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EXHIBIT TO TESTIMONY OF

Jason L. Ball

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

Innovation in the Mobile Industry

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How Cross-boundary Disruption-from-above Superseded Incumbents' Sustaining Innovation in the Mobile Industry: Qualitative, Graphical and Computational Insights

Robert A. Burgelman and John K. Thomas

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Abstract

This study of the transformation of the mobile device industry examines how cross-boundary disruption (XBD) superseded the incumbents' sustaining innovation, which helps explain the rapid rise of Apple and Google Android and the equally rapid fall of Nokia and other incumbents between 2007 and 2013. Four concatenated strategic factors limited the incumbents' capacity to adapt: (1) incumbents' market myopia about latent unserved needs of the high-end customer segment, (2) incumbents' dynamic capabilities gaps for meeting these needs, (3) demand shift timing of high-end customers toward the disruptors' radically innovative products, and (4) the rapid growth of novel ecosystems around the disruptors' technology platforms. Graphical interpretation further elucidates these concatenated strategic factors and suggests computational implications. The paper's qualitative, graphical and computational insights help formulate a conceptual framework of XBD-from-above, which contributes to theory development about inter-industry disruption and transformation.

Keywords: cross-boundary disruption-from-above, sustaining innovation, incumbent market myopia, incumbent dynamic capabilities gap, incumbent demand shift timing, disruptor ecosystem growth, signal processing and dynamic capabilities, inter-industry dynamics.

Recognizing the importance of industry structural change, strategic management research has traditionally focused on *intra*-industry competitive processes to explain it (e.g., Porter, 1980; Rumelt, Schendel and Teece, 1994; Barnett and Hansen, 1996). Organizational ecology scholars, however, have highlighted the difficulties of understanding the dynamics of large-scale change from the "… analysis of a single population of organizations, because the dynamics of populations are usually linked (and each is environment to the other)" (Hannan and Freeman, 1989:92). This meta-population view of *inter*-industry competitive dynamics has gained in saliency because of the convergence of different industries (populations) driven by technological (e.g., digitization of content) and regulatory (e.g., deregulation of the telecommunications industry) forces.

Previous research of *inter*-industry competitive dynamics identified "cross-boundary disruption" (XBD): disruption by established companies that are able to enter an adjacent industry as powerful entrepreneurial change agents (Burgelman and Grove, 2007). As XBD leads to transformation of the adjacent industry and replacement of its leading incumbents, it could be meaningfully distinguished from the less dramatic and well-documented entry by diversifying companies coming from other industries or by new startup companies (e.g., Carroll, Bigelow, Seidel, and Tsai, 1996).

Previous research about disruptive technology (Christensen and Bower, 1996; Christensen, 1997; Christensen and Raynor, 2003) distinguished "sustaining" innovation from "disruptive" innovation. Sustaining innovation relates to incumbents' strengths in

bringing out better products sold at higher prices to high-end customers. Disruptive innovation, in contrast, usually involves new entrants that offer novel products that are not as good as currently available products, but are simpler and less expensive and are attractive to low-end customers. This research also introduced the concept of "new-market disruption" that involves low-end products that are competing against "non-consumption" on the part of customers who could not afford the available products, again usually offered by new entrants (Christensen and Raynor, 2003). The theory predicts that incumbent firms usually win against newcomers with sustaining innovations, but are likely to lose against newcomers with disruptive innovations.

The original XBD research intended to complement received disruptive innovation theory in the context of inter-industry transformational dynamics. To that end it examined Apple's demonstrated success as a PC industry-based disruptor in transforming the music industry in the early 2000s and the company's efforts to do the same in the cellular phone industry in 2007. The conceptual framework derived from this research identified strategic factors that made target industries ripe for XBD (e.g., relative stagnation, customer-unfriendly business models, technologically laggard) and established companies motivated and able to pursue XBD (e.g., cash- and talent-rich, strong brand, technologically advanced, hungry for growth). It also identified combinations of home industry support and target industry collective resistance strength that made startup companies or established companies coming from other industries more likely to succeed as industry disruptors. In addition, it identified the importance of strategic leadership on the part of companies coming from other industries to recognize and execute the XBD

opportunity (e.g., Steve Jobs's focus on outstanding user experience manifest in his successful hardware-software integration in the PC industry). Finally, it identified the importance of securing the sequential but fast support of some major incumbent adopters as XBD force multipliers.

Based on this framework and the expectation that incumbents are likely to be more successful against the threat of competing sustaining innovations than against the threat of disruptive (low-end) innovations (Christensen, 1997; Christensen and Raynor, 2003), the original XBD research predicted that Apple was likely to become a viable participant in the cellular phone industry but probably not an XBD. By 2010, however, it was already obvious that this prediction had underestimated the spectacular XBD success that Apple and Google Android had been rapidly able to achieve at the expense of industry leader Nokia and other strong cellular phone industry incumbents.

CROSS-BOUNDARY DISRUPTION-FROM-ABOVE

In light of the failure to predict Apple and Google Android's success, the present paper addresses the research question of why Apple and Google Android were able to become cross-boundary disruptors of the mobile industry, and why Nokia and other leading incumbents were unable to defend their strategic positions in spite of their strong sustaining innovation record. With the benefit of data generated between 2007 and 2013, the paper identifies and examines the strategic factors that the previous research of Apple's XBD prospects was unable to anticipate. It found that Apple's efforts to disrupt the mobile industry involved "XBD-from-above:" disruption through the introduction of

the iPhone, a radically new type of mobile device, to meet unserved latent high-end customer needs that went beyond the incumbents' sustaining innovation capabilities (Christensen, 1997; Christensen and Raynor, 2003). XBD-from-above helped shed new light on why Apple was able to see and act upon the iPhone opportunity while Nokia remained stuck with the smartphone concept and associated sustaining innovation trajectory that it had successfully adopted. This also helped identify more clearly the importance of the dynamic capabilities (Teece, Pisano, and Chuen, 1997; Teece, 2007) that Apple as a computer company had and that Nokia and other major mobile industry incumbents lacked.

More specifically, the novel lens of XBD-from-above drew attention to four concatenated strategic factors that were not quite clear in 2007. First, the introduction of Apple's iPhone revealed *incumbent market myopia* on the part of Nokia and other major incumbents with respect to the unserved latent needs of the very high-end market segment of the mobile industry. Second, this exposed a *dynamic capabilities gap* on the part of Nokia and the other incumbents relative to Apple that made it inherently difficult for the incumbents not only difficult to perceive the revealed unserved needs of the high-end customer segment but to actually meet them. Third, the *demand shift timing* - significant and rapid - of the high-end customer segment of the mobile phone industry to the iPhone (and to Google Android-based mobile devices) gave Nokia and the other incumbents little time to close the dynamic capabilities gap. Fourth, the *rapidly growing ecosystem* of valuable applications around the iPhone's operating system (and around the

Google Android operating system) exacerbated the incumbents' difficulties of catching up.

Recent research about Nokia's rise and fall in the mobile phone industry used a large number of accounts of success and failure in the popular management literature to identify four broad discursive categories: strategic leadership, capabilities, organizational design and environment (Laamanen, Lamberg, and Vaara, 2016). This research found that the four discursive categories remained the same but that the relative emphasis on these placed by different authors changed significantly as Nokia evolved from success to failure. Concerning capabilities, these researchers found that during the period of success the narratives emphasized Nokia's capability to master the full value chain; whereas during the period failure they emphasized Nokia's emphasis on selling "devices" versus Apple's selling "lifestyle." Still other recent research examined how distributed attention structures influenced shared emotions in Nokia's managerial ranks during the period 2005-2010, and how such shared emotions hindered the subsequent integration of managerial attention (Vuori and Huy, 2016). This research showed that this hindrance of attention to integration influenced innovation processes and outcomes resulting in temporal myopia defined as a focus on short-term product innovation at the expense of long-term innovation development.

In addition, longitudinal research (started in the 1990s) of Nokia's rise and fall in the mobile phone industry raised three possible explanations (Doz and Wilson, 2018). The first explanation viewed Nokia's decline as an extreme case of Schumpeterian creative

destruction. The second one viewed Nokia's decline as a case of unsuccessful organizational evolution due to failing to adapt to radical technological disruption and business model change. The third one viewed Nokia's decline as a case of failed management volition and the associated shortcomings in strategy, organization and execution. This research provided strong evidence that management volition of its top management "dream team" during the 1990s made the rise of Nokia possible. To explain Nokia's decline it provided evidence showing that the decrease in the quality of management volition in the early 2000s had already begun to set Nokia on the path of reduced adaptability before the arrival of the iPhone's disruption and, in combination with the other two explanations, determined its rapid fall after 2007.

These studies touched in various more or less explicit ways on the strategic factors associated with XBD-from-above that are the focus of this paper. However, as these studies systematically focused on the putative internal causes of Nokia's rise and fall they did not provide an explanation for why other major incumbents such as Motorola, Ericsson and Blackberry also failed in the face of Apple's XBD-from-above. This leaves room for proposing an integrated systematic and parsimonious conceptualization of how the four concatenated strategic factors identified in the present paper help explain the catastrophic outcomes caused by XBD-from-above for all the major incumbents in spite of their continued sustaining innovation efforts. In addition, the graphical interpretation of these concatenated strategic factors suggests computational implications rooted in signal processing theory for quantifying dynamic capabilities. Importantly, these novel qualitative, graphical and computational insights suggest that the cognitive and emotional

disarray associated with decreased quality of managerial volition, systematically observed at Nokia and more impressionistically at the other leading incumbents, may have been the *consequence* rather than the *cause* of catastrophic failure.

The next section of this paper explains the research methods. The recapitulation section summarizes previous findings about Nokia's success in the mobile industry pre-2007, and explains why the original XBD framework failed to explain Apple's dramatic success by 2010. The findings section examines how the Apple iPhone and Google Android-based mobile devices superseded the sustaining innovations of Nokia and the mobile industry incumbents after 2007, and identifies the four concatenated strategic factors associated with XBD-from-above that caused their rapid fall. The discussion section summarizes qualitative insights about the four concatenated strategic factors, presents a graphical interpretation, derives computational implications, and offers a simplified example to illustrate the potential usefulness of the computational implications for the quantification of dynamic capabilities in further comparative research. The conclusion and implications section articulates how XBD-from-above complements received knowledge about sustaining and disruptive innovation and suggests further research directions for developing cumulative knowledge about inter-industry disruption and transformation.

METHOD

The discovery of cross-boundary disruption (XBD) was grounded in longitudinal qualitative research that involved developing a series of case studies of the evolution of the music industry since the emergence of digital distribution (multiple case studies are

available from the authors). To address the question of how to explain the rapid transformation of the music industry, the research focused on Apple's strategic actions as a new entrant from the PC industry in the music industry. The research used Apple as an exemplary case (e.g., Siggelkow, 2002; Danneels, 2010) to identify XBD as the emerging phenomenon of interest and to enable theory generation and elaboration (Lee, 1999; Siggelkow, 2007). At the industry level, the case analysis described the evolving external context dynamics of the music industry that Apple as a new entrant faced. At the organizational level, the case analysis compared the strategic situation and actions of Apple and key music industry incumbents. Combining grounded theorizing and insights from modern historical methods (Glaser and Strauss, 1967; Gaddis, 2002) helped generate the grounded conceptual framework of XBD summarized above.

Rooted in comparative longitudinal case research, this conceptual framework aimed at providing a first representation of how the complex XBD system hangs together and of its operative logic. Beyond the value of offering increased understanding and explanation of a complex phenomenon, however, the scientific validity of such conceptual frameworks depends on their capacity to make predictions, "where 'prediction' is very broadly construed as testing an explanation 'out of sample'" (Watts, 2017: 1295). Prior to having had the benefit of Watt's incisive discussion of the difference between "understanding" and "scientific validity," the original XBD research did test the validity of the conceptual framework by using it to predict - unsuccessfully as it turned out - the prospective success of Apple as XBD of the mobile industry.

To do so, the previous research focused on the evolving strategic situation of Apple (potential XBD) and Nokia (incumbent) in the converging computing and mobile communications industries. This part of the previous research benefited from the composition of case studies of Nokia during the early 2000s (multiple case studies are available from the authors). Given Apple Computer's well-known secrecy about strategy and product development the research had to rely on public data to put together a time sequence of key events, people and issues involved in the XBD process. The previous research, however, benefited from comments that Steve Jobs made as a guest speaker in a seminar setting at a major university in the fall of 2007, which provided some first-hand insights of the main protagonist in the XBD process.

Discovering XBD-From-Above

The failure of the conceptual framework based on the original XBD research to predict the spectacular success that Apple and Google Android were rapidly able to achieve at the expense of industry leader Nokia and other strong cellular phone industry incumbents motivated further research. This research focused on identifying the strategic factors that the previous research had missed and/or failed to anticipate and that made this success possible. It examined how cross-boundary disruption evolved at multiple levels in the vertical structure of the mobile telecommunications industry since 2007. Most relevant for the present paper, at the operating system level the research compared iOS, Google Android, Microsoft Mobile, Blackberry, and others. At the device level, it compared Apple, Nokia, Blackberry, Samsung, and Xiaomi, among others (multiple case studies are available from the authors).

The combined qualitative and graphical analyses of these case studies indicated that XBD could emerge "from above;" that is, from the XBD's ability to perceive and serve a latent very high-end customer segment that the incumbents were not able to perceive until it was revealed by the XBD's radically novel product. Most importantly, these combined analyses indicated that XBD-from-above superseded the incumbents' sustaining innovation (Christensen, 1997; Christensen and Raynor, 2003). Further research helped document the key performance dimensions that distinguished Apple's iPhone and Google Android-based mobile devices from the most advanced smartphone devices offered by the incumbents (shown in Figure 1 in the Findings section). Further research also involved collecting detailed data about the differences in dynamic capabilities between the computer companies (Apple and Google) and the mobile communications companies (Nokia and the incumbents) that enabled the former to supersede the latter's vigorous sustaining innovation efforts (shown in Figure 2 below). The combined qualitative and graphical analyses indicated the importance of the speed with which the incumbents' customers moved toward the disruptors' products, thereby limiting the incumbents' time for adaptation. Consequently, the research also collected data to document the speed with which this demand shift had happened after the introduction of the iPhone in 2007 (shown in Figure 3 below). In addition, given the importance of ecosystem development for the success of new technological platforms, the research also collected data indicating the rapid rate of growth of the number of applications available on the disruptors' technological platforms (shown in Figures 4 and 5). These rapid ecosystem developments accelerated the speed of the demand shift, thereby further limiting the incumbents' time for adaptation. While the graphical analysis helped with identifying and visualizing the

four concatenated strategic factors associated with XBD-from-above (Figure 6), it also helped develop a visual representation of the forces driving the direction of convergence of the computer and the mobile communications industries (Figure 7).

These qualitative and quantitative analyses helped explain how XBD-from-above was able to destroy the viability of the major mobile incumbents far more rapidly than anticipated by the original XBD research. Importantly, the graphical analysis also indicated the possibility of relating signal-processing theory as developed in electrical engineering (e.g., Scharf and Thomas, 1998) to dynamic capabilities. This, in turn, suggested computational implications for quantifying the differences between the dynamic capabilities of the XBD-from-above entrants and the incumbents in further research.

Strengths and Limitations

The theory-building efforts for this paper combine historical research and grounded theorizing (Gaddis, 2002; Glaser and Strauss, 1967, Burgelman, 2011). At this point, the concept of XBD-from-above constitutes the generalization of a phenomenon identified within particular case studies of the cellular telephony industry (Gaddis, 2002). Hence, the well-known limitations of case study research apply to this study. In light of this, the paper's limited aim is to develop a substantive grounded conceptual framework of XBD-from-above. At the same time, however, XBD-from-above represents a previously undocumented manifestation of disruptive innovation. By identifying the differences between XBD-from-above, sustaining innovation and disruption-from-below

(Christensen, 1997) the paper suggests directions for future research to move closer to a grounded theory of inter-industry disruption and transformation.

RECAPITULATION: NOKIA'S PRE-2007 SUCCESS LEADS TO FAILING TO PREDICT APPLE'S XBD SUCCESS IN 2007

Nokia's Success Throughout 2007

Nokia, founded in 1865 as a paper manufacturer and named after Finland's river Nokia, had become a conglomerate firm by the 1980s making tires, rubber boots and other consumer and industrial rubber products, as well as cable for power generation and telecommunications. In the late 1980s Nokia top management decided to turn Nokia into a leading player in the emerging cellular telecommunications industry when Jorma Ollila, its young new CEO at the time, realized that "voice will go wireless." Based on this insight Nokia decided to divest its non-telecommunications businesses and to focus on pursuing profitable growth opportunities in the emerging wireless telephony and wireless network equipment industries. Top management created two divisions to pursue these opportunities: Nokia Mobile Phones (NMP) and Nokia Telecommunications (NTC). The remainder of this paper focuses on the Nokia Mobile Phones division.

NMP becomes the dominant handset maker. Until 1999, there was rough parity in the handset market. Since then Nokia had eclipsed the competition. By 2002, Nokia Mobile Phones was the world's largest mobile phone producer and had over twice the market share of Motorola, its closest competitor (Ewing, 2007). In 2002, Nokia's market share rose for the fifth consecutive year to an estimated 38 percent. Mobile phones were the lifeblood of the Nokia Group, generating almost 80 percent of sales and 90 percent of

earnings, with operating margins of 20 percent. At its peak, Nokia sold every year some 400 million cell phones worldwide.

Nokia Mobile Phones' success by 2003 depended on its strong consumer marketing capabilities. The division had developed products with strong market fit in each of the many segments that it served. Already by 1995, the division recognized that the cell phone had become viewed by consumers as a fashion product, and developed many sustaining product innovations (e.g., the ability of easily changing the outside shell color of its handsets to match a consumer's clothing outfits). At a strategic offsite meeting of the mobile phone division's top management in Germany in December 1995, for instance, a design consultant offered the proposition that in the future customers would "wear their phone" (reference available from the authors).

Continuously strong sustaining innovation. By 2003, Nokia was moving deeper into the entertainment industry by launching a portable game console with a built-in cellular connection that allowed users to play games with each other over the cellular network, or make voice calls. Nokia planned to include a built-in digital music player and radio in the console. Nokia also established separate partnerships with Sony and Matsushita to develop software that would allow swapping of video, pictures and music files between mobile phones and home-electronics devices. Nokia regarded the mobile phone also as a remote control for other equipment that surrounds users; one that they can carry with them. In October 2006, Nokia bought an iTunes rival called Loudeye, the largest independent music distribution platform, for $60 million, which would create a potentially dangerous threat to Apple's iPd and iTunes. That same month Nokia also

purchased gate5, a maker of navigation software for mobile phones. In July 2007, Nokia bought media-sharing site Twango, and in July of that year launched "Ovi" (Finnish for "door") an online service for a variety of content. Ovi included an online music store aimed primarily, but not exclusively, at the 200 million music-capable Nokia mobile phones already on the market. It also featured an interactive multiplayer game service accessible to the 40 million Nokia N series phones already in use. In 2008, Nokia planned to add a service that would let consumers swap personal photos, videos, and audio. Nokia's new Chief Executive Officer at the time, Olli-Pekka Kallasvuo (formerly Nokia's Chief Financial Officer), reportedly said, "Devices alone are not enough anymore. Consumers want a complete experience" (Schenker, 2007).

Co-evolutionary lock-in with GSM and Symbian. Nokia Mobile Phone Division's tremendous success in the rapidly growing mobile industry, however, created co-evolutionary lock-in: a positive feedback process that increasingly ties the success of an incumbent company's strategy to that of its existing product-market environment, thereby making it difficult to change strategic direction (e.g., Burgelman, 2002). One form of co-evolutionary lock-in related to system-level digital mobile communications technology. Nokia had greatly benefited from deregulation in telecommunications within Europe that occurred in the early 1990s as well as from the European Union's decision to support the GSM platform for mobile communications, based on the digital Time Division Multiple Access (TDMA) technological standard. The first GSM mobile call used a Nokia phone over a Nokia-built network in Finland in 1991. GSM proliferated in Europe and elsewhere around the world. In the United States, however, Qualcomm's Code Division Multiple Access (CDMA) technological standard was becoming dominant

and its superiority would eventually dominate the TDMA-based GSM standard in later generations of mobile technology (case study available from the authors).

At the communications device level, Nokia also became locked-in with Symbian, a private independent company founded (in June 1998) by Ericsson, Nokia, Motorola and British personal digital assistant maker Psion. The Symbian OS, an open standard operating system for data-enabled mobile phone, provided the underlying software code that enabled handset support functions and applications such as graphics, security and Internet access. By 2003 Symbian's ownership had expanded to include its original founders and Siemens, Panasonic, Samsung, and others. Symbian faced potentially serious competition from Microsoft's "Smartphone " OS, released in October 2002, that enabled users to communicate via voice, e-mail, instant messaging or SMS over the same sleek handset, and was designed to work well with other Microsoft applications such Outlook. Network operators offering Microsoft's Smartphone, however, were likely to order handsets in quantities of hundreds of thousands. By contrast, market leading brand name makers, such as Nokia, Motorola and others produced handsets in quantities in the millions. Such scale disadvantages were likely to make Microsoft Smartphone-based handsets more expensive to produce (case study available from the authors).

Signs of trouble. By early 2004, however, the tide seemed to be changing. Nokia's mobile device sales volume grew only 19 percent, while the industry volume had increased 29 percent. The company's critics pointed to two increasingly important sustaining innovation problems: style and function. Nokia's sustaining innovation process had long used the same physical format for its phones (some called it a "candy

bar" shape) at a time when competitors were introducing more and varied styles, many with the so called "clamshell" formats (e.g., Motorola's RAZR). Along with these new design formats competitors introduced more advanced features. Competitors emerged (especially in Asia) to challenge Nokia's dominance in the high-end, mid-end and low-end segments of the handset market. Nokia also faced challenges from mobile operators, the major buyers of handsets. With its extremely popular models and interface, Nokia had been reluctant to cede any brand control. However, as global operators consolidated Nokia was increasingly under pressure to accept co-branding. In spite of these problems, Nokia remained a formidable company. It was sitting on a cash pile of €11.4 billion in early 2004. During 2004, Nokia planned to launch up to 40 new handset devices, many with innovative designs and features aimed at the middle and upper markets (case studies available from the authors).

By 2004, however, Nokia's top leadership "dream team" – CEO Jorma Ollila; Pekka Ala-Pietila and Matti Alahuhta, who had successively been in charge of NMP's extraordinary success; Sari Baldauf, who had run the equipment division (NTC) and Olli-Pekka Kallasvuo (the CFO and confidant of Ollila) – was beginning to fall apart (Doz and Wilson, 2018). The process had started in 2003 with the ill-conceived creation of a giant matrix organization structure in which Alahuhta, who had been running the highly successful Nokia Mobile Phone division, was put in a corporate staff position. At the end of 2004, he left Nokia to become CEO of Kone (a major Finnish elevator company). Shortly thereafter Sari Baldauf also left to pursue other interests. Ala-Pietila, who as

President had nevertheless become somewhat sidelined as head of Nokia's new venture organization (NVO), refused the offer to become CEO and resigned in 2005.

Nevertheless, during 2006-2008 Nokia Mobile Phones made several strategic sustaining innovation moves to strengthen the appeal of its products. In 2007, the Nokia Group reached its highest level of revenue (slightly over 51 billion euros) and highest operating profit (almost 8 billion euros). The Nokia Mobile Phones division still reached revenues of 35 billion euros in 2008. However, the Nokia Group revenues fell to 40 billion euros in 2009, with the Nokia Mobile Phone division revenues falling to roughly 28 billion euros in 2009 (Doz and Wilson, 2018).

Failure to Predict Apple's Success as XBD in the Mobile Industry

Apple's success as an XBD in the music industry with its iPod and iTunes innovations caused it to change its corporate strategy, as signaled by its decision to delete "Computer" from its name in 2007. In June 2007, Apple launched the iPhone exclusively with service provider AT&T, who agreed to a novel business model that required it to share certain service revenues with Apple. Selling for $599, within three months Apple sold over 1 million units of the device. In contrast, it had taken Apple almost two years to sell a million iPods (Burgelman and Grove, 2007).

Different industry context. Nevertheless, several important differences with the music industry required consideration to assess Apple's chances to be successful as an XBD in the cellular phone industry in 2007. First, in contrast to the music industry the cellular telephony industry contained several vigorously innovative rivals, such as Nokia,

Blackberry, Motorola, Samsung, Sony-Ericsson, LG, and Siemens. As a result, as noted above, the rate of sustaining innovation was very high and required the capacity to bring to market new product generations in rapid succession. Second, the technological requirements for success in the cellular telephony industry by 2007 far superseded those in the music industry. Many would-be entrants in the industry had found out that the software stack (operating system and applications) was much more complex than in the PC industry. The iPhone used Apple's OS X operating system and, at this point, it seemed that the iPhone was an iPod with cellular telephony capability, rather than a breakthrough implementation of a cell phone. In light of this, it was not unreasonable to expect that the iPhone might share the fate of personal digital assistant (PDA)-type products with cell phone capability whose growth had significantly lagged the growth of smart cell phones in recent years (case study available from the authors).

Third, there existed several very strong operator networks with different technological requirements and standards, making it difficult for any device manufacturer to become ubiquitous without their support and without having leading edge, complete reference designs. On the other hand, mobile service operators had not had much success cracking the market for value-added mobile service. For example, British operator Vodafone Group, the world's largest global service provider at the time, spent $37.9 billion on third-generation mobile licenses, in large part in order to provide customers data services such as mobile music. But as of spring 2007, only 32.3 million of its 206.4 million subscribers used its Vodafone Live! portal. That left Vodafone and other mobile operators in danger of becoming "dumb pipes," or providers of generic wireless data access, unable to

differentiate themselves from competitors or to profit by selling content (Schenker, 2007). Fourth, in contrast to the iPod, strongly complemented by Apple's widely adopted iTunes software, the iPhone was a stand-alone product that was dependent and optimized for AT&T's cellular network.

Finally, Apple was not the only potential XBD. In late 2007, Google was planning to introduce its advanced open source Android operating system software (basically freely available to device manufacturers) that would allow handset manufacturers to bring Google-powered phones to market by mid-2008 that would make it easier for customers to get a variety of additional services on their phones – from maps to social-networking to video-sharing (Sharma, 2007). However, it was far from clear in 2007 that Google Android would rapidly become a force multiplier for the XBD-from-above process started by Apple (multiple case studies available from the authors). In fact, Steve Jobs did not welcome Google's entry into the mobile market, and Google's CEO Eric Schmidt left Apple's Board of Directors.

What could Apple hope to achieve beyond 2007? In 2007, it appeared unlikely that Apple would be able to transform the cellphone industry. Even if Apple were able to sell 10 million iPhones, Nokia and some of the other branded device manufacturers would still dwarf it. Also, while Apple was able to negotiate a novel and advantageous business agreement with AT&T (giving Apple a share of certain AT&T revenues), AT&T, and other potential operators adopting the iPhone as well, were likely to try to limit Apple's bargaining power through various means. AT&T, for instance, was planning to launch in mid-November of 2007 its own instant over-the-air music

download service. Apple's iPhone could at this point not download music directly, not even from the iTunes music store (Taylor, 2007).

In summary, the conceptual framework that helped explain Apple's XBD success in the music industry did not provide sufficient explanatory power to predict the XBD success that Apple was on the verge of achieving in the cellular phone industry beyond 2007.

FINDINGS: APPLE'S RAPID RISE AND INCUMBENTS' FALL POST-2007

While the break-up of Nokia's "dream team" during 2004-2005 may have diminished Nokia's visionary foresight capability, the cellular telephony industry contained several other rivals with vigorous sustaining innovation strategies, such as Motorola, Ericsson and Blackberry. The sustaining innovation efforts of these incumbents, however, need to be examined in light of Christensen and Raynor's (2003:80-87) analysis of different approaches to sustaining innovation. Illustrated with examples of mobile devices existing at the time of their pre-iPhone research (Blackberry, Palm, Nokia and others), they distinguished three approaches: (1) product view (the handheld wireless device market), (2) demographic view (the traveling sales person), and (3) job-to-be-done view (use small snippets of time productively). They argued in favor of the job-to-be-done view. As further discussed below, this distinction was useful to highlight the novel tasks (usage models) that the iPhone allowed customers to do versus what the Nokia smartphone allowed them to do.

Apple's iPhone Reveals a Latent Radically Novel Usage Model

Nokia and the other major mobile industry incumbents turned out to be relatively myopic with respect to the potential usage-model changes and associated customer demand shift enabled by moving from feature handsets to the radically innovative type of smartphone introduced by Apple in 2007. In the case of market leader Nokia, detailed longitudinal analysis confirms that top management's vision was constrained by the logic of the strategy that had made it the market leader in the first place (Doz and Wilson, 2018). Also, the first iPhone was a stand-alone product that was dependent and optimized for AT&T's 2.5 G (not yet 3G!) cellular network. In fact, rumor has it that Nokia's top management looked at the first iPhone as not really a phone, but simply a pocket computer with a radio (Doz and Wilson, 2018).

Apple's decision to enter the smartphone industry in 2007, however, not only helped defend its leading position in the music industry against the threat, noted above, of mobile devices adding music delivery capabilities, it also provided the opportunity to attack the smartphone industry with a radically different usage model. As Steve Jobs put it in a presentation at a major university (October 30, 2007), he and his top executives all "hated their cell phone" and they wanted to determine what the feature set would be of a phone they would really like. As a result, Apple top management's vision of the range of potential high-end usage models of smartphones was wider than that of Nokia's top management, and revealed the existence of a latent unserved very high-end demand segment for mobile devices. In fact, Steve Jobs also asserted that neither incumbents nor customers on their own would have been able to define the iPhone's winning features. This he demonstrated in a 2007 promotional video, revealing that the iPhone combined

three- new-products-in-one (iPod with a wide touch screen, cell phone, internet communications device) with attendant novel usage models – "jobs-to-be-done" (Christensen and Raynor, 2003) - for mobile communications not envisaged by the incumbents. For example, the Safari browser of the iPhone was a fully function browser which meant that it could display and interact with practically every web page. The Nokia browsers were limited in their capability and consequently were unable to render many websites. Google maps on the iPhone provided the user with the complete map experience from a PC and included the ability to invoke a webpage of an establishment at a particular location. Furthermore, the iPhone enabled the integration of Google maps with the phone's dialer that made it possible for a user to call the phone number associated with an establishment at a particular location. The map functions on Nokia devices, in contrast, were limited to looking up locations and some limited turn-by-turn directions. There was very limited, if any, integration with either the browser or the dialer. Furthermore, likely due to CPU and memory limitations, Nokia devices had to download map updates as the user moved from one location to another, all of which contributed to a sub-par experience for the user. Also, the iPhone was launched with a visual voicemail system that allowed users to "see" all their voicemails at the same time and directly access any particular voicemail and interact with it. The Nokia handset only allowed sequential access, which meant a user had to listen the messages in the order received. To provide these enhanced capabilities the iPhone consumed massive amounts of data from the cellular networks and the additional processing resulted in relatively poor battery life. The rapidly growing base of iPhone users, it turned out, apparently were willing to tradeoff limited battery life for extremely high network data utilization, which

allowed the cellular operators to grow their subscriber base and sell more data services. In the end, Apple's ability to create a computer-like user experience - a "PC in the pocket" - superseded whatever sustaining innovations Nokia was able to deliver by 2007. Figure 1 compares some of the performance differences (usage models) between the Apple iPhone and the most advanced Nokia smartphone.

Figure 1 About Here

Finally, while globally there existed several very strong operator networks with different technological requirements and standards, making it difficult for any device manufacturer to become ubiquitous without their support and without having leading edge, complete reference designs, mobile service operators had not had much success cracking the market for value-added mobile service. Nokia's hold on the operators in many regions outside the U.S. was very strong, if beginning to weaken somewhat by 2007. Hence, here too they experienced market myopia with respect to the range of new usage models enabled by smartphones caused by the co-evolutionary lock-in resulting from their highly successful strategy. Apple, on the other hand, focused on the very large, quasi-duopolistic U.S operator industry and noticed how both Verizon and AT&T were struggling to capture the business opportunities emerging from the growth of consumer demand for mobile communications. Similar to what they had done in the music industry, Apple went to the weaker player of the duopoly (AT&T) and offered them a novel ecosystem-based business model offer (again like in the music industry) that they could not refuse and counted on the probability that Verizon eventually would have to fall in line (which they did).

Apple's Dynamic Capabilities Dominated the Incumbents' Dynamic Capabilities

While the technological requirements for success in the cellular telephony industry far superseded those in the music industry, and the software stack (operating system and applications) was much more complex than in the PC industry, Apple actually had the superior software competences to deal with this complexity. While Nokia and Blackberry both analyzed the iPhone, Jim Lazaridis of Blackberry reportedly told his staff: "If that thing catches on, we're competing with a Mac, not a Nokia (Silcoff, Mcnish, and Ladurantaye). The team at Apple, indeed, had experience building Macintosh computers as well as the iPod (including iTunes) for music distribution. As a result, they had learned what browsing should look like, what integrated applications should look like, and what user-centric music consumption should look like. They were not seeing such experiences on the most sophisticated mobile phones of that time and postulated that there must be latent demand for a "mac+ipod-like" experience on mobile devices. Having recognized this new growth opportunity rooted in their advanced software capabilities, they developed the strategic intent to pursue it and created the iPhone - a Mac in the form of a cell phone - to satisfy that latent demand. Most critical was the "multi touch" capability of the iPhone, which resulted in an experience that was difficult to copy. While others were able to copy multi-touch, they were not able to copy the multi-touch *experience* because their central processing unit (CPU) was not powerful enough, their operating system was not ready, and many of the copying devices did not have a graphical processing unit (GPU). The iPhone had the combined CPU/GPU advantage over Nokia and Blackberry. Jonathan Ive recalled that his design team had already been working on a multi-touch input for the trackpads of Apple's MacBook Pro, and that they were

experimenting with ways to transfer that capability to a computer screen (Isaacson, 2011: 468).

As XBD-from-above, Apple thus brought dynamic capabilities from its home industry to create radically different product offerings with which to service a latent very high-end demand segment in the mobile industry. At the same time, it also turned out that wireless and cellular connectivity was not as much of a hurdle as initially anticipated for several reasons. By the mid-2000's, the rapid improvement in cellular performance had started to slow. As a result, the dominance of Qualcomm was starting to wane and numerous competitors were starting to offer comparable solutions. Also, Qualcomm and its competitors had started offering reference designs to make it simpler and less costly for handset manufacturers, including Apple, to create cellular phones. Finally, Apple came into the phone business with considerable prior experience with wireless based on deploying WiFi in the Macintosh computers. They had significant experience in data connectivity, developing and deploying applications that used data connectivity and the associated issues. As a result, the incorporation of cellular data with the assistance of chip manufacturers and their reference designs proved to be less of a barrier than anticipated. To illustrate the differences between Apple's and Nokia's capabilities, consider the different components between the first iPhone and a leading smartphone from Nokia, the E61, which was available at roughly the same time. Figure 2 lists the differences in dynamic capabilities between Nokia's E61 and Apple's iPhone 1.

Figure 2 About Here

Figure 2 shows that the iPhone featured a 429Mhz ARM 11 CPU and a GPU (graphical processing unit) and 128M of memory, whereas the E61 had the slower 220Mhz ARM 9 CPU, no GPU and 64M of memory. The first iPhone had a 320x480 touchscreen with resolution of 163 PPI (point per inch), whereas the E61 sported a smaller 320x240 non-touch screen with a lower resolution of 138 PPI. The iPhone was launched with Phone OS 1.0, which was a version of Apple's desktop macOS, whereas the E61 featured the less capable Symbian 9.1. The superior hardware of the iPhone coupled with essentially a desktop OS, allowed Apple to include a full capability browser, whereas the E61 was limited to the inferior WAP2.0 mobile browser. Furthermore, its superior hardware-and-software integration capability allowed Apple to create superior user experiences that were not easily doable on the lower cost hardware and software of the E61. Even though the E61 had the more advanced 3G WCDMA cellular connectivity whereas the first iPhone only had 2G EDGE capabilities, it is this hardware-and-software integration difference that represents the dynamic capabilities gap favored Apple over Nokia.

Incumbent Demand Shifting to Apple's iPhone and Google Android

The magnitude and speed of the shift in customer demand toward the iPhone was dramatic. As noted already, while selling for $599 Apple sold over 1 million units of the iPhone within three months, whereas it had taken Apple almost two years to sell a million iPods. Also, Apple was not the only XBD-from-above. In late 2007, Google introduced the advanced and open-sourced Android operating system that allowed handset manufacturers, especially Samsung, to bring Android-powered yet differentiated smartphones with comparable performance dimensions as the iPhone to market by mid-

2008. The introduction of Google Android thus served as a force multiplier for the virtuous circle that benefitted a radically novel type of smart mobile devices at the expense of the feature phones and smart phones offered by Nokia and other incumbents (most notably Blackberry). Figure 3 shows the rapid change in market shares of the XBD- from-above operating systems relative to those of the incumbents during 2007-11.

Figure 3 About Here

Figure 3 shows the market share of Apple iOS rising from 0 percent to 15 percent during 2007-2011. Most impressively, Android's market share rose from 0 percent in 2008 to 53 percent by the third quarter of 2011 and was still climbing. In contrast, Symbian's market share fell from a high of 66 percent in the second quarter of 2008 to 44 percent in the first quarter of 2010, and then most precipitously to 17 percent by the third quarter of 2011 and was still falling. Translated into device volumes, these very rapid decreases were bound to create tremendous supply chain, manufacturing and salesforce management challenges within the Nokia mobile phones division. Also of great importance for Nokia's later strategic moves Figure 3 shows the market share of Microsoft Smartphone OS falling from 17 percent in the first quarter of 2007 to only about 2 percent by the third quarter of 2011.

New Ecosystems Support the Novel Usage Models

Apple and Google created new ecosystems based on, respectively, the iOS and Android technological platforms with easy to use application programming interfaces (APIs) and attractive new and disruptive business models for developers. This created the powerful

positive feedback force called "increasing returns to adoption" (e.g., Arthur, 1987). Increasing returns to adoption depend on creating a large installed base for a technological platform that then motivates many outside parties, such as independent software vendors (ISVs), to develop applications for the platform, which increases the value of the technological platform for the users. This, in turn leads to an increase in the installed base, and the so-called "virtuous cycle." In the case of Apple and Android, these new ecosystems introduced the prospect of a rapidly growing number of innovative customer-friendly applications - from maps to social-networking to video-sharing - via, again respectively, Apple's and Google's "App" stores. This, in turn, created a powerful force multiplier for iPhone and Android-based mobile devices. Figures 4 and 5 show the growth of available applications for Apple and Android, respectively.

Figures 4 and 5 About Here

Figures 4 and 5 also suggest that Nokia's board of directors made a strategic error by hiring Stephen Elop as its new CEO in 2010 and letting him bring to Nokia Microsoft's mobile operating system. As shown in Figure 3, by early 2011 Microsoft's mobile OS had only 2 percent market share left, and therefore lacked the installed base that would motivate software developers to write applications for it. While Elop was aware that "the industry has shifted from a battle of devices to a war of ecosystems" (Issac, 2012), his strategic moves demonstrated a lack of understanding of the importance of increasing returns to adoption (Arthur, 1987) for creating a viable ecosystem. By early 2012 only Apple's iOS and Google's Android were the remaining meaningful global smartphone operating system competitors.

Saving Nokia's Independence as a Long-Lived Company.

The catastrophic outcome of XBD-from-above and the associated cognitive and emotional disarray that this created for Nokia's mobile phone division nevertheless did not lead to Nokia's demise as an independent long-lived company (Doz and Wilson, 2018). Nokia's new board chairperson Risto Siilaasma, a highly successful Finnish entrepreneur, was able to let go of the non-adaptive past strategy before it was too late - selling off the losing mobile phone business to Microsoft in time to generate financial resources that would allow it to get a new lease on life. At the same time, Siilaasma was able to recognize a major opportunity for strategically redirecting the company in the mobile equipment business - buying back Siemens share in Nokia-Siemens, and acquiring Lucent-Alcatel.

DISCUSSION: INSIGHTS INTO HOW CROSS-BOUNDARY DISRUPTION-FROM-ABOVE SUPERSEDES INCUMBENTS' SUSTAINING INNOVATION

Analysis of the findings about the rapid fall of the highly innovative mobile incumbents post-2007 suggests four concatenated strategic factors that provide qualitative insights into how XBD-from-above superseded the sustaining innovations of these incumbents and set the stage for the disruption of the mobile industry that previous XBD research was unable to predict. Relating these qualitative insights to the original graphical representation used to depict disruptive innovation (Christensen, 1997) suggests additional insights that further highlight the difficulties incumbents face in anticipating XBD-from-above. These graphical insights, in turn, suggest computational insights that

help establish the dynamic capabilities challenges incumbents face in trying to respond to XD-from-above.

Qualitative insights

Incumbent market myopia. Apple's and Google Android's success in radically changing the mobile communications industry has revealed XBD-from-above as a hitherto undocumented form of disruption that depends on superseding the incumbents' sustaining innovation efforts (Christensen, 1997; Christensen and Raynor, 2003). The first iPhone clearly was a very high-end product for which there was initially only unserved latent demand on the part of highly sophisticated potential customers (like Steve Jobs and his executive staff); Nokia's high-end customers simply did not demand the novel performance dimensions before the arrival of the iPhone. This initial lack of demand for the new performance dimensions in Nokia's core markets, which were outside of Silicon Valley (and the rest of the US), revealed Nokia's *incumbent market myopia*. Nokia and other leading incumbents were unable to anticipate the new usage models enabled by the high-end performance dimensions of the iPhone that were radically different from the set of performance dimensions of their own sustaining smartphone innovations generated by their natural process of "overshooting" (Christensen, 1997).

Insight #1: *Incumbent companies are likely to be relatively myopic to XBD-from- above opportunities that open up at the very high-end of their customer demand distribution, where sophisticated customers can be attracted with previously unimagined usage models based on novel product features that the incumbent is unable to anticipate.*

Incumbent dynamic capabilities gap: XBD-from-above tends to add novel high-end performance dimensions in a product's multidimensional performance space. These new high-end performance dimensions were not demanded by Nokia's existing customers, made no claims on product development and did not materially affect priorities in the company's resource allocation process (Christensen and Overdorf, 2000). These new high-end performance dimensions depended on advanced software capabilities. These advanced software capabilities favored Apple and Google relative to Nokia and other leading incumbents, while at the same time Nokia's communication capabilities became more readily available to Apple and Google. Hence, the dynamic capabilities-based challenges for Apple and Google to develop novel types of mobile communications devices turned out to be lower than for Nokia, exposing a *dynamic capabilities gap*. This dynamic capabilities gap was associated with the firm's dominant logic (Prahalad and Bettis, 1986) and with incumbent management's cognitive capabilities (e.g., Laamanen and Wallin, 2009; Kor and Mesko, 2013; Helfat and Peteraf, 2015), and helps explain the relative incumbent market myopia mentioned above. At the same time, and most importantly, this dynamic capabilities gap prevented Nokia and the incumbents from developing sustaining innovation-based products that would allow high-end customers to perform the different novel tasks (see Figure 1) that the radically new iPhone and Android-based mobile devices made possible.

Insight #2: *Incumbent companies are likely to face a significant dynamic capabilities gap that prevents their sustaining innovation efforts from developing products to meet the new performance demands of the very high-end customers served by the radically new products of the XBD-from-above.*

Demand shift timing: After achieving rapid success with high-end customers interested in the hitherto unserved new performance dimensions and usage model delivered by the iPhone (in spite of it not being a great "phone"), the iPhone's traditional cellphone dimensions also improved rapidly over time (e.g., moving to 3G) through further sustaining innovation. Similarly, Samsung and other handset makers recognizing the potential of smartphones based on Google Android to meet latent customer demand became force multipliers by rapidly introducing competing products. As result, Nokia's own technologically-sophisticated customer base (mostly outside the US) that previously did not express interest in the new smartphone performance dimensions (in fact probably did not even imagine them) rapidly found the iPhone and Google Android-based smartphones attractive substitutes for the company's more limited "feature phones" and switched. This upward *demand shift timing* left Nokia (and other incumbent companies) with a rapidly deteriorating strategic situation.

Insight #3: *XBD-from-above is more likely to succeed if the perceived value of the radically different disruptive product as experienced by the initially unserved very high-end market segment spreads to the broader customer base and causes rapid demand shift timing away from the incumbents' products.*

Rapid new ecosystem growth: Apple and Google Android also created technological platforms for the development of new ecosystems of highly valued novel applications, which accelerated the demand shift timing and thereby rapidly increased the disruptors' installed user base. This set in motion the powerful positive feedback process - the "virtuous cycle" - associated with increasing returns to adoption (e.g., Arthur, 1987). Other parties with different interests in the disruption process, such as various types of

partners, security analysts and the media, may help reinforce the movement of a new ecosystem toward the disruptor and away from that of the incumbent (e.g., Snihur, Thomas, and Burgelman, 2018). For example, as noted earlier in the case of Nokia, during the period of success the popular media narratives emphasized Nokia's capability to master the full value chain; whereas during the period failure they emphasized Nokia's emphasis on selling "devices" versus Apple's selling "lifestyle" (Laamanen et al., 2016).

Insight #4: *XBD-from-above is more likely to be successful if the upward shift in the demand distribution gives the disruptive high-end product the opportunity to become a platform for the rapid growth of an ecosystem of complementary products and services that benefits from increasing returns to adoption.*

Graphical Insights

Identifying the four concatenated strategic factors associated with XBD-from-above involved multiple iterations between qualitative and graphical analysis. These iterations produced a graphical interpretation of XBD-from-above that extends the original graphical analysis of sustaining and disruptive innovation (Christensen, 1997; Christensen and Raynor, 2003). It also provides further insights into the relationships between these factors and their strategic implications. Figure 6 shows this graphical analysis.

Figure 6 About Here

Inherent incumbent market myopia: Figure 6 shows the "current demand for average performance" curve for Nokia's mobile phones in 2007, as well as the entire

"current demand for performance distribution" curve around Nokia's current demand for average performance curve. As posited in disruption theory (Christensen, 1997), it shows that "Nokia's current product offerings" curve - its sustained innovations - overshoots the current demand for average performance curve. This is manifest in the fact that Nokia's 2007 product offerings involve a range of products that are based on performance dimensions that match the needs of the various customer segments (high to medium to low) of its envisaged 2007 demand distribution.

Figure 6 also shows, however, that the unserved "latent potential demand for very high-end performance" curve intersects the current demand for performance distribution curve at the very high-end tail. As shown earlier in Figure 2, this unserved latent demand of the very high-end customer segment could be served with products that had performance features that none of Nokia's current product offerings were able to provide. This latent demand remained invisible to Nokia until revealed by the 2007 introduction of Apple's iPhone. The 2007 introduction of the "Apple iPhone product offering" curve intersects at the point of the unserved "latent demand for very high-end performance" curve, thereby tapping into and serving that very high-end latent customer segment of the current demand distribution. In spite of its own overshooting and associated sustained innovation, the "Nokia current product offerings" curve intersects with the "current demand for performance distribution" curve below the point where the Apple iPhone intersects with it in 2007.

Figure 6 furthermore shows how the success of the Apple iPhone by 2010 caused the upward shift of the demand for performance distribution curve around the "latent demand for high-end performance" curve. By 2010 this was becoming the new "demand for average performance" curve with the introduction of Google Android-based devices (but the iPhone is still a high-end product in 2010). As the 2007 current demand distribution curve shifts further upward by 2010, Nokia's current product offerings curve in 2010 intersects only with the mid-to-low-end of the demand distribution curve - which reveals the strategic consequences of Nokia's inherent *incumbent market myopia*.

Insight #5: *Incumbents are inherently unable to envisage the latent very high-end demand before the XBD-from-above reveals its existence. This strongly suggests that disruption from above will typically come from outside the incumbents' industry.*

Difficult to bridge net dynamic capabilities gap: Figure 6 in addition shows that because of Apple's own continued overshooting and associated sustained innovation Apple's product offerings curve will continue to be able to serve more sophisticated customers beyond 2010. The vertical line in 2010 between the "current demand for average performance" curve and the "new demand for average performance" curve" (basically the previous "latent demand for high-end performance" curve) indicates the dynamic capabilities necessary to serve the very high-end of the mobile demand distribution that has emerged between 2007 and 2010. Where the ongoing overshooting of Nokia's product offerings curve intersects with the vertical line shows the *net dynamic capabilities gap* between Nokia and Apple. The net dynamic capabilities gap is challenging for Nokia because the new performance dimensions of the iPhone are outside the set of performance dimensions that Nokia was familiar with, and providing them

requires dynamic software capabilities and software-hardware integration capabilities that Apple previously honed in the PC industry. Finally, the angle δ between the diagonal line connecting the "current demand for average performance" curve in 2007 with the "new demand for average performance" curve in 2010 and the current average demand curve in 2007 indicates the length of time that Nokia has to close the net dynamic capabilities gap, which is a function of the demand shift timing. The larger the angle, the shorter the time that is available to Nokia for closing the gap.

Insight #6: *The net dynamic capabilities gap together with the demand shift timing determines the difficulties the incumbents face in competitively responding to the XBD-from-above challenge.*

XBD-from-above drives industry convergence. To illustrate how XBD-from-above drove the convergence of the computer and mobile communications industries it is useful to examine simultaneously the evolving dynamic capabilities of the players in the two industries. The three-dimensional Figure 7 illustrates this.

Figure 7 About Here

In Figure 7, the horizontal axes are time and industry and the vertical axis represents the features that make-up the dynamic capability space. As there are multiple players in both industries, and each player likely has multiple products with varying capabilities that evolve over time, the dimensions of the multi-dimensional surface represent the capabilities that define the players' product or set of products.

In the middle and to the right of Figure 7 appears the dynamic capability surface representing the time-evolving capabilities required to meet the latent high-end demand (for the new usage models) that the XBD-from-above's product revealed to exist. The dynamic capability surface depicting the evolution of the incumbent's industry appears at the near-edge of Figure 7. It reflects the multi-dimensional capabilities that define the incumbent's product or set of products. Over time, the incumbent deploys a range of capabilities to create products designed to meet perceived familiar customer segments. Similarly, the dynamic capability surface depicting the evolution of the XBD-from-above's industry appears at the top of Figure 7. It reflects the multi-dimensional capabilities that define the XBD-from-above's product or set of products. Over time, the XBD-from-above deploys a range of capabilities to create products designed to meet the perceived new, high-end customer segment.

Figure 7 shows the dynamic capability surface of the incumbent's industry (mobile) as tilted towards the dynamic capability surface of the XBD-from-above's industry (PC) in order to convey how the increasing performance of mobile phones were moving those devices closer to a PC. Similarly, the dynamic capability surface of the XBD-from-above's industry (PC) is tilted towards the incumbent's industry (mobile) to denote the increased mobility features such as portability and wireless connectivity (WiFi as well as cellular). Figure 7 also shows that for the incumbent the ratio of the dynamic capability gap to the time available to close the gap depends on the angle δ (the same δ from Figure 6). Similarly, for the XBD-from-above the ratio of the dynamic capability gap to the time available to close the gap depends on the angle θ. The angles δ and θ are a

quantitative representation of the relative difficulties the incumbent faces in closing the dynamic capabilities gap with XBD-from-above, and also indicate the direction of the convergence of the two industries. Consistent with the previous discussion, Figure 7 shows that the relative difficulties of Nokia to close the net dynamic capabilities gap with Apple in time to meet the newly revealed high-end customer demand (with radically new usage models) before it was too late ($\delta > \theta$) were probably impossible to overcome (see further below). It also indicates that Apple's iPhone and Android-based devices drove the mobile industry toward convergence with the computer industry, rather than the other way around.

Insight # 7: *The net dynamic capabilities gap together with the demand shift timing determine the direction of convergence between the incumbent's and the XBD-from-above's industries.*

Computational Insights

Correlated multidimensional dynamic capabilities. For the disrupted incumbent, given the maximum time available to close the net capability gap, the multidimensionality of the net dynamic capabilities gap is the most critical strategic determinant of the difficulties in closing it. The touchscreen that Apple as XBD-from-above deployed in the first iPhone is an illustrative example. Apple developed the touchscreen as an interface mechanism for their computer platform as they were contemplating a tablet product prior to the iPhone. The experience Apple wanted to deploy was to enable a user to touch a portion of the screen to activate a service (launch an app, launch a page in the browser, select an item etc.) instead of moving a cursor with

a thumbwheel, touchpad or mouse. Creating the touchscreen experience, however, pre-supposed that the application processor, OS, browser or app all had the capability to service the requested Internet connections of sufficient speed. In other words, the touchscreen, apps processor, OS, browser and connection speeds are *correlated* multi-dimensional dynamic capabilities.

These correlational relationships between performance dimensions of the XBD-from-above's dynamic capabilities made it extremely difficult for the incumbent to develop an effective competitive response. For instance, Blackberry responded to the iPhone by launching the Blackberry Storm, which featured a touchscreen as well. The Storm was reportedly a disaster with the common complaint that the "touch" response was too slow (Silcoff, Mcnish, and Ladurantaye). Evidently, Blackberry added a touchscreen without sufficient changes to the apps processor, OS, or browser thereby creating a relatively poor user experience. What Blackberry may not have realized initially was that it was not about the touchscreen itself that was the capability gap. Rather, it was multiple capabilities (apps processor, OS, browser etc.) along with the touchscreen that worked synergistically that created the iPhone experience. The touchscreen as a competitive differentiator was in fact a multidimensional capability where the multiple capabilities are all interdependent or correlated.

Insight #8: *The higher the correlations between the performance dimensions of the XBD-from-above's dynamic capabilities the more difficult it is for the incumbents to develop an effective competitive response.*

Signal processing aspects of dynamic capabilities: The dynamic capabilities to serve the latent very high-end demand in the mobile industry were more similar to the dynamic capabilities of the PC industry than to those used for sustaining innovation in the mobile industry. In relation to signal processing theory in electrical engineering, lay terms such as "similar" or "dissimilar" correspond to the information theoretic concept of "mutual information," which is a measure of the amount of information that one piece of data brings about another piece of data. As noted above, Apple had already developed wireless connectivity for their computers and their designs of its laptops were becoming smaller, thinner, lighter for easier portability; its iPod was driving the packing of increasing complexity and processing capabilities into a pocket device; and its iPad development was driving the multi-touch capability. All of these capabilities were aligned in the direction of the iPhone (i.e. high mutual information), which indicates that the development of the iPhone was fundamentally a sustaining innovation for Apple in the PC industry that drove disruption-from-above in the mobile industry.

In light of this, the mutual information between Apple's PC industry-based multi-dimensional dynamic capabilities and the dynamic capabilities required to serve the latent very high-end demand of the mobile industry revealed by the iPhone must have been high. Conversely, the mutual information between Nokia's mobile industry-based multi-dimensional dynamic capabilities and the dynamic capabilities required to serve the latent very high-end demand in the mobile industry must have been significantly lower. This helped explain why Apple was more readily able to see this latent demand and serve it with the iPhone, while Nokia remained myopic in dealing with this demand until the iPhone introduction revealed it in 2007.

Insight #9: *Successful XBD-from-above depends on the mutual information between the dynamic capabilities of the XBD-from-above and the product performance features required to meet the latent very high-end demand to be significantly higher than that of the incumbents.*

A Computational Illustration

Insights #8 and 9, coupled with the graphical representation of XBD-from-above in relation to the incumbents in Figure 7, which highlights that demand spaces of the XBD-from-above and incumbents are multi-dimensional and correspond to their respective multi-dimensional dynamic capabilities, suggest connections to prior research revealing relationships between mutual information, canonical correlations and angles between multi-dimensional spaces (Sharf, 1998; Thomas, 1996). Importantly, these relationships also provide a mechanism for computation of dynamic capability differences between the XBD-from-above and the leading disrupted industry incumbents. While the full mathematical treatment of the computation of dynamic capability differences, capability gap, time to close the capability gap and subspace angles is beyond the scope of this paper, the following simplified computational example illustrates the key ideas.

Consider a high-end Nokia device, the original iPhone and a personal computer (PC) with wireless capabilities that was available at a single point in time (say, 2007), and compare these devices across the following four capabilities. For computational purposes, these capabilities assume the following associated values:

- Central Processing Unit (CPU): Value = 1 (low performance device: e.g. Nokia), or 2 (medium performance: e.g. iPhone) or 3(high performance: e.g. in a PC)
- Graphical processing unit (GPU): Value = 0 (if absent) or 1 (if value is present)
- Capacitive touch: Value = 0 (if absent) or 1 (if value is present)
- Wireless connectivity: Value = 0 (if absent) or 1 (if value is present)

Using these values the capability vectors for Nokia, Apple and a PC are built as follows:

Capabilities	**Nokia**	**Apple iPhone**	**PC in 2007**
CPU	1	2	3
GPU	0	1	1
Capacitive Touch	0	1	0
Wireless Connectivity	1	1	1

Given these three vectors that define capability, we address the "similarity" of these devices. As described earlier, we approach the notion of "similarity" by computing the angle between these vectors, which is a relative measure of the mutual information between these vectors and hence these devices. In order to compute the angle, we use the fact that the cosine of the angle between two vectors **x** and **y** is given by the formula: Cosine (angle) = **x**.**y**/||**x**||.||**y**||; where ||**x**|| = square-root of the sum of the squares of the elements of **x**.

Once the value of the cosine is calculated, the arc-cosine (which is the inverse of the cosine) of that value can be used to compute the angle in radians or degrees. This computation can be applied to the capability vectors shown above as follows. The numerators are calculated by taking the inner product, which is the sum of the element-by-element product of the vectors. For the illustrative example:

- Nokia & PC: $[1\ 0\ 0\ 1]x[3\ 1\ 0\ 1]^T = 1x3+0x1+0x0+1x1 = 3+0+0+1 = 4$
- Apple & PC: $[2\ 1\ 1\ 1]x[3\ 1\ 0\ 1]^T = 2x3+1x1+1x0+1x1 = 6+1+0+1 = 8$
- Nokia & Apple: $[1\ 0\ 0\ 1]x[2\ 1\ 1\ 1]^T = 1x2+0x1+0x1+1x1 = 2+0+0+1 = 3$

The denumerators for the illustrative example are:

- ||Apple|| = Sqrt(7)
- ||Nokia|| = Sqrt(2)
- ||PC|| = Sqrt(11)

Using the above makes it possible to compute the cosine of the angle and the angle itself:

- *Cosine (Angle between Nokia & PC)) = (4/Sqrt(22); therefore the angle between Nokia and PC is 31.5degrees.*
- *Cosine (Angle between Apple & PC)) = (8/Sqrt(77); therefore the angle between Apple and PC is 24.25degrees.*
- *Cosine (Angle between Nokia & Apple)) = (3/Sqrt(14); therefore the angle between Nokia and Apple is 36.7degrees.*

In the above example, for the dynamic capabilities considered, Apple iPhone and the PC were closer in capability (or more similar) at 24.25 degrees than the Nokia device and the

PC at 31.5 degrees. The Nokia and Apple indicate a separation of 36.7 degrees, which is actually greater than the separation between Nokia and the PC.

This illustrative example indicates that the computational insights allow a practitioner to calculate the relative "closeness" of the dynamic capabilities that meet a new demand to the dynamic capabilities of other players. For example, they make it possible to compare the dynamic capabilities gaps between the iPhone and PC and, similarly, the dynamic capabilities gap between the iPhone and Nokia devices. They provide insights into what dynamic capabilities a player (such as Nokia) might have had to deploy in order to meet the latent demand that Apple identified and was able to satisfy with the iPhone.

It is important to note, however, that these sorts of computations are (at least for the time being) neither directed toward predicting and defining high-end latent demand, nor toward determining the necessary dynamic capabilities to address such a latent demand. The latter predictions and determinations remain in the realm of discovery and invention associated with the uniquely creative market insight of persons like Steve Jobs and his Apple team that lead to the creation of the iPhone. On the other hand, it seems reasonable to expect that these sorts of uniquely creative market insights are more likely to occur in organizations that already have the necessary dynamic capabilities that, in novel combinations, make it possible to address them.

CONCLUSION AND IMPLICATIONS

This paper builds on and extends previous research that discovered the phenomenon of cross-boundary disruption (XBD) through comparative case studies of the rapid ascendance of Apple Computer as a new entrant in the music industry during the early 2000s and the company's subsequent efforts to become an XBD in the cellular telephony industry in 2007. While the previous research provided insight into the XBD phenomenon, the conceptual framework derived from it was unable to predict the success of Apple as XBD in the cellular telephony industry.

Motivated to examine the reasons for this failure, the research reported in this paper has discovered XBD-from-above as a form of disruption that supersedes incumbents' sustaining innovation. It has provided insights into four concatenated strategic factors associated with XBD-from-above - incumbent market myopia, incumbent dynamic capabilities gap, demand shift timing, and rapidly growing ecosystems - that help explain the rapid rise of Apple and Google Android and the equally rapid fall of Nokia and other major incumbents in the mobile phone industry.

Graphical interpretation of XBD-from-above provided further insights into the relationships between the four concatenated strategic factors and their strategic implications for the incumbents' ability to respond effectively. In particular, the graphical analysis indicated the importance of quantifying the disruptor's advantages and the incumbent's disadvantages for capitalizing on (for the disruptor) or coping with (for the incumbent) the four concatenated strategic factors. The graphical analysis, in turn, suggested connections to signal processing theory in electrically engineering, which

indicated steps to quantify in further research the dynamic capabilities of both the XBD-from-above and the incumbents in relation to product performance features required to serve the latent very-high-end market segment revealed by the radically new product successfully launched by the XBD-from-above.

The research findings reported in this paper complement and extend received literature by identifying the conditions under which XBD-from-above is likely to defeat target industry incumbents in spite of their own vigorous sustained innovations efforts (Christensen, 1997; Christensen and Raynor, 2003). The graphical and computational analyses suggest that coping with XBD-from-above is likely to be extremely difficult for the incumbents, perhaps more difficult than coping with disruptive innovation (from below). Further research focused on documenting and explaining the differences between XBD-from-above, sustaining innovation and disruption-from-below may serve to move closer to a general grounded theory of the role of inter-industry disruption in the dynamics of industry transformation.

Also, as noted earlier, recent research (Vuori and Huy, 2016; Doz and Wilson, 2018) has documented the tremendous cognitive and emotional upheaval in Nokia's managerial ranks during 2007-2013 caused by Apple's (and Google Android's) entry into the mobile phone industry. These fears created a vicious circle of informational deception between top and middle management, leading to overly optimistic assessments of the short-term strengths of corporate capabilities and systematic neglect of long-term investments required to match the innovation challenges posed by XBD-from-above. The insights presented in this paper highlight the virtually insurmountable strategic challenges that

XBD-from-above poses. Hence, it seems reasonable to hypothesize that the four concatenated strategic factors associated with XBD-from-above are likely to be a major cause of the strong cognitive and emotional disarray in the incumbents' managerial ranks systematically documented within Nokia and more impressionistically in other major incumbents such as Blackberry (e.g., Silcoff, Mcnish, and Ladurantaye). Future research based on XBD-from-above theory could test this hypothesis in other industry contexts.

Finally, the catastrophic outcome of XBD-from-above did not lead to Nokia's demise as an independent long-lived company. Nokia's board was able to resolve strategic dissonance, reflective of cognitive and emotional disarray, by letting go of the non-adaptive strategy of the mobile communications business before it was too late, and by recognizing a major opportunity for strategically redirecting the company in the mobile equipment business. Comparative future research about incumbents' success or failure to capitalize on internal strategic dissonance caused by XBD-from-above may further inform theory about organizational adaptation in the face of inter-industry transformational dynamics.

REFERENCES

Arthur, W.B.

1987 "Competing Technologies: An Overview." In G. Dosi (ed.), Technical Change and Economic Theory: 590-607. New York: Columbia University Press.

Barnett, W.P., and M.T. Hansen

1996 'The Red Queen in organizational evolution." Strategic Management Journal, Summer Special Issue, 17: 139-157.

Burgelman, R.A.

2002 "Strategy as vector and the inertia of coevolutionary lock-in." Administrative Science Quarterly, 47: 325-357.

Burgelman, R.A.

2011 "Bridging history and reductionism: Key role for longitudinal qualitative research." Journal of International Business Studies, 42: 591-601.

Burgelman, R.A., and A.S. Grove

2007 "Cross-boundary disruptors: Powerful interindustry entrepreneurial change agents." Strategic Entrepreneurship Journal, 1: 315-327.

Carroll, G.R., L.S. Bigelow, M-D. L. Seidel, and L. Tsai,

1996 'The fates of *de novo* and d*e alio* producers in the American automobile industry 1885-1981." Strategic Management Journal, Special Issue 17: 117-137.

Christensen, C.M.

1997 The Innovator's Dilemma. Boston: Harvard Business School Press.

Christensen, C.M., and J.L. Bower

1996 "Customer power, strategic investment, and the failure of leading firms." Strategic Management Journal, 17: 197-218.

Christensen, C.M., and M. Overdorf

2000 "Meeting the challenge of disruptive change." Harvard Business Review, March-April.

Christensen, C.M., and M.E. Raynor.

2003 The Innovator's Solution: Creating and Sustaining Successful Growth. Boston: Harvard Business School Press.

Danneels, E.

2010 "Trying to become a different type of company: Dynamic capability at Smith Corona." Strategic Management Journal, 32: 1-31.

Doz, Y.L., and K. Wilson.

2018 Ringtone: Exploring the Rise and Fall of Nokia in Mobile Phones. Oxford: Oxford University Press.

Ewing, J.

2007 "Why Nokia is leaving Moto in the dust." BusinessWeek, July

Gaddis, J.L.

2002 The Landscape of History: How Historians Map the Past. Oxford: Oxford University Press: 71-89.

Glaser B.J., and A.L. Strauss

1967 The Discovery of Grounded Theory. Chicago: Aldine.

Hannan M.T., and J. Freeman

1989 Organizational Ecology. Cambridge, MA: Harvard University Press: 92.

Helfat, C.E. and M.A. Peteraf

2015 "Managerial cognitive capabilities and the microfoundations of dynamic capabilities," Strategic Management Journal, 36: 831-850.

Issac, Mike.,

2012, Wired “Nokia, Microsoft build “beachhead” in the war of the mobiles”.

https://www.wired.com/2012/01/nokia-microsoft-lumia/

Isaacson, W.

2011 Steve Jobs. New York: Simon & Schuster: 468.

Kor, Y.Y. and A. Mesko

2013 Dynamic managerial capabilities: Configuration and orchestration of top executives’ capabilities and the firm’s dominant logic,” Strategic Management Journal, 34: 233-244.

Laamanen, T. and J. Wallin

2009 “Cognitive dynamics of capability development paths,” Journal of Management Studies, 46: 950-981.

Laamanen, T., J-A. Lamberg, and E. Vaara

2016 “Explanations of success and failure in management learning: What can we learn from Nokia’s rise and fall?” Academy of Management Learning & Education, 15: 2-25.

Lee, T.W.

1999 Using Qualitative Methods in Organizational Research. Thousand Oaks, CA: Sage.

Porter, M.E.

1980 Competitive Strategy. New York: Free Press.

Prahalad, C.K. and R. Bettis

1995 “The dominant logic: Retrospective and extension,” Strategic Management Journal, 16: 485-501.

Rumelt, R.P., D.E. Schendel, and D.J. Teece

1994 Fundamental Issues in Strategy. Boston: Harvard Business School Press.

L. L. Scharf and J. K. Thomas,

1998 "Wiener filters in canonical coordinates for transform coding, filtering, and quantizing," *IEEE Trans. Signal Processing*, vol. 46, pp. 647–654, Mar. 1998.

Schenker, J.L.

2007 "Nokia barges into mobile services." BusinessWeek, August 29.

Sharma, A.

2007 "Can a Google Phone connect with carriers?" The Wall Street Journal, October 30, B1.

Siggelkow, N.

2002 "Evolution toward fit." Administrative Science Quarterly, 47: 125-159.

Siggelkow, N.

2007 "Persuasion with case studies." Academy of Management Journal, 50: 20-24.

Silcoff, S., Mcnish, J., Ladurantaye, S.,

2013, 2018 "How Blackberry Blew it: The inside story", The Globe and Mail, published September 27, 2013, Updated April 7, 2018**.** (https://www.theglobeandmail.com/report-on-business/the-inside-story-of-why-blackberry-is-failing/article14563602/?page=all)

Snihur, Y., Llewellyn, L.D.W., Burgelman, R.A.

2018 "An ecosystem process model of business model disruption: The disruptor's gambit," Journal of Management Studies.

Taylor, P.

2007 "AT&T dials into Napster downloads." Financial Times, October 22.

Teece, D.J., G. Pisano, G., and A. Shuen

1997 “Dynamic capabilities and strategic management.” Strategic Management Journal, 18: 509-533.

Teece, D.J.

2007 “Explicating dynamic capabilities: The nature and microfoundations of sustainable enterprise performance.” Strategic Management Journal, 28: 1319.

Vuori, T.O., and Q.N. Huy

2016 “Distributed attention and shared emotions in the innovation process: How Nokia lost the smartphone battle.” Administrative Science Quarterly, 61: 9-51.

Watts, D.J.

2017 “Response to Turco and Zuckerman’s ‘Verstehen for Sociology.’” American Journal of Sociology, 122: 1292-99.

Figure 1: Performance Differences (Usage Models): Nokia versus Apple

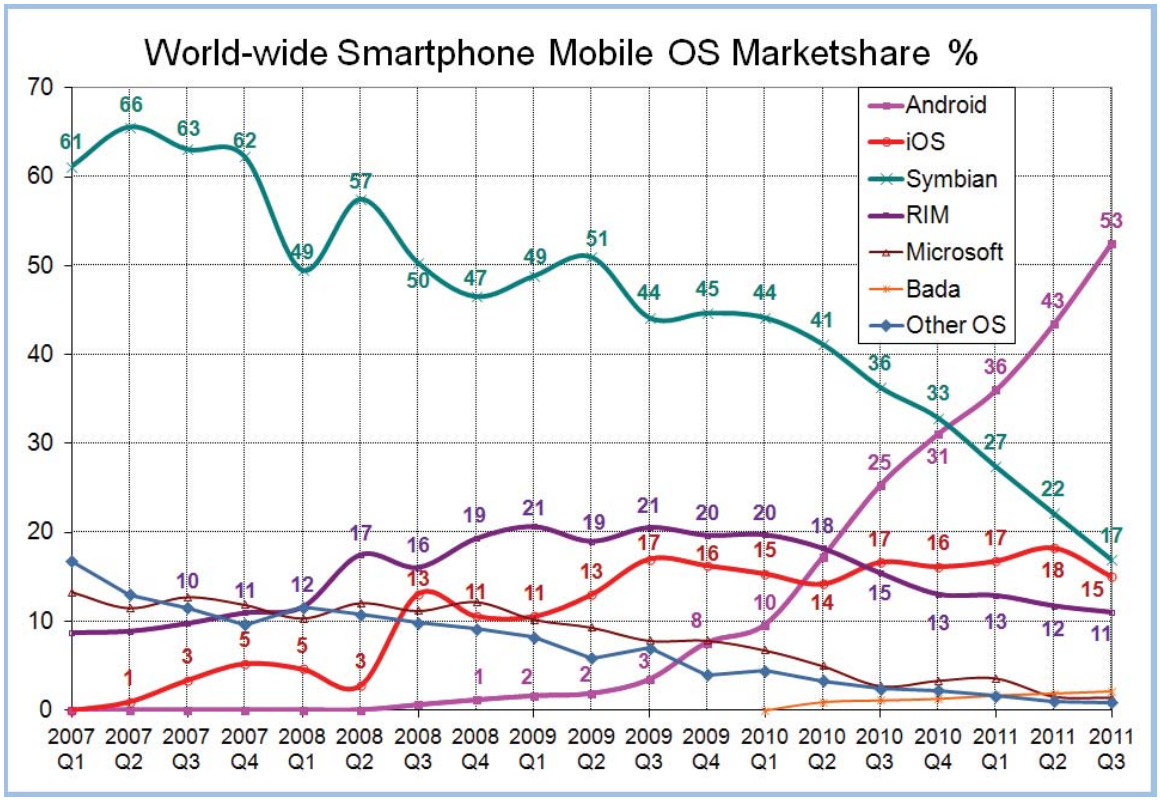
Nokia	**Apple**
Limited browsing capability	Full browsing capability - akin to computer
Nokia's proprietary maps was limited	Google maps was well integrated with iPhone functions
Traditional sequential voicemail	Modern visual voicemail
Limited applications	Fully functional applications
Limited app development tools	Extensive development kits + business model for developers
Extended battery life	Limited battery life - (users did not mind)
Limited use of cellular network	Extremely high network data utilization
Limited user experience	Complete "computer-like" experience - "PC in the pocket"

Figure 2: Dynamic Capability Differences: Nokia E61 versus iPhone (First release)

Nokia E61	iPhone (first release)
No touch screen	Capacitive touch screen
1 CPU – 220 Mhz ARM9 dual processor	1 CPU – 429 Mhz ARM 11 Processor
No GPU	1 GPU
Symbian 1 – Phone OS	iPhone OS1 – a version of MacOS
Memory – 64MB	Memory – 128MB
WAP browser	Full browser
Regular voicemail	Visual voicemail
Resolution 320x240pixels (~138ppi)	Resolution:320x480;
No Camera	Rear-facing camera
Connectivity: 3G WCDMA	Connectivity: 2G EDGE

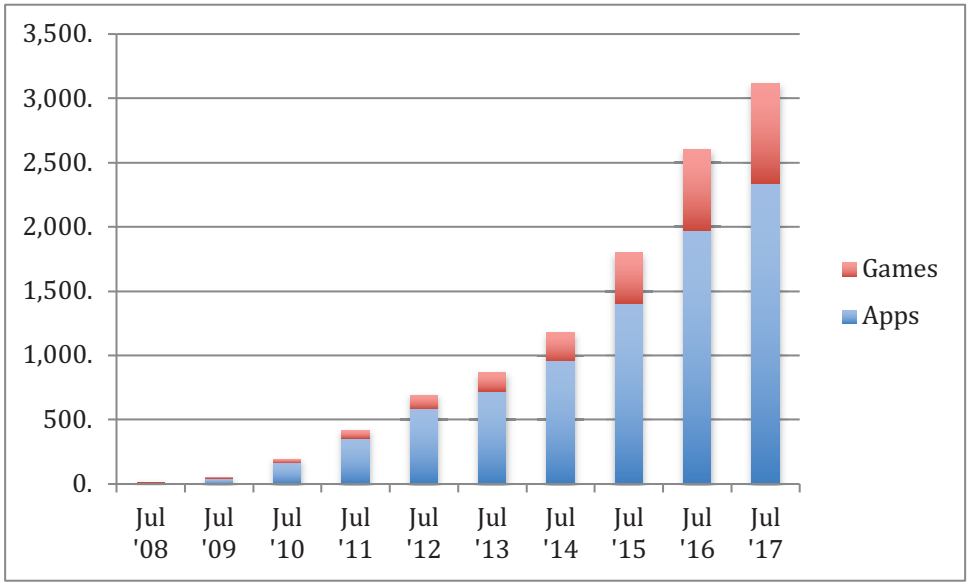
Source: "iPhone – Features – OS X". Apple Inc. Archived from the original on October 6, 2007.

Figure 3 World-wide Smartphone Market Share



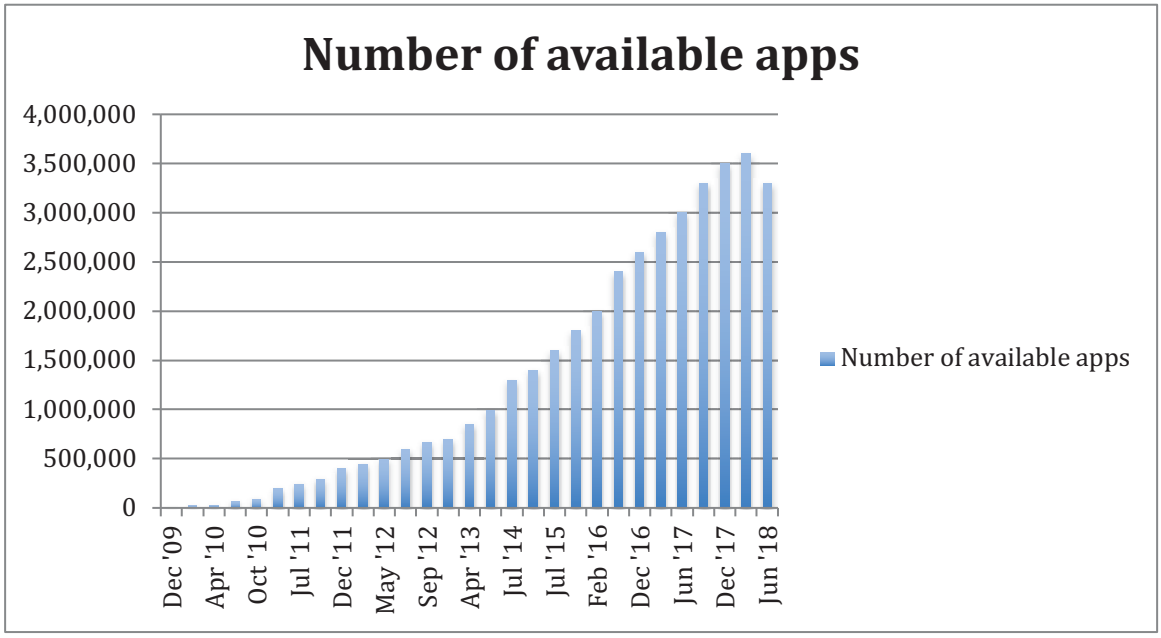
Source: https://commons.wikimedia.org/wiki/File:World-Wide-Smartphone-Market-Share.png

Figure 4: Growth of the iOS Ecosystem



Source: https://www.statista.com/statistics/268251/number-of-apps-in-the-itunes-app-store-since-2008/

Figure 5: Growth of the Android Ecosystem



Source: https://www.statista.com/statistics/266210/number-of-available-applications-in-the-google-play-store/

Figure 6: Demand Curve Shift and Capability Gap

Figure 7: XBD-from-above Drives Industry Convergence