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Improving New Product Development Using Big Data: A Case Study of an Electronics Company

R & D Management
DOI: 10.1111/radm.12242

Big data is becoming more important to the new product development (NPD) efforts of global firms. Although the term of big data is not new, very few studies have investigated how firms can harvest big data to facilitate NPD. The purpose of this paper is to present the means by which big data can be used to assist firms in NPD to shorten the time to market, improving customers' product adoption and reducing costs. This research is based on a two-step approach. First, we identified and analysed three world-leading firms that have successfully integrated big data in supporting their NPD. Then, the observations from the firms were used to determine the principle involved in leveraging big data to reduce product development lead times and costs. Given the exploratory nature of the research objective, a participant-observation case study is adopted in which during a six month period a NPD project in a fast moving high-tech industry was investigated. This study provides empirical confirmation for the three principles to big data supported NPD: a) Autonomy; b) Connection; and c) Ecosystem. It is termed the ACE principles which we believe represent a paradigm shift to helps firms unlock the power of big data and make NPD faster and less costly. This paper provides guideline to firms in harvesting big data to better support their NPD: it allows organisations to launch new products to market as quickly as possible; it helps organisations to determine the weaknesses of the product earlier in the development cycle; it allows functionalities to be added to a product that customers are willing to pay a premium for, while eliminating features they don't want; and it identifies and then prioritises customer needs for specific markets.

Key words: Big Data, Accelerated Innovation, Chinese Firms, Product Development, Electronics Industry
Paper type: Research Paper

1.0 Introduction

Big data is becoming more important to the new product development (NPD) efforts of global firms. For companies, taking advantage of valuable knowledge that can be drawn from big data is becoming the basis to competition in today's rapidly changing business environment (Barton

and Court, 2012; Salehan and Kim, 2015). Consequently, companies are increasingly looking at harvesting big data: a) to better understand their customers; b) to design better products, and c) to provide customers with more customised services. Davenport (2012) argues that one of the greatest potential advantages of collecting big data is its use in the development of new products and services. However, very few studies have been conducted to investigate how firms can harvest big data to improve their NPD. This paper aims to show how firms can use big data to support the development of new products, by shortening the time to market, improving customers' product adoption and reducing costs.

Big data in this study can be referred to as multimedia-rich and interactive low-cost information resulting from mass communication. It is characterised by its 3V characteristics (volume, velocity and variety) and can be generated through different information systems and technologies, including smartphone applications, online communities, sensor networks, internet clicks and social media platforms (McAfee and Brnjolfsson, 2012; Chan et al., 2015; Zhan et al., 2016). Several researchers have pointed out that big data can enhance firms' NPD in many respects (Gomez-Uranga et al., 2014; Manyika et al., 2011; Gobble, 2013; Tan et al., 2015). Manyika et al., (2011) reports that predictive modelling using big data can cut three to five years off the approximately 13 years healthcare companies generally need to bring a new drug to market. Capgemini (2012) estimates that the process improvements enabled by big data may lead to an average 26% performance improvement over a three-year period. Moreover, the analysis of big data may have huge operational and strategic impacts on business process innovation at the firm and supply-chain levels (Trkman et al., 2012; Bauer and Leker, 2013), and may therefore allow adopting firms to achieve competitive advantage.

Today, time to market is widely recognised as an important attribute of strong innovators to gain competitive advantages, particularly in fast-cycle industries in which product life cycles are often three years or less (Datar, 1997; Brexendorf et al., 2015). Many studies have determined that the faster a company completes the product development process, the greater is its likelihood of surpassing its competitors in the marketplace (Day and Wensley, 1988; Ahmad et al., 2013; McKinsey, 2015). Additionally, important cost benefits can be achieved by companies that learn to develop their products quickly (Barczak, 2012). Significant advantages accrue because resources are utilised more creatively and efficiently, costs are reduced, and work-in-process bottlenecks are minimised (Millson et al., 1992; Cooper, 2014; Adner and Kapoor, 2010).

In this context, lean thinking concepts have gained a lot of attention in the past decade in terms of identifying and removing wastes from manufacturing and many fast-cycle industries (Kennedy, 2003; Morgan and Liker, 2006; Tyagi et al., 2015). Besides, the term lean thinking is compatible with a range of what can be called agile manufacturing development methods (Thomke and Reinertsen, 1998) such as Feature-Driven Development, Scurm, Dynamic Systems Development, eXtreme Programming, and Adaptive Software Development Methods (Abrahamsson et al., 2003; Kettunen, 2009). These methods are powerful enablers for shortening time-to-market as well as improving performance. However, it is evident in literature that current product development approaches are still too time-consuming; too many are either simply a waste of time or are cost ineffective; others are too bureaucratic and provide no focus (Ortt and Duin, 2008; Sheu and Lee, 2011; Copper, 2014). Thus, researchers believe that a good process of NPD should be adaptable, provide companies with a much more efficient roadmap, bring products to market faster and improve the use of scarce resources (Barczak, 2012; Cooper 1994; Wooder and Baker, 2012). With big data, firms can gain a better

understanding of their products, customers and markets, and this is crucial to NPD (Manyika et al., 2013; Wong, 2012; Salehan and Kim, 2016). However, the main challenge to firms is how to use big data to improve NPD by making the development of new products faster and less costly. This challenge leads to the following research questions:

1. What are the principles involved in leveraging big data to improve NPD?
2. How can big data be applied to support NPD?

To assist our understanding of using big data to facilitate NPD, this paper next reviews how big data is transforming NPD. It then presents three examples where big data was used successfully. Thereafter, three key principles for facilitating NPD in a big data environment are explained. A case study with an electronics company is used to illustrate how the three key principles can be applied in order to derive more benefit from big data. The implications for practitioners and academia are discussed and, finally, conclusions drawn.

2.0 Big Data Analytics Transforming Product Innovation

Taking advantage of the valuable knowledge that can be extracted from big data is essential if today's enterprises are to be competitive (Barton and Court, 2012; Ross, 2013; Tan et al., 2015). Davenport et al. (2012) suggest that 'big data' come from a wide variety of sources – from click stream data from the Web to genomic and proteomic data from biological research and medicine. The use of big data offers several key benefits: dramatic cost reductions, substantial improvements in the time required to perform a computing task, or new production innovation and service offerings (Davenport, 2013; Salehan and Kim, 2016).

The explosion in the volume of data is a natural consequence of the fact that, if harvested properly, it can provide companies with better product development (Wong, 2012). According to Dutta and Bose (2015), big data provides organisations with big ideas, which can lead to big

solutions and new concepts and big solutions – the growth engines of the future. The acquisition of large amounts of information from different sources facilitates NPD (Li et al., 2014). An example of such data acquisition would be an enterprise quickly ascertaining market acceptance of its new products, customers' needs or even competitors' market movements (Gobble, 2013; Opresnik and Taisch, 2015). Moreover, a firm's success will rely on its ability to draw insights from the various kinds of data available to it (Wong, 2012; Dijcks, 2013; IBM, 2013; Tan et al., 2015). A company that can generate different types of data will be able to gain great advantage, by developing better customer services, identifying potential new customers, identifying and developing new products and services, and having a better-informed strategic direction, and so on (Chen et al., 2012; Lohr, 2012; Chang and Taylor, 2016). For instance, firms can easily track online customers' clickstream data from the Web and use that to leverage a behavioural analysis, which in turn can be used to support product development (Procter et al., 2014). Furthermore, firms are now capable of gathering users' feedback in near real time to track changes in customer behaviour. Such rapid market feedback can make NPD faster and less costly (Cooper, 2011) by communicating the information to the R&D team, who can then ensure that product development is sufficiently flexible to incorporate new functionality quickly (Lavalle et al., 2011; Mayer-Schönberger and Cukier, 2013; Kitchin, 2014). Although many studies have shown that the use of big data can offer great competitive advantage, there is no principle available to guide managers on the value captured from big data for NPD.

By summarising the progress made to date in NPD (Rothwell, 1994; Niosi, 1999; Miller, 2001; Ortt and Duin, 2008; Cooper, 2016), it has been underpinned by some trends of increasing importance. First of all, the ability to develop new product quickly has become an increasingly significant factor in recent years in determining competitiveness, especially in industries where product cycles are short and technological change rates are high (Rothwell, 1994; Adner, 2006;

Goktan and Miles, 2011; Cooper, 2014; Chang and Taylor, 2016). Secondly, companies are tending to conduct simultaneous processing, with cross-function teams working independently; this improves the speed, efficiency and flexibility of the process of NPD (Li et al., 2009; Williamson and Yin, 2014). Thirdly, the current approaches to NPD pay more attention to good connections with customers so as to understand customers better and gather feedback quickly for continuous improvement (Bohlmann et al., 2012; Mahr et al., 2014). Many studies point out that inadequate understanding of customers and a lack of customer connection are the two major reasons for failures in NPD, especially in high-technology and industrial-product firms (Dodgson et al., 2006; Cooper and Kleinschmidt, 2011; Copper, 2014). Fourthly, unlike early generations of NPD approaches, which mainly relied on information from internal research, with very little use of external sources (e.g. market ideas, customer complaints), current approaches (e.g. open innovation) are more likely to look outside the company, for example to customers, suppliers and competitors, in order to find new partners and build comprehensive networks to create both more value and competitive advantage (Christensen and Overforf, 2000; Chesbrough 2006; Colombo et al., 2014).

Many sophisticated approaches have been described, and indeed successfully applied, all over the world (Cooper; 1994; Hartung and MacPherson, 2000; Brandenburg, 2002; Chesbrough, 2003; Hansen and Birkinshaw, 2007; Sheu and Lee, 2011; Williamson and Yin, 2014). Nonetheless, what is required today are the key principles to guide the NPD process in a big data environment, one which can accelerate the problem-solving element, and shorten the overall process, in part through effective connection to customers, as well as ensuring low cost especially when limited resources are available.

Much of the existing literature is based around concepts of the characteristics and well-established theories of big data, its uncovered value and traditional NPD approaches (Wong, 2012; Manyika et al., 2011; 2013). While stochastic theories and industrial economics shed light on some phenomena of interest, they are far from full explanations of the use of big data to facilitate NPD. In the following section, three examples of successful, fast-growing Chinese companies are presented and their NPD approaches discussed.

3.0 Examples of Successful Firms

This research adopted an inductive approach (Yin, 1994) to study how firms incorporate big data to make NPD faster and less costly. Three cases of emergent leading companies in China were selected: (1) Xiaomi, a manufacturer of smartphones; (2) Lenovo, a computer hardware and electronics company; and (3) Dididache, a taxi service company. Brief outlines of the three firms are provided in Tables 1, 2, and 3. These cases were selected for a number of reasons. First, they all have used big data to speed up their NPD. According to Williamson and Yin (2014), the ability of Chinese firms to launch new products in rapid succession over short periods of time is worth worldwide attention, as this could inform the next generation of NPD. Second, the three cases reflect certain aspects of the dynamism and rapid growth of Chinese companies in recent years. Third, the companies investigated were all develop software-intensive or high-tech products. Fourth, they collectively provide coverage of different industries. Thus, the result may be generalizable to different industries.

In reviewing the NPD approaches of these three leading Chinese companies, each of the cases can be seen as an independent part. The objective is to try to understand their main approaches to support NPD and big data activities involved, that is, how they integrate big data to increase efficiency and reduce the cost and cycle time in NPD. The information presented here was

collected from news, industrial reports, annual reports, newsletters and official websites. Yin (1994) argues that a richer portrait of any particular case can be acquired by using multiple sources information and by mitigating bias in historical data interpretation. The next main section of the paper then draws together some of the common findings from these three cases and suggests lessons for using big data to support NPD.

Case 1: Xiaomi Inc.

Xiaomi Inc., a five year old young Chinese mobile phone company, is now the world's third largest manufacturer of smartphones and is worth more than $46 billion (BloombergNews, 2014). Some 60 million Xiaomi smartphones were sold in 2014 and $1.1 billion of new funding from investors was received towards the end of December 2014 (BBC NEWS, 2015), which made the company the world's most valuable technology start-up; at that time, its valuation exceeded $46 billion (Xiaomi, 2015) (see Table 1).

Case 2: Lenovo Group Ltd

Lenovo Group Ltd was founded as a Chinese computer technology company in 1984. It is currently valued at some $38.7 billion and has expanded its operations across more than 160 countries (Annual Report, 2014). There is deep integration across its 'Idea'-branded consumer PCs, 'Think'-branded commercial PCs, workstations, servers and mobile Internet devices, including tablets and smartphones. It is the largest personal computer vendor in China and the second largest in the world (Annual Report, 2014) (see Table 2).

Case 3: Dididache Inc.

Dididache, which means 'hire a taxi quickly', is a Chinese taxi services company founded in September 2012. It is among China's 13 most valuable start-ups and was valued at over $3 billion in April 2014 (Dididache, 2015). Currently, it has over 60 percent of the Chinese market, with over 154 million users, one million registered licensed taxi drivers, 5.2 million peak daily orders, and it covers over 300 cities (Wang, 2014) (see Table 3).

Approach	Big Data Activities	Benefits
Teams work independently with Xiaomi customers	Cross-function teams are working independently as well as simultaneously with Xiaomi customers. Under this approach, Xiaomi develops new smartphones in 3 months on average. The collection and use of big data not only helps teams to communicate with each other (through Chinese communication services such as Wechat, QQ and Weibo), but also turns every customer into Xiaomi's source of information. Customers' suggestions and feedback are quickly rendered as inputs to Xiaomi's product improvement ideas.	• Fast product development • Lower development costs • Flexibility to incorporate new functionality quickly
The company connects and communicates with its customers	Xiaomi has forums across all the key social media platforms in China and leverages big data as its primary channel to interact with customers. For example, the main forum is called 'Xiaomi forum' on its official website. It posts (in different formats) more than 500,000 topics per day, including new product information, announcements, feedback and discussions. The core operating system of Xiaomi, MIUI, is highly customisable, allowing more than 85 million keen users upload their ideas and suggestions to facilitate the company's product innovation and invention of new features.	• Low research costs • Signals a firm commitment to improvement through co-creation • Gets feedback and ideas extremely quickly and effectively
Fast launch-and-improve ecosystem	Xiaomi collects feedback from customers and partners on a daily basis and updates its operating system on a weekly basis. The new features and functionalities are co-developed with various business partners. The ecosystem of Xiaomi involves app stores, games centre cloud storage services, theme stores, browsers, suppliers and intermediates. For example, one of the partners of Xiaomi is Tudou Youku, which has more than 500 million monthly users and the number of videos viewed on Tudou Youku have passed 800 million. Xiaomi gathers feedback and transfers the latest information on the most promising features quickly via its supportive ecosystem.	• Fast development and release • Turns feedback to advantage quickly • Increases brand and customer loyalty • Lower development and research costs

Table 1: Innovation approaches of Xiaomi Inc. (Bai et al., 2015; BloombergNews, 2014; Li, 2014; BBC News, 2015; Stone, 2014; Xiaomi, 2015)

Approach	Big Data Activities	Benefits
Different cross-function teams work in parallel	Team members are from different departments and work together on different product development elements in parallel, but under one project leader's supervision. Research teams are encouraged to engage users independently, and as early as possible. Product concepts tend to go through dozens of labs/tests at the same time before being put on the market. The new product development cycle of Lenovo is about 6 months for a personal computer and 3 months for a smartphone, which is at least three times quicker than for comparable Chinese companies using other innovation approaches to their product development	• Low research and development costs • Fast NPD • Autonomy improves creativity as well as efficiency • Makes a large portion of the wide range of products the company produces compatible with each other
Connects customers promptly	The company connects with its customers through its own Talend big data platform. It understands customers' behaviours and needs better by acquiring datasets from about 300 processes that run simultaneously and come from sources including third parties, social networking feeds and Application Programming Interfaces (APIs).	• Faster and smarter decision making in product development • Cost saving • More flexible in making decisions/strategies toward the changing market
Customer feedback and improve network	Lenovo Group Ltd builds complex but powerful networks with thousands of partners in 44 different countries. It has launched a customer feedback programme to collect billions of pieces of information from its users and partners on a daily basis. For example, a thriving 'voice of the customer' programme gathers feedback from more than 30 million customers online per day to improve customers' experience and to facilitate product innovation.	• Low research costs • Understands customers better • Interprets data and reacts quickly to develop new products • Validates impact and monitors results over time

Table 2: Innovation approaches of Lenovo Group Ltd. (Annual Report, 2014; Zhou and Huang, 2014; Gellert, 2016)

Approach	Big Data Activities	Benefits
Divides a project into small elements and groups work separately	Groups are drawn from different functions and work separately in parallel to accelerate the NPD process. For example, it took only 1 month to develop the first version of Dididache App (excluding the time spent on market research). Big data is used to maintain connections and communication, such as idea exchanges between groups, market investigation of problems identified, as well as to characterise market size, competitors, etc.	• Low research and development costs • Fast NPD • Flexible and fast incorporation of new functionality
Build a terminal system that connects drivers and travellers	The Dididache app is a platform that connects to 100 million users, sending an average of 5 million customer orders a day. It uses real-time mobile internet data (text message, locations, voice message, images, etc.) to determine traffic conditions, connect to customers, redistribute taxi resources and gather feedback at the same time.	• Time saving for both taxi drivers and travellers • Improves traffic conditions • Cost saving
Fast launch-and-improve ecosystem	Dididache has a strong partnership with Tencent which is the largest and most used Chinese internet service company. After integrating with Tencent's Wechat service platform in Jan 2014, its registered users doubled from 20 million to 40 million within 3 weeks. Dididache creates a variety of channels to encourage feedback and rapidly communicate this to the R&D team. This informs the development of new versions, with better features and functionalities. For example, after the first release of the app, Dididache gathered feedback quickly and launched 3 new versions with new functions and capabilities over two months. More recently, the app has been updated approximately once per month.	• Low research and development costs • Interprets and reacts quickly to develop new products • Gains more market opportunities

Table 3: Innovation approaches of Dididache Inc. (Mishkin, 2014; Wirtz and Tang, 2016; Wang, 2014; Dididache, 2015)

4.0 Research Design

The three cases show a variety of approaches to the use of big data to support NPD. In short, all three companies focus on establishing teams that can work both autonomously and simultaneously in order to speed up product development. They also connect with their wide range of customers at the earliest stage possible of product development. They launch their new products as quickly as possible to gain market recognition as well as further feedback from customers to trigger further continuous innovation. In order for them to harvest big data to inform product development, they identify and remove time and cost wasting processes during the NPD as much as possible, and they are able to use big data to facilitate a more agile, lean, dynamic product NPD process that is faster and adaptive. Based on the literature and empirical cases, key principles to accelerated NPD informed by big data can be summarised as: Autonomy (A); Connection (C); and Ecosystem (E). It is termed the ACE principles that allow firms to use big data to support accelerated NPD.

According to Wynen et al. (2014), autonomy is the mother of motivation and creativity. The first principle is to give autonomy to the NPD teams. This means allowing R&D team members a high level of freedom to make decisions by themselves in their workplace. For example, the project leader of Xiaomi who grants teams autonomy briefly introduces the teams to the final goal of a project or product then lets the teams make their own choices in achieving that goal. Autonomy here also implies that project teams work in parallel, rather than sequentially. The project approach begins with dividing the NPD process into many small elements. After that, the divided project activities are undertaken by cross-function teams (which mean a team of people from different functional areas) who work on different elements in parallel. By doing this, the so-called innovation ‘assembly line’ can be accelerated and results can be delivered quickly. For example, Lenovo overcomes the usual problems of implementation by: gathering

team members from different departments and work together on different product development elements in parallel. Additionally, autonomy does not mean being separate: project teams need alignment with the core, using big data to share innovation portfolios as well as to cultivate a network of peers and relationships, to facilitate innovation.

Barwise and Meehan (2012) believe that Apple built its success not as a pioneer, but as a good follower of its customers. The second principle is customer connection, i.e. a focus on building a close relationship with customers and better understand their needs via big data analytics. NPD can be facilitated by evolving ideas while listening to the voice of customers; the product is better when potential customers can be identified and their needs satisfied (Prahalad and Ramaswamy, 2004). For example, Xiaomi's MIUI system and Lenovo's Talend big data platform are both good ways to build a close connection to customers. Dididache spent a lot of time building various platforms to connect to its users as well as the market (including using big data to clarify its product definition and to identify its main competitors, market size and customers' problems and needs). Moreover, instead of making changes late in the project, customer connection encourages changes to occur earlier, when they are less expensive. The NPD process can be accelerated by using big data in the form of, for example, usage information, which is much more rapidly available than, say, the results of market surveys (Williamson and Yin, 2014).

The third principle is innovation ecosystem which represents an innovation and market-testing environment to develop new products at fast speeds and lower costs. Adner (2006) argues that innovation ecosystems have become a core element in the growth strategies of organisations in a wide range of industries. For example, in order to further enhance its smartphone ecosystem and take ownership of the future products roadmap, Lenovo Group in 2014 acquired world-

renowned Motorola Mobility from GOOGLE Company. The acquisition immediately make Lenovo a powerful global competitor in smartphones through scaling Motorola Mobility into a major player within its existing Android ecosystem and facilitating the new product innovation across the new Android ecosystem (Google, 2015). Another example of Xiaomi indicates that due to its supportive ecosystem, Xiaomi is able to sell its products and a wide range of accessories at near-production cost to keep prices competitive and sell a large volume of goods. Producing such products in an open innovation ecosystem depends on contributions from across the network of suppliers and creates value for the eventual buyer (West et al., 2014). A fast launch-and-improve ecosystem involves the principles of autonomy and customer connection and helps the NPD teams to move quickly to a market-winning product through a series of iterations: new product ideas, fast launch, feedback gathering, fast improvement and re-launch.

4.1 Case Selection and Data Collection

This research uses the in-company case research strategy and the developed principles were assessed by company applications. The underlying rationale is based on some key features well suited for the purpose of this research study. First, it allows investigation of how the principles allow NPD unfolds in a real-world environment in which decisions actually take place (Yin, 1994). Second, the case study method is well suited for studying the overall picture of the research object as a whole and allows the researchers to deeply understand and fully describe the context of the phenomenon under study (Dyer and Wilkins, 1991). Thirdly, the method allows the incorporation of different sources of evidence, including archival documents and interviews. Therefore, the present study here draws on an in-depth case study on the use of the proposed ACE principles by NOC, a young but innovative high-tech company, so as to draw lessons for the effective use of big data to improve NPD.

In this particular case, one of the authors had the opportunity to step into a project started in the NOC Company in which the objective was to design and to develop a new wearable electronic headset product for old people to better monitor their brain activities. NOC is a Chinese SME manufacturer founded in 2007. It is an innovator in wearable medical equipment technology. The company is best known for its wearable electronic headset, which can be used to monitor brain activity. The brain activity data is stored in the system or streamed to a smartphone. The data is then transmitted in real time to a receiver located up to 10 miles away from the system. The company has stated that its main consumers are patients in old age; the product can help doctors intervene earlier and avoid complications. However, since this market size is comparatively small and most doctors are not familiar with the product, sales of the product are decreasing year by year. Therefore, in order to improve its market performance and gain competitive advantage, the company needs to innovate and to launch new products with a different market focus.

The main data collection involved two waves. First, a retrospective approach (Miller et al., 1997) was used to become familiar with the initial part of the project when the concept took shape in 2013. To avoid distortion of past facts and written reports were used to support observations. Starting in 2014, the second wave of data collection consisted of 6 months research in real time, meaning that the researcher lives with an organisation over time or carries out periodic interviews (Pettigrew, 1990). This involved: on-site observations, discussions with the NPD team members, analysing internal documents (industrial reports, strategic planning reports, annual reports, newsletters, technical or non-technical documents and project reports). It is important to clarify that one of the authors was actively involved in the project when data were collected through market research on the project.

5.0 Case Study

NOC's CEO championed the project and introduced the ACE principles to the NPD team. The team consisting of the CEO, NPD team manager, an electronic engineer, a researcher, and a marketing manager was setup. The NPD team was asked to comment on the principles in terms of its feasibility for leveraging big data to accelerate the development of a smart wearable device for a new market. The researchers played the facilitator roles, i.e. providing clarifications and guidance to NOC's NPD team when needed.

5.1 Autonomy

In terms of the autonomy, this approach begins with a defined outcome of the product, and then all the development teams focus their energies on achieving that outcome as soon as possible. After applied the autonomy principle, the NOC Company has developed an agile approach to speed things up by tackling certain steps in parallel. For a specific project, the approach begins by dividing the NPD process (which normally includes the business case, development, testing and validation) into a large number of small steps and team members work on different elements in parallel, under the supervision of one manager. In this way, the company overcomes the usual problems of product innovation by: breaking down its product development into separate modules linked by standardised interfaces; redesigning its software to be compatible across all activities associated with the new product; establishing short lines of communication, where each team member can represent his or her respective functional department; and introducing open design processes, where information is shared with the entire team and their customers as early as possible. By implementing the autonomy principle, people from different function departments are grouped together to work actively. It cuts across boundaries of different departments and there is no more marketing team or production team.

Instead, every team member becomes involved in marketing, engineering, design, production or R&D. In this way, this approach helped the company to save a lot of time and eliminated vast number of unnecessary double communication within various teams.

Big data plays a significant role. In terms of traditional NPD approaches, the NOC Company found it difficult to adopt the autonomy principle, because of barriers such as difficulties in coordinating multidisciplinary teams and unwillingness by engineers to release information early. The company now can rely directly on big data analytics (the company currently using Google Analytics as a web-based technology for website customer behaviour analysing and social media marketing) to gather the latest information. Different function teams contact each other via ICT-enabled inter-team communication (such as information uploaded to the cloud or posted online, OA messages, app mentions, etc). Team members are now working and living in a big data environment, which ensures their communication and knowledge sharing are both effective and efficient. In this way, team collaboration can be enhanced by applying unified communications data analytics. When an innovation initiative encounters a problem, it supports the project team quickly gather everyone together (the 'huddle') from different functions, who can help them find a solution.

5.2 Customer connection

Currently, NOC has little direct feedback from customers. Only recently did NOC start to monitor consumer comments on the social media about its products. By applying the customer connection principle, the company has developed an application which is highly customisable. It allows its partners as well as customers to upload their ideas and suggestions to facilitate the company's NPD and invention of new features. Therefore, the new features and functionalities are co-developed with various customers based on the feedback collected. Moreover, the

Company connects to customers through a wide range of sources at low cost (e.g. official forum, mobile app platforms, popular websites) where customers can interact with the company and each other. The latest product information is updated to the difference sources on a daily basis, as well as to attract more customers and gain feedback for further developments. In this way, the company collects a wide range of customer feedback from different channels and platforms extremely quickly. For example, a thriving "voice of the customer" programme gathers feedback from more than a million customers online per day, and this information is used to improve customers' experience and to facilitate NPD. Therefore, big data in the form of feedback can be an important source of useful information and new ideas.

Engagement with big customer data also helps NOC to better understand its customers as well as the market. In this situation, big data supports NOC's customer connection by discovering the factors that could influence customer loyalty and how to keep customers coming back again and again. To achieve better management of its big data, NOC pointed out that there are a number of different data platforms can be used (e.g. Hadoop, Tableau and SAP's enterprise resources planning). NOC recently ditched a Microsoft system which it claims became too expensive to scale as data volume increased. Currently, NOC collects information such as customer feedback, market preferences and competitors' information. The firm is also using a data management and processing tool, namely SAP's enterprise resources planning, to schedule data-crunching tasks more effectively when it is ready to release a new product on time. With big data analytics, the company now can determine the optimal marketing investment across multiple channels, and keep optimising its marketing strategies through analysis, measurement and testing.

5.3 Fast launch-and-improve ecosystem

In terms of the ecosystem, the company always look for NPD practices that could enhance their capabilities for speed in development, speed to market and speed in improvement. Rather than spending time on internal R&D to make the product perfect, the NOC Company tend to launch their new product ideas on the market quickly (and are able to do so through implementation of the autonomy principle) and then improve them through extremely fast and continuous rounds of commercial realisation and testing within their ecosystems. Hence, companies can earn a premium by staying abreast of competitors' innovations and by having up-to-date products available in volume at affordable prices. Moreover, nurturing interactions in the proposed ecosystem improves efficiency and creativity, and also makes NPD a cycle of continuous improvement and information transformation. Based on customer feedback the NPD teams continue to iterate the design. This rapid launch-and-improve process has now become the company's core approach to NPD.

The core competitive advantage of the ecosystem principle arises from the use of big data to attract and connect to a wide range of networks in each step of product development. On the one hand, the emergence of big data and the internet allow for the combination of organisations' business strategies and those of outside suppliers within an ecosystem. For competitive advantage, NOC identified the key components and all the intermediates within its networks involved in product development before a new product reaches the eventual customers. As a result, it costs NOC less time and money than would ordinarily be required, concentrating on new product research and development rather than other time-wasting processes. Therefore, NOC can provide new products to meet its customers' requirements in a much more efficient and effective way. On the other hand, enormous cost advantages can be acquired from big data by supporting the firm to identify the key competencies of their components and focus on them, and acquire the less important components from the ecosystem. In order to support its

ecosystem, NOC invested half a million US dollars in online video content partners with a large Chinese Internet TV company to provide an platform for better customer and supplier interactions. In such situation, NPD are made from interrelated networks and these empower organisations to rapidly integrate useful information from customers and partners. Through repeated NPD cycles, NPD teams can iterate the product in sync with evolving market requirements and stay ahead of the competition.

6.0 Discussion

From the case, we have evidence to indicate that the proposed ACE principles appropriately reflect the smooth integration of big data and NPD. In general, the case supports the fundamental conceptual aspects of the ACE principles and endorsed many of the suggested guidelines in each of the principle. For example, the ACE principles reflect what is "happening in Xiaomi" and incorporate the pillars of accelerated NPD in today's dynamic and evolving marketplace. Proactive assessment of customer needs and behaviours is vital in today's competitive environment (Narasimhan et al., 2006; Mahr and Lievens, 2012). The principle of customer connection (i.e. establishing communication with consumers as early as possible) is vital for accelerated NPD because developers should observe and communicate meaningfully with customers and work with them to design product features. Overall, the ACE principles are conceptually accurate in capturing the essence of NPD in a big data environment, especially in the consumer electronics industry. According to Salge et al (2013), the demand for intelligence on product defects, improvements and usage has never been greater, especially in high-technology firms in the healthcare and telecommunications industries. The proposed approach is suitable for industries which evolve rapidly. However, the exact implementation of the ACE principles may differ from one firm to another, and is dependent to some extent on the

operational environment of the firm under consideration. Thus, it may meet with differing degrees of success and lead to different outcomes.

Traditionally, the NPD process has involved inefficient sequential processing of information between functional specialties. The ACE principles allow firms to adapt and respond rapidly to changing market needs and to develop innovative products in such an environment. Rather than spending years to exploit in-house capabilities, the ACE principles can be used to build a network to piece together production capabilities. Hence, it ensures company remains on the cutting edge of NPD. Today, many customers are too sophisticated to satisfy because they always demand products with the latest technology, cutting-edge functionality, at an unprecedented low price, and immediate services. At the same time, they don't have much brand loyalty and keep comparing the product with others. The proposed ACE principles can provide companies with the ability to take a product to market as fast as possible, to capture increased margins over a narrow time frame and to gather feedback from customers. It is meaningful for products and services with short product life cycles, notably the consumer electronics industry and social media applications, where demand is driven mainly by lifestyle trends. Particularly, by applying the fast launch-and-improve ecosystem, the NOC Company can see the benefits to be gained from the approach. Compared with traditional NPD approach, NOC was able to launch a range of new products in less than five months, at a total cost of $2 million. The company estimate that competitors using traditional design approaches have to invest around $20 million over twelve months to complete a similar set of new designs. Nonetheless, the challenges NOC faced in implementing the ecosystem approach were identified such as IT infrastructure, managing relationships with intermediates, and the culture shift from product focus to customer focus.

7.0 Conclusion

There is no magic formula for NPD. However, firms could expand their existing competence in many ways by tapping into the knowledge afforded by big data. The proposed ACE principles are based on information elicited from the literature, and the unique NPD approaches adopted by three successful Chinese firms. It provides a blueprint for using big data to make NPD faster and less costly. Compared with existing NPD approaches, the principles give particular emphasis to efficiency and cost saving. In this research, the principles were applied in the electronics industry, in the development of a high technology wearable device. It demonstrated that it can facilitate better planning and organisation of parallel work teams and groups that may be involved in accelerated NPD. This paper extends the accelerated innovation boundaries pointed out by Williamson and Yin (2014), and provides further evidence to ascertain the vital role of the fast improve-and-relaunch process within an innovation ecosystem in NPD. However, the implementation of the ACE principles may put considerable strain on an organisation. We posit that any stress presented by the introduction of these approaches will be more than compensated for by the time and cost reductions achieved in the modification of the NPD process.

This study also contributes to practice. This paper points to the vital role of big data in helping firms to improve NPD. The incorporation of big data into the fast launch-and-improve ecosystem can be significant (Gomez-Uranga et al., 2014). First of all, it allows organisations to launch new products to market as quickly as possible. Secondly, it helps organisations to determine the weaknesses of the product earlier in the development cycle. Thirdly, it allows functionalities to be added to a product that customers are willing to pay a premium for, while eliminating features they don't want. Last but not least, it identifies and then prioritises customer needs for specific markets. To stay competitive, Cooper (2014) points out that the

next generation of NPD process should be leaner, faster, adaptive and flexible. This study shows how firms could utilise big data to achieve that. However, the ACE principles are impossible in the absence of a strong leader, who can establish autonomous organisational structures that recognise and support NPD. Thus, managers need to adopt a strong business orientation toward NPD and embed this orientation in their organisation's operating systems and cultural values (Verganti, 1997; Sarpong and Maclean, 2012).

This study has its limitations. First, since using big data to support NPD is new, there is little literature to build on, and we have had to rely on observation of successful firms' practice to develop the principles. Second, the observations were conducted on Chinese firms; it is not known to what extent the approach can be generalised beyond the Chinese context. Third, our case study applies only one company, a young developer of high-technology wearable devices, and, similarly, the results may not be generalisable to all industry. Fourth, developing high-level principles for such a complicated phenomenon as NPD may highlight some obvious connections while failing to capture others. We are hopeful, though, that these broad principles will provide a means to help integrate the wealth of research on big data supported NPD in order to advance both research and practice.

Future empirical studies might explore the proposed model across different industries. An interesting question is whether this type of NPD approach extends to other countries or industries where product life cycles are comparatively long. Second, this research could take a longitudinal approach to analysing the implementation of the ACE principles in a firm over time. Learning and innovation processes can be properly studied only over a period of time. The findings would have useful implications for future research and policy design and implementation. Finally, the proposed model relates big data to accelerated NPD, which is

underpinned by three principles: a) autonomy; b) connect; and c) ecosystems. The fine-tuning of the three principles represents a promising area for future conceptual and empirical research.

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