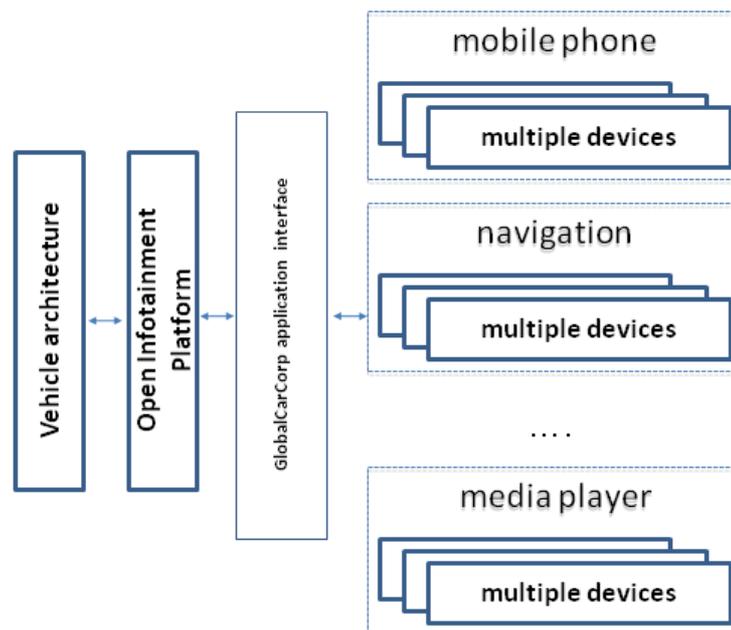


Figure 3: The Flexible Architecture, 2006-2007

Seeking to realize an open platform, the anticipated technical design was a device-independent platform based on multiple communication channels. Unlike the previous

⁵ DLNA is a cross-industry initiative of consumer electronics, mobile device, and computing industry firms to deliver a framework and design guidelines for interoperability between home appliances (see www.dlna.org).

generation that only supported a limited number of mobile devices through a single Bluetooth standard, the new design was developed to support a wider range of devices such as portable navigation systems, portable music players, and portable DVD players. In practice, this meant broadening the scope beyond Bluetooth to communication protocols such as USB and Firewire. However, due to the lack of standards on the application level, for instance, navigation devices, CarCorp designers appreciated the need to develop application interfaces that would enable external service providers to use in-car resources such as sensor data screens and loud-speaker systems in their service innovation.

Responding to the pressure from the rapidly changing consumer electronics market, CarCorp formed a project network that included a few selected partners in order to explore new design options that would be easily updated over time. Rather than holding onto traditional embedded computing technologies such as the operating system QNX, the project team – which now included an online navigation vendor, a system integrator, and a large mobile manufacturer – decided to develop a new platform based on Linux embedded and a Java Virtual Machine. The new design was anticipated to facilitate software updates or the addition of new functionality more easily. On the basis of the design, GlobalCarCorp would be able to engage in dedicated projects in which outside application developers could port their applications for in-car use.

A recurring theme in developing the new platform during this period was the contradiction between the openness of the new platform design and the control agenda institutionalized in the current product design. One of the senior engineers in the design team commented:

Openness is to invite other firms, to allow third-party firms to develop applications that can be executed on the car platform in the same way that cell phones can execute Java applications developed by third-party vendors. [...] The advantage of allowing this is something we have discussed extensively at CarCorp, but the closer we'll come to product launch, the more evident the difficulties will become. Who should take the responsibility for the software? What if something goes wrong, is it related to the car or the third-party software? This liability issue is not something that the marketing department wants to tackle [...] While they want to offer this to customers, it is a question about courage and the ability to handle it organizationally.

Reflective of the concerns voiced by this senior manager, the platform and its interface was finally configured to work as a resource for preferred vendors only. Rather than developing an open interface, the synthesis of the contradictions between openness and control led to a focus on flexibility, where the goal was to devise a platform that could be updated rapidly through dedicated development projects with preferred partners over time.

The project team developed and tested the new flexible platform by porting different applications directly into the flexible platform. As the project was still in the research and development stage, the team relied on ad-hoc closed coordination with the participating firms. On the basis of successful initial results, the newly ported applications were implemented in a demonstration car. At the turn of 2007, the results of the project were demonstrated for multiple GlobalCarCorp managers visiting CarCorp. It was soon decided that the new platform would be included in a series of vehicle roll-out plans.

Phase 3, 2008 – : Building the External Application Development Community

In view of the success of the flexible platform, the CarCorp designer who managed the implementation project soon got invited to take charge of a new infotainment project based on open source business models. While the proposal originated from the European headquarters of GlobalCarCorp, she appreciated open source-like application development and revenue-

generation as natural extensions of the path initiated through the flexible platform-project in the previous phase. After all, having 12 years of experience with NDS design, she and her design team viewed GlobalCarCorp's traditional stage-gated and closed project model, along with the terms and conditions for supplier contracts, as major hurdles in making the flexible platform a success. Despite the successful development of flexible platform design at the cognitive layer and the related prototype at the material layer, the organizational structures in infotainment innovation at GlobalCarCorp were still based on old embedded solutions and long-term supplier relations. Therefore, the old organizational structure significantly hampered the possibility of leveraging creativity and innovation from ad-hoc collaborations with outside firms. GlobalCarCorp's conventional practice of managing suppliers and external collaboration did not resonate well with the idea of promoting third-party software. Many times, the design team voiced concerns about the manufacturing legacy in the organization and how they needed to circumvent existing practices. As an illustrative comment, the project manager noted that: "you really need to be creative to avoid GlobalCarCorp's organization and stop signs."

The new project was explicitly inspired by Chesbrough et al.'s (2006) writings about open innovation. The project manager commented:

I very much believe in not trying to solve everything for ourselves, to believe we are the champions, but rather trust in the capacity of others to generate creative and useful ideas. Then we have to manage that creativity so that everyone gains something.

Because there were no automotive counterparts, the benchmark of the strategy was done in view of the recent successes of so-called developer programs in the consumer electronics and telecommunication worlds. Apple, SonyEricsson, Nokia, Navteq, T-Mobile, and the Android project all exemplified attempts to create application communities for generating ecologies of developers around the promoted platform. Initially inspired by SonyEricsson's and Nokia's developer programs, CarCorp wanted to develop Application Programming Interfaces (API)⁶ and a Software Development Kit (SDK)⁷ that would be available to application developers who become members of GlobalCarCorp developer's community (see Figure 4). While application developers would be able to reach GlobalCarCorp's customers, they would simultaneously ensure that GlobalCarCorp's infotainment platform would be more updated and attractive. The vision was ultimately that independent content developers (whether they were into games, media, or digital maps) could develop their applications for multiple mobile devices that receive information from sensors in the car and utilize hardware resources (such as displays, speakers and control units).

⁶ API is set of software routines, data structures, object classes and protocols of computer operating systems that are published in order to assist the development of applications.

⁷ SDK is a set of software development tools including an integrated development environment and debugging tools.

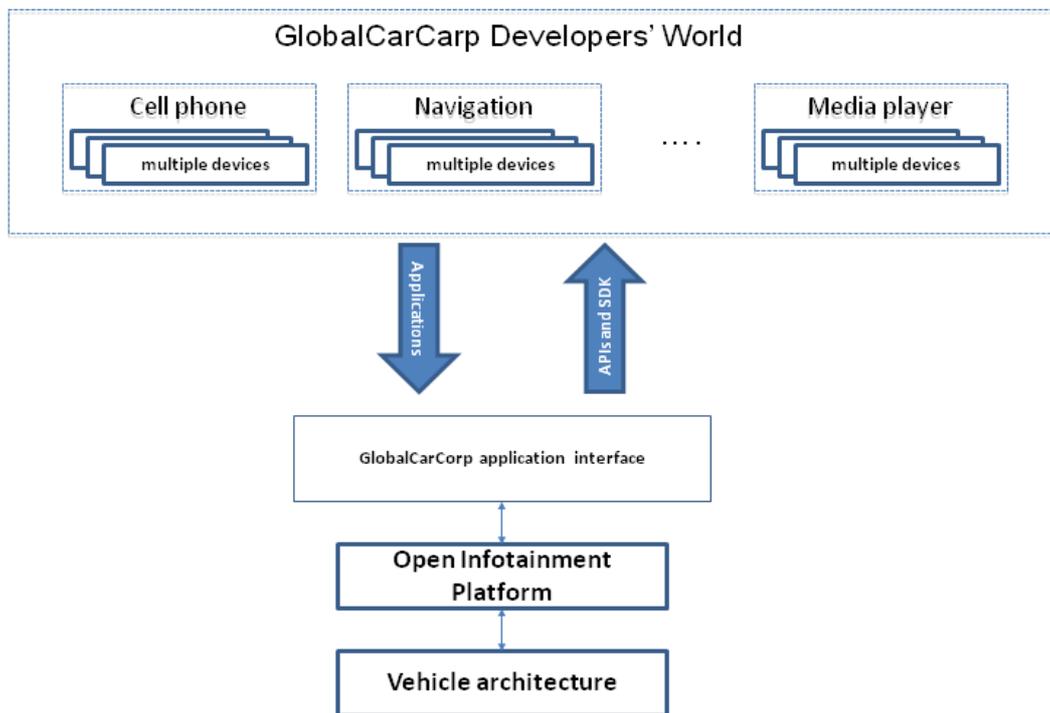


Figure 4: The Open Architecture, 2008-

In May 2008, the project manager went to the headquarters in Detroit to gather feedback on the initial concept of the project from relevant top executives. After meeting infotainment managers, software designers, and R&D engineers, the project manager received sanction for the project as well as additional budget support. As a result of the successful Detroit trip, the project manager decided to propose a follow-up project that would not only take the application development community idea to implementation but also to investigate its consequences for business and software processes at GlobalCarCorp. Looking more closely at the internal organizational structures, including the closed innovation model, was deemed necessary but challenging, since it broke substantially with the proposed new mode of innovation in infotainment.

In September 2008, the strategy was formally approved at the project's final stage-gate review meeting, which included managers from GlobalCarCorp's regions worldwide. Despite the immediate crisis of the automotive industry in the wake of the world's financial problems, the idea of going further in this previously untested direction was supported and funded. After 12 years' struggle, a new path spanning over material, cognitive, and organizational structures of designing car connectivity was sanctioned at the highest level and established in practice.

DISCUSSION

Over a period of 12 years, CarCorp made a radical and decisive shift in the area of infotainment systems. Pursuing the vision of the "connected car," its initial car-embedded phone system was eventually replaced with an NDS implemented as a platform of distributed and

mobile applications. At first glance, one might suspect the new path was swiftly created on the basis of a clear design vision. However, our empirical study tells a different story. Our study shows that the shift in the material layer of the infotainment system reveals a set of contradictions at other layers of design structure: the conventional closed architecture contradicted with an emerging open architecture (cognitive) and the traditional hierarchical control over products and suppliers contradicted with an emerging distributed polyarchy crisscrossing several industry boundaries (organizational).

While the scope of these shifts may look impressive, they were not the result of a path creating decision by a visionary designer or manager (cf. Garud and Karnoe 2003). Rather, our study shows that they resulted from the on-going struggles of designers who were caught in the dialectics between their vision of a new sociotechnical reality (emergent structure) and the dominant sociotechnical reality (dominant structure) of car design and retaining some aspects of the legacy of the automotive culture (residual structure). Their struggles were laden with partial and uneven understandings of the possibilities with the new technology, their efforts filled with serendipity and surprises, set-backs and disappointments, as well as sense-making and improvisation. The story of CarCorp designers' struggle demonstrates how path creation in digital innovation involves dialectic contradictions at the material, cognitive, and organizational layers (see Table 1).

| Design Layers | Dominant structure | Emergent structure |
|----------------------|---|--|
| material layer | embedded products with long product life cycles | consumer electronic devices with short product life cycles |
| cognitive layer | closed product architecture | open platform architecture |
| organizational layer | centralized hierarchical control | distributed polyarchical coordination |

Table 1. Contradictions in Different Design Layers

In what follows, we seek to extend the path creation perspective (Boland et al. 2007, Garud and Karnøe 2001, 2003) by explicating the multi-layered nature of the internal dynamics of path creation at CarCorp. On the basis of this discussion, we then outline implications of our research results.

Path Creation across Multiple Layers

CarCorp's path creation was characterized by contradictions at multiple layers (see Figure 5). The contradictions were interwoven with one another in the temporal dynamics by which CarCorp designers negotiated and re-negotiated dominated design structures that stood in the way of their innovation process. As such, the contradictions were selectively foregrounded in a staccato-like manner at different points in time. This selection did not follow a ready-made plan but rather was a result of situated learning, sense-making and improvisation in the design practice. The enacted shift in attention across design layers is at the heart of the internal dynamics of multi-layered path creation in digital innovation.

For example, until 2005, CarCorp designers approached NDS as a new product that would increase customer convenience compared to traditional embedded solutions. During this phase, however, a contradiction at the material layer was brought to the fore without any particularly satisfactory resolution. The contradiction resided in the fundamental lifecycle difference between automotive and consumer electronics products. Epitomizing this contradiction, the products developed in the Nokia and Bluetooth projects were outdated before they reached the market since the consumer devices supported by them were already outgoing.

In light of the disappointment at the material layer, designers at CarCorp re-directed their attention to the cognitive layer in 2006. Encouraged by the small signs of progress in the material layer, designers now wanted to enhance the NDS path through a new cognitive structure, an infotainment platform design that would allow for ad hoc collaborations with actors both inside and outside the automotive industry. In so doing, they enacted an emergent structure that triggered a contradiction between the envisioned open platform and existing design agenda of closed platforms. Simultaneously, the contradiction at the material layer was pushed backstage, thus making it less salient. Pushing the material layer contradiction backstage, however, did not mean that it was resolved. Working on a subsystem embedded in the larger context of car design, the designers had to continually deal with the material constraints of the automotive setting, which receded into the background as a residual structure.

A similar dynamic took place in the last phase of our case study. As designers recognized established organizational practices as a major obstacle to yielding benefits from the open platform, they foregrounded the contradiction at the organizational layer, while backgrounding the contradictions at the cognitive layer. Again, the contradiction at the cognitive layer was never fully resolved, but simply receded into the background as a residual structure.

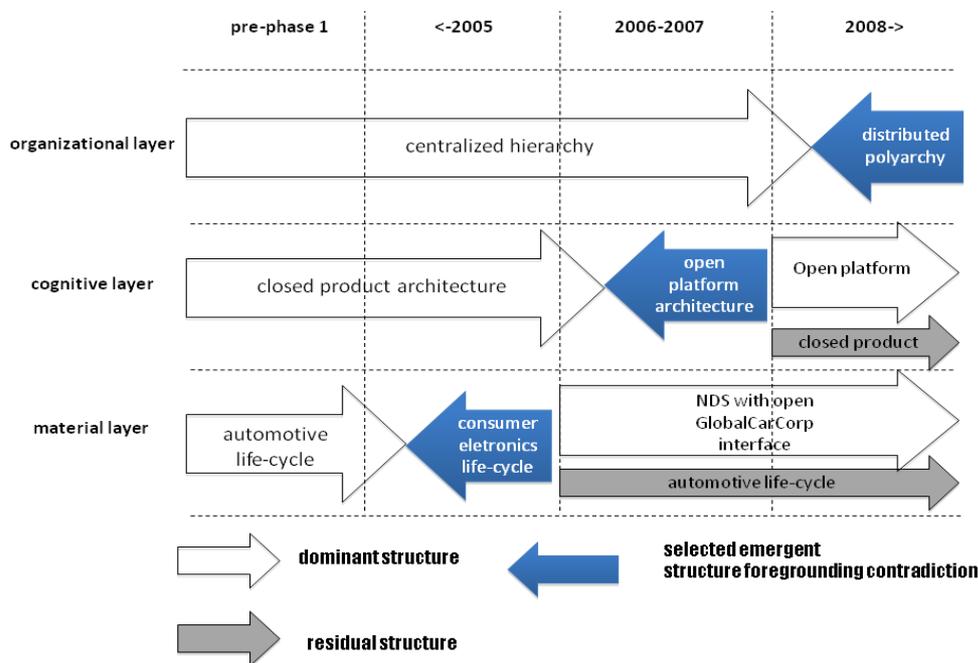


Figure 5. Multi-layered Contradictions in Path Creation

The picture that emerges from our study of CarCorp is that a path in digital innovation is not an unproblematic singular straight line. Instead, it is a problematic thick thread of multiple layers that are intertwined. We see designers continually negotiate and re-negotiate different layers of dominant structures with selected elements of emergent and residual structures. The process is not a clear-cut turn of the path from the “as-is” to the “to-be” status. There is no global design vision that guides this fundamental shift from the original design vision of telematics to a distributed mobile application on an open platform. Instead, there are a series of incremental and localized experiments that unfold in response to the observed contradictions between the familiar and the new (Orlikowski 1996).

The agency of the designers at CarCorp shows how contradictions at different layers of the design structure caused them to be reflective. It transformed them from passive participants in the reproduction of the existing sociotechnical order into active change agents (Seo and Creed 2002). For example, the failure of the Nokia and Bluetooth projects made the designers aware of the limits of the established innovation order within which CarCorp occupied a powerful position relative to suppliers. Equally important to note, they also actively pursued alternative sociotechnical orders. Our study shows that the designers at CarCorp continued to explore new cognitive and organizational layers of design structure as they became aware of the difficulty in creating a new path by concentrating all attention to the material layer only. Thus, design agency is an essential micro-level mechanism that underpins path creation with new technology.

Path Creation Cycles

With the process model as a backdrop, it is possible to further detail the dynamics of the path creating process. This process can be described as a series of path creating cycles playing out on different design layers. Figure 6 depicts the plot of such a path creating cycle.

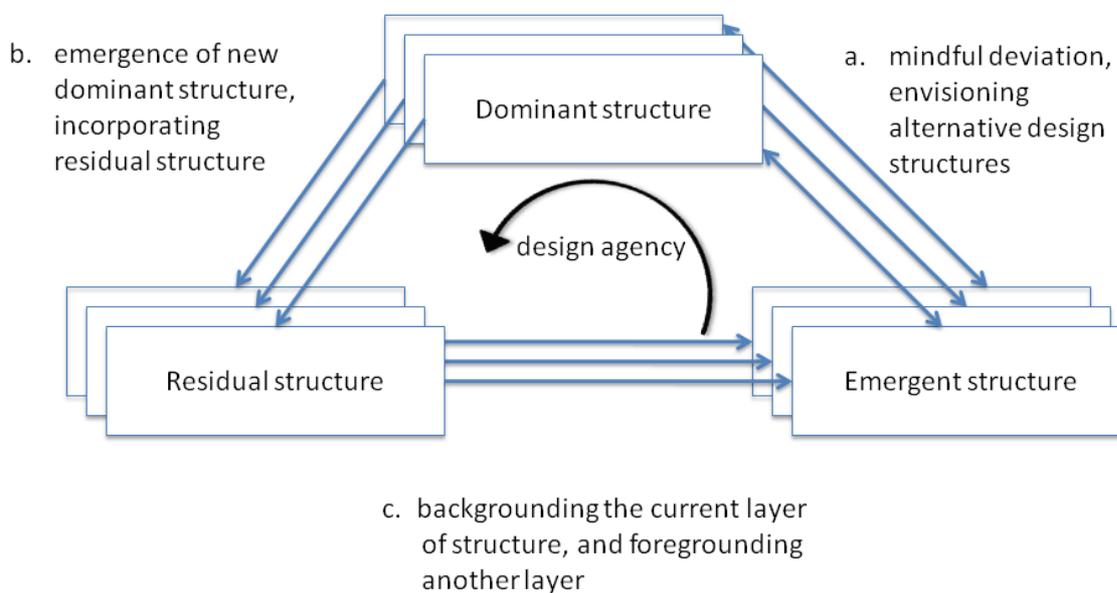


Figure 6. The Path Creation Cycle

CarCorp designers mindfully deviated on a focal layer of the dominant structure (e.g., closed product architecture) by enacting an alternative emergent structure (e.g., an open platform

architecture) (arrow a). As a result of the contradiction between the dominant structure and the emergent structure, designers selected elements of the emergent and residual structures in enacting the new dominant structure (arrow b). As new dominant structures were enacted at the current layer, designers could refocus their attention on another layer of design structure (in this case, supporting organizational principles) that needed to be aligned with the emergent structure enacted (arrow c). At the point where attention was refocused, a new path creation cycle was initiated at another layer.

In the CarCorp case, we observed a series of three path creation cycles. As highlighted in Figure 5, contradictions were brought forward and then pushed into the background at different points in time. It was as if CarCorp designers stood upon the pedestal of one layer where a new path had been created and discovered new possibilities that were unseen by them until they mounted that pedestal. As if there were a pool of never-ending riddles, designers at CarCorp continued to move from one contradiction to another, as they pursued the new innovation path. It is such design agency that propels ongoing path creation dialectics, as long as organizational actors are willing to continue to play with them.

As CarCorp designers continued to create a new path for infotainment innovation, the dominant design structure at CarCorp was slowly replaced by enacting the path creation cycle of one design layer at a time, with an emerging design agenda based on digital technology, which is open, flexible, and fast-paced. In the process, the dominant structure of the designer group was continually active and adjusting, selectively incorporating emergent structures (Williams 1980). Despite the seemingly successful case, it is important to note that infotainment designers were still embedded in a larger system of CarCorp and GlobalCarCorp. Traditional automotive structures continued to reside at all three layers because infotainment systems were but a subsystem interconnected with the car's digital infrastructure. Therefore, much of the traditional automotive structures remain as residual structures, equipped to strike the fragile new design structures that the designers were able to establish.

Implications

Our path creation perspective, including the multi-layered process model and path creation cycle, offers a number of implications for the innovation literature. First, it illustrates the path creation process of a firm that embraces digital technology in their traditional mechanical product. It shows that digital innovation at CarCorp was much bigger than the simple embedding of a new digital technology in the material layer. Instead, it included the re-negotiation of dominant structures both at the cognitive and organizational layers. What was originally conceived as a relatively simple modification of a material property of a closed product eventually became something much bigger and more complex (the creation of a platform with heterogeneous artifacts and a new development community with distributed and diverse members) than the designers originally anticipated. This suggests that the introduction of new digital technologies into an existing product cannot be accomplished as a mere step along the existing innovation path. It involves the creation of new opportunities in path creation practice. Therefore, the dialectic path creating cycle exacerbates the continuous state of "becoming" typical of organizations that embrace digital technology. In this regard, our research offers some empirical backing to Benson's (1977) dialectical view of organizations.

Second, the path creation cycle with its focus on design agency and dominant-emergent-residual structures (cf. Williams 1980) provides a useful lens with which to appreciate the reciprocal relation between path creation and path dependency. Consistent with path dependency

perspectives, design agency is often bound by what path creators already know in the form of dominant design structures. For instance, they are constrained by the material reality of their self-designed artifacts and the tools that they have used over time. For instance, CarCorp designers could not know or anticipate new technological options that would become possible in a few years. Similarly, they could not foresee the emergence of open innovation (Chesbrough et al. 2006) as a viable innovation logic. In this regard, design agency is always localized and distributed in time and space. Yet, the future is unknowable and open to path creators. The design goal is never fully given and disclosed, but needs to be discovered as they continue to explore new emerging structures for the material, cognitive, and organizational layers. To echo Cooren et al. (2006), through design agency, path creators discover the capacity to act “when studying how worlds become constructed in a certain way.” Our study shows that designers at CarCorp could not control the design space as digital technology continues to bring new options. However, they could enact such options as emergent structures and learn from their contradiction with dominant design structures.

Finally, our multi-layered process model complements previous path creation studies by zooming in on the creation of particular innovation paths and how they collide with other paths in an innovation network. Boland et al. (2007) show that designers’ mindfulness and design visions collectively act as a powerful force that instigates and keeps the wakes of innovation rippling through a design network. Our finding provides a condition under which designers become mindful in their design actions. As shown in the CarCorp case, the mindfulness of path creators becomes heightened as the contradictions within layers of structure develop, deepen, and penetrate the designer’s social experiences (Seo and Creed 2006).

Limitations

There are a number of limitations related to our study. First, our findings cannot be generalized across different types of innovations, as our study focused on the impact of new digital technology for product-lead firms such as automakers, which have a greater responsibility in designing and integrating products compared to other firms participating in the design process. Thus, it is likely that product-lead firms go through more dramatic changes, compared to their contractors, in the material, cognitive and organizational design layers as a result of path creation in digital innovation. Second, our empirical study ended in the midst of the third phase as CarCorp was implementing its new direction. It is therefore not possible to determine whether their open innovation, strategy-based boundary-spanning practices and application developer communities will be successful. However, we expect that designers at CarCorp will become aware of unexpected contradictions as a result of their current efforts. Consequently, they will exercise their design agency and continue to transform car infotainment across layers of design. Third, in this study, we treated the design group at CarCorp as a homogeneous set of actors. However, past research shows that members of contemporary organizations carry multiple, and often conflicting, identities that are embedded in multiple institutions. Lastly, our study is conducted in the context of the automotive industry. The industry is unique in that it is highly concentrated. The pattern of path creation dialectics might be different in a more distributed and heterogeneous industry.

Directions for Future Research

Our study suggests several possible directions for future research. First, it would be useful to replicate our study in other industries. By studying other industries and different types of products, we can generalize and validate our path creation perspective by including the multi-

layered process model and the path creation cycle. Second, other methodologies can be adopted to examine the general impact of the digitization of physical products on layers of structure. For example, a cross-sectional survey across different industries using econometric methods or agent-based simulation can deepen our understanding of this phenomenon and generate additional theoretical insights. Third, our study focused on the path creation of a single group of designers over some 12 years. Future research can explore the path creation of a broader group of actors, the firm itself, or even innovation networks. Finally, we explored the digitization of car infotainment as if it were independent of the development of other technologies in cars. In practice, infotainment systems are connected to, for instance, car communication networks, which themselves are going through rapid changes. This suggests that future research on path creation dialectics needs to carefully consider the multiplicity of social actors and the heterogeneous materiality of different technologies and their interactions.

CONCLUSION

When the digital camera was first introduced, it was considered to be merely replacing the chemical-based film with a digital sensor to capture images. However, although a digital camera essentially serves the same function as its analog counterpart, its functionality has been radically expanded over time. It not only displays the pictures immediately and stores thousands of images on a memory card; it is now also coupled with other digital artifacts, such as cell phones and global positioning systems (GPS), creating unpredictable paths for future innovation. In fact, since 2004, more camera phones have been sold worldwide than digital and film-based cameras combined. With these new devices, pictures can be tagged with the exact longitude and latitude of the location, and then be uploaded on photo sharing websites that plot pictures onto digital maps. Mobile phone users can now easily download pictures taken by complete strangers who visited the place where they are currently located.

As in the case of the digitization of the camera, digital technology is often seen as the holy grail for innovation. In part, such an innovation expectation around digital technology is in part due to the unique generativity of digital technology (Zittrain 2006). Such generativity of digital technology causes the continual expansion of the meaning of the product as we saw in the case of CarCorp. The short story of the evolution of the digital camera shows that the multi-layered dialectical path creation that the designers at CarCorp enacted was not necessarily unique to them. Our study shows that digital technology not only challenges the innovation path of the material and its cognitive layer, but also brings inevitable changes in the organizational layer. Path creation is then multi-layered and much more internally dynamic than previously perceived.

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REFERENCES

- Arthur, W. B. 1989. Competing Technologies, Increasing Returns, and Lock-in by Historical Events. *The Economic Journal*, **89**, 116-131.
- Baldwin, C.Y., K.B. Clark. 2000. *Design Rules - The Power of Modularity*. MIT Press, Cambridge, MA.
- Barr, P.S., J.L. Stimpert, A.S. Huff. 1992. Cognitive change, strategic action, and organizational renewal. *Strategic Management Journal* **13**(S1) 15-36.
- Bassanini, A.P., G. Dosi. 2001. When and How Chance Can Twist the Arms of Clio: An Essay on Path Dependence in a World of Irreversibilities. R. Garud, P. Karnoe, eds. *Path Dependence and Creation*. Lawrence Erlbaum Associates, Mahwah, New Jersey, 41-68.
- Benson, J.K. 1977. Organizations: A Dialectical View. *Administrative Science Quarterly* **22**(1) 1-21.
- Boland, R.J., K. Lyytinen, Y. Yoo. 2007. Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction. *Organization Science* **18**(4) 631-647.
- Brooks, F. P. 1995. *The Mythical Man-Month*. Boston, MA: Addison-Wesley.
- Charmaz, K. 2006. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. SAGE Publications, Thousands Oaks, CA.
- Chesbrough, H. 2006. Open Innovation: A New Paradigm for Understanding Industrial Innovation. H. Chesbrough, W. Vanhaverbeke, J. West, eds. *Open Innovation: Researching a New Paradigm*. Oxford University Press, New York, 1-12.
- Cooren, F., Taylor, J., & Van Every, E. (Eds.). 2006. *Communicating as Organizing: Empirical and Theoretical Exploration in the Dynamic of Text and Conversation*. Mahway, NJ: Lawrence Erlbaum.
- David, P.A. 1985. Clio and the Economics of QWERTY. *The American Economic Review* **75**(2) 332-337.
- Feldman, M., B.T. Pentland. 2003. Reconceptualizing Organizational Routines as a Source of Flexibility and Change. *Administrative Science Quarterly* **48** 94-118.
- Foote, N. W., J. Galbraith, Q. Hope, D. Miller. 2001. Making solutions the answer. *The McKinsey Quarterly* (3): 84-93.
- Galbraith, J.R. 2002. Organizing to Deliver Solutions. *Organizational Dynamics* **31**(2) 194-207.
- Galunic, D.C., S. Rodan. 1998. Resource Recombinations in the Firm: Knowledge Structure and Potential for Schumpeterian Innovation. *Strategic Management Journal* **19**(12) 1193-1201.
- Garud, R., C. Hardy, S. Maguire. 2008. Institutional Entrepreneurship as Embedded Agency: An Introduction to the Special Issue. *Organization Studies* **28**(7) 957-969.
- Garud, R., P. Karnøe. 2001. Path Creation as a Process of Mindful Deviation. R. Garud, P. Karnøe, eds. *Path Dependence and Creation*. Lawrence Erlbaum Associates, Mahwah, New Jersey, 1-38.
- Garud, R., P. Karnøe. 2003. Bricolage versus Breakthrough: Distributed and Embedded Agency in Technology Entrepreneurship. *Research Policy* **32**(2) 277-300.
- Giddens, A. 1984. *The Constitution of Society - Outline of the Theory of Structuration*. Polity Press, Cambridge.
- Hanseth, O. 2000. The Economics of Standards. C. Ciborra, K. Braa, A. Cordella, B. Dahlbom, A. Failla, O. Hanseth, V. Hespø, J. Ljungberg, E. Monteiro, K.A. Simon, eds. *From Control*

- to Drift - The Dynamics of Corporate Information Infrastructures*. Oxford University Press, Oxford, 56-70.
- Hargadon, A.B., Y. Douglas. 2001. When Innovations Meet Institutions: Edison and the Design of the Electric Light. *Administrative Science Quarterly* **46** 476-501.
- Hirschheim, R., H. Klein, H. and K. Lyytinen. 1995. *Information Systems Development - Conceptual and Philosophical Foundations*. Cambridge University Press.
- Langley, A. 1999. Strategies for Theorizing from Process Data. *Academy of Management Review* **24**(4) 691-710.
- Leavitt, B., J.G. March. 1988. Organizational Learning. *Annual Review of Sociology* **14** 319-340.
- March, J.G. 1991. Exploration and Exploitation in Organizational Learning. *Organization Science* **2**(1) 71-87.
- Markus, M.L., D. Robey. 1988. Information technology and organizational change: Causal structure in theory and research. *Management Science* **34**(5) 583-598.
- Miles, M.B., A.M. Huberman. 1994. *Qualitative Data Analysis*. Sage, California.
- Nandhakumar, J., M. Jones. 1997. Too close for comfort? Distance and engagement in interpretive information systems research. *Information Systems Journal* **7** 109-131.
- Orlikowski, W. J. 1996. Improvising organizational transformation over time: A situated change perspective. *Information Systems Research* **7**(1) 63-92.
- Pettigrew, A.M. 1990. Longitudinal Field Research on Change: Theory and Practice. *Organization Science* **1**(3) 267-292.
- Poole, M.S., A.H. Van de Ven. 1989. Using Paradox to Build Management and Organization Theories. *Academy of Management Review* **14**(4) 562-578.
- Powell, W.W. 1991. Expanding the Scope of Institutional Analysis. P.J. DiMaggio, W.W. Powell, eds. *The New Institutionalism in Organizational Analysis*. University of Chicago Press, Chicago, 183-203.
- Sawhney, M., S. Balasubramanian, V. Krishnan. 2004. Creating Growth with Services. *MIT Sloan Management Review* **45**(2) 34-44.
- Seo, M.-G., W.E.D. Creed. 2002. Institutional Contradictions, Praxis, and Institutional Change: A Dialectical Perspective. *Academy of Management Review* **27**(2) 222-247.
- Stack, M., M.P. Gartland. 2003. Path Creation, Path Dependency, and Alternative Theories of the Firm. *Journal of Economic Issues* **37**(2) 487.
- Thrun, S., A. Levandowski. 2009. Four Ways for Detroit to Save Itself *The New York Times*, (www.nytimes.com/interactive/2009/01/03/opinion/20090103_opedthrun_ready.html, accessed: January 16, 2009)
- Tsoukas, H. 1996. The Firm as a Distributed Knowledge System: A Constructionist Approach. *Strategic Management Journal* **17**(Winter Special issue) 11-25.
- Van de Ven, A.H. 1992. Suggestions for Studying Strategy Process: A Research Note. *Strategic Management Journal* **13**(Summer Special Issue) 169-188.
- Van de Ven, A.H. 2007. *Engaged Scholarship: A Guide for Organizational and Social Research*. Oxford University Press, Oxford.
- Walsham, G. 2006. Doing Interpretive Research. *European Journal of Information Systems* **15**(3) 320-330.
- Weick, K.E. 1979. *The Social Psychology of Organizing*, 2 ed. McGraw-Hill, New York.
- Weick, K.E. 2004. Rethinking organizational design. R.J. Boland, F. Collopy, eds. *Managing as Designing*. Stanford Business Books, Stanford, CA, 36-53.
- Williams, R. 1977. *Marxism and Literature*. Oxford University Press, New York.

- Williams, R. 1980. *Culture and Materialism: Selected Essays*. Verso, New York.
- Yin, R.K. 2009. *Case Study Research: Design and Methods*, 4 ed. SAGE Publications, Thousand Oaks.
- Yoo, Y., R.J. Boland, K. Lyytinen. 2006. From Organization Design to Organization Designing. *Organization Science* **17**(2) 215-229.
- Zittrain, J. 2006. The Generative Internet. *Harvard Law Review* **119** 1974-2040.

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