
The PwC Mobile Innovations Forecast

Making sense of the rapid change in mobile innovation

With a quick boot, instant response to touch and speedy downloads from the cloud-based App Store, the application processor was one of the iPhone's many competitive advantages when it debuted in 2007. One factor contributing to the powerful processing capability was Apple's decision to use NAND flash memory instead of NOR. At the time Apple made that decision, NOR was the standard flash technology used in mobile phones and NAND was an emerging technology—faster and denser than NOR, but more expensive. For those performance reasons, Apple chose NAND, taking a calculated risk that the price-performance would improve, due in part to the demand that Apple itself would create with a successful launch of the iPhone.

Within two years, NAND became the standard, not only for system boot up but also for storage.

Looking back, moving from NOR flash to NAND flash was the enabling technology for iPhone. In order to develop a more powerful operating system and processor, greater memory for general storage and transfer of data was required. To get greater memory, you couldn't do that without the NAND flash. NOR isn't capable of supporting the higher level apps processor like the one in the iPhone.

NAND was just one catalyst for the iPhone, which became one of the most successful high-tech product launches of all time.

Apple's redesign of the iPhone, thinner and battery life, wasn't about beating others to market, but rather they recognized the fundamental changes in technology, usage and materials—things that you could do with user interface and industrial design.

The point is this: Apple's decisions about NAND and other components illustrate how understanding the evolutionary curve of technological innovation, even of commodities like flash memory, can lead to a disruptive product that transforms an entire ecosystem. Where will the disruptions in mobile innovation arise over the next five years? How will they change consumer and employee behaviour? What business opportunities will result? What can companies do to take advantage of these disruptions? How do they fit into broader market trends now driving the technology sector?

New capabilities

The Mobile Innovations Forecast includes technologies that are not currently significant enablers of innovation, but could become important within our five-year period. In our four-part framework we categorize these as new capabilities and they will be the focus of a future report. [See “Coming soon” at www.pwc.com/ca/mobileinnovations]

In many cases, what we are seeing is the development of new capabilities from existing technologies and emerging technologies driving disruptive mobile innovation and use cases.

New capabilities include technologies that could change how users interact with the devices and how the devices interact with the environment. Based primarily on qualitative research to date, we can suggest several examples we might include: near-field communications (NFC), high-definition audio (HDA), 3D computing, future generations of voice recognition, artificial intelligence, advanced video compression, gesture sensing and olfactory sensing (artificial nose).

Based on our historical understanding of technology adoption, new capabilities for the purpose of our forecast framework are those that have not yet met the threshold of 20 per cent penetration of mobile devices but are likely to do so within our five-year timeframe.

One such example is NFC, which allows for secure, simplified transactions, data exchange and wireless connections between two devices near each other—known as proximity detection. NFC’s device penetration reached an estimated 7 per cent by the end of 2011, but we expect it to hit the 20 per cent threshold within a couple of years. NFC has the potential to drive use cases and business models around device-based electronic

Introducing the PwC Mobile Innovations Forecast

Answering these kinds of questions requires not just a keen understanding of the evolutionary curve of the enabling technologies, but a broader framework for analyzing mobile innovation quantitatively and qualitatively. So with the goal of providing business leaders early warnings about coming disruptions and actionable intelligence about new opportunities, PwC introduces its Mobile Innovations Forecast (MIF), a four-part framework for analyzing and understanding mobile innovation. The four parts are:

- Enabling technologies
- New technological capabilities
- New use cases
- New business models

The four parts will be explored in periodic articles on this website in the months ahead. We expect that examining, analyzing and forecasting mobile innovation along these lines will shed light on the interdependencies that are otherwise cloaked by the unorganized daily stream of innovation announcements from the mobile ecosystem.

The first category—enabling technologies—is the focus of PwC’s Mobile Technologies Index, a new quantitative method developed to analyze the rate of improvement in key technologies that are fundamental to mobile innovation, and to help forecast new use cases and business models. (see sidebar, “Creating the Mobile Technologies Index, page 8) These enabling technologies have led to the rapid improvement of mobile device capabilities, dramatically changing our personal and work lives, and the way several billion people interact with each other.

Over the next five years, the smartphone will continue to acquire capabilities that will make it more and more like a full-fledged personal computer, but in the same period mobile innovation will continue to extend beyond smartphones and tablets. Mobile innovation in health care, automotive, home entertainment, manufacturing and other diverse sectors is likely to be just as robust.

With higher processing speed, it allows for more features and a more innovative approach to do something different. The monitoring of new technologies, new business models and new threads will be important to see when new concepts are being brought to market.

This article, the first of many, introduces the PwC Mobile Technologies Index; then explains where the Index fits in the four-part framework of the Mobile Innovations Forecast, and concludes with a look at how mobile computing contributes to the market and industry forces that are driving the broader technology sector. PwC identifies mobile computing as one of four market forces that are individually and collectively redefining customer demand, expectations and business opportunity. The others are cloud computing, social technology and the emergence of intelligent devices (the digitization of inanimate objects). Together, these mega-trends are leading us toward an era of ubiquitous computing, which relies especially on wireless networks.

payment systems as an alternative to credit cards (already happening in parts of rural China), to being a proxy for tangible keys, money, tickets, travel cards and identity documents.

Based on our future research, there could be several micro-electro mechanical systems (MEMS) that we would include as new capabilities. At present, the most widely adopted MEMS device is the accelerometer, which rotates the smartphone screen from vertical to horizontal. Its device penetration rate increases from an estimated 45 per cent by the end of 2011 to an estimated 69 per cent by 2015. Compasses, gyroscopes and pressure sensors are three other MEMS devices we are tracking with data. Compasses reached an estimated 20 per cent by the end of 2011, and will hit an estimated 44 per cent in 2015, but the other two do not reach 20 per cent by then.

New versions of Wi-Fi and Bluetooth currently under development could re-energize these technologies and make them “new capabilities” once again. A new version of Wi-Fi will offer ultra-high bandwidth for line-of-sight or in-room applications. A new version of Bluetooth is anticipated for ultra-low power applications. When these new versions appear, we would likely cover them as new capabilities.

We also include power and batteries under new capabilities. A smartphone that only needed recharging once a week would be a game changer. Batteries have improved only gradually for the past decade and are expected to continue their relatively slow advance. New capabilities that would accelerate improvements in mobile device batteries would create new opportunities, so our forecast will be sensitive to major disruptions emerging from innovation in power management and battery life. ■

The Index: 41% CAGR through 2015

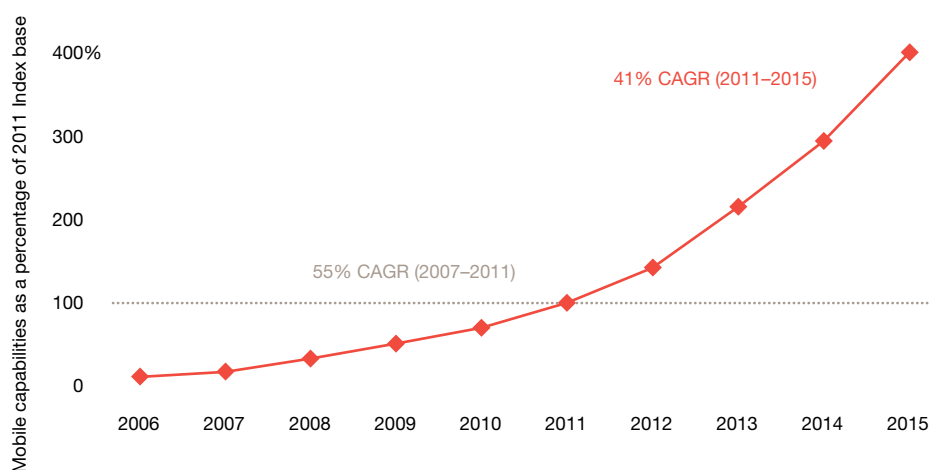
Our examination of mobile innovation begins with the key enabling components, introduced here and then analyzed in more depth, component by component, in separate articles in the weeks ahead. For this purpose, we have created the PwC Mobile Technologies Index, a broad composite of seven enabling components that underlie the power of the mobile device to sense, analyze, store and connect information. Since the first brick-like mobile phones began to appear in the chauffeured limousines of business executives and movie stars in the 1970s, disruptive breakthroughs in mobile have resulted due, in part, to the continuous progress of these components at predictable price points. Thus, our forecast begins with them.

In this first release of the Mobile Technologies Index, PwC forecasts a combined compound annual growth rate (CAGR) of the Index between 2011 and 2015 of 41 per cent. [see Figure 1, “PwC Mobile Technologies Index”] As Figure 1 shows, this is less than the 55% CAGR of the Index between 2006 and 2011, but still represents large enough improvements in the underlying components to anticipate many new mobile value propositions.

Here is the forecast through 2015 for each of the seven enabling technologies in the Index:

- **Infrastructure speed:** In average Megabits per second (Mbps), will improve 54 per cent CAGR.
- **Device connectivity speed:** In Megabits per second per dollar (Mbps/\$), will improve 37 per cent CAGR.
- **Processor speed:** In GigaHertz per dollar (GHz/\$), will improve 53 per cent CAGR.
- **Memory:** In Gigabits per dollar (Gb/\$), will improve 48 per cent CAGR.
- **Storage:** In GigaBytes per dollar (GB/\$), will improve 35 per cent CAGR.
- **Image sensor:** In Megapixels per dollar (MP/\$), will improve 20 per cent CAGR.
- **Display:** In performance per dollar per square inch (P/\$/in²), will improve 16 per cent CAGR. (Performance is a weighted aggregation of resolution, brightness, power efficiency and other factors.)

Figure 1: PwC Mobile Technologies Index



Source: IHS iSuppli Mobile and Wireless Communications Service

New use cases

The technologies that comprise the Mobile Innovations Forecast and new capabilities are important, but some of the most interesting questions about mobile innovation centre on evolving use cases.

Tracking rates of change in various technologies will help us make modest predictions about use cases already under development. For example, within the five years of our forecast period we anticipate the smartphone will add new and improved features that will give it the power and capabilities of today's desktop and laptop computers. Why shouldn't phones have the same amount of storage capacity as, for example a desktop, with the option of docking it for a bigger screen (tablet, laptop or TV at home)?

The extent to which the smartphone actually disrupts personal computers remains to be seen. But consider this: the Apple App Store now offers more than 650,000 apps,¹ and the number of Android apps has topped 450,000.² This continuing proliferation of apps suggests any number of future mobile use cases that will extend the power and scope of mobile devices.

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¹ <http://www.bgr.com/2012/06/11/apple-kicks-off-wwdc-2012/>

² <http://androidcommunity.com/android-growth-continues-450000-apps-850000-activations-daily-20120227/>

You might notice that the Index does not include battery or power management. This is not an oversight, but an informed decision. Our research indicates that battery performance improvements have been limited in nature and are not currently forecasted to be anything close to what we have seen for the components we chose to include in the Index, such as processor speed or storage. We will keep a close watch on battery technology; if there is significant change in the offing we anticipate that it will be covered in future articles describing new technological capabilities. (see sidebar, “New capabilities”)

The Index from an historical perspective

The price-performance improvements of these enabling technologies are largely responsible for the current trend in which smartphones are gaining market share over feature phones. But all mobile devices become cheaper, faster, more

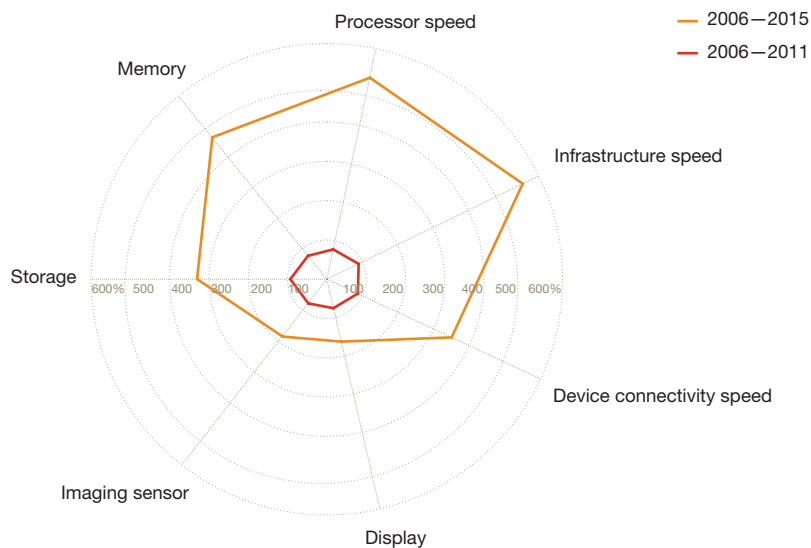
capable sooner, not later, and are able to deliver more, better and more diverse services and digital content of all kinds.

For the next few years, on average, the seven components together will improve 41 per cent a year, each year. So the dramatic change from phones in 2006 and the iPhone in 2007 will continue.

By calibrating each component at 100, with 2006 as the base year, the spider diagram illustrates how the seven components are progressing relative to each other. [see Figure 2]

In the weeks ahead, we will examine these technologies in a series of articles, including one that looks at the operating system (OS), which is not included in the Index, but is a key enabler of mobile innovation. [See “Coming soon” at www.pwc.com/ca/mobileinnovations] The first of these articles, looking at device connectivity speed, is available [here](#).

Figure 2: PwC Mobile Technologies Index—Relative progress of components



Note: Infrastructure speed, Device connectivity speed, Storage, Memory and Processor speed are core technologies. Each accounts for 16% of the Index. Imaging sensor and Display each account for 10% of the Index. See “Creating the Mobile Technologies Index” on page 8 for more information.

Source: IHS iSuppli Databases

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The smartphone is already causing disruption in several categories of electronics—alarm clocks, digital cameras, gaming devices, audio players and GPS devices, to name a few. Smartphone penetration in other use areas will also become predictable.

But if we only deal with obvious use cases entirely predictable from technology trends, then we will be limited to simply forecasting improvement in those uses over time. Our future research will lead us to discover and examine ideas still in the pure concept stage. Some of these seeds, planted over the next five years, are likely to come to fruition.

Such use cases will be found in numerous areas: health sensors and medical applications from on-person monitoring to alert systems; the electronic wallet; the automobile as an evolving mobile computing platform; wearable computing; highly evolved personal assistants. We can anticipate new classes of business use cases as well.

When we take a closer look at use cases in a future report, we will answer two key questions:

- What use cases are still on the shelf because of unsolved problems—technical or otherwise—and which of those problems have a chance of being solved in the next five years, thus unlocking the use case.
- What use cases not even on the shelf yet could move quickly ahead if some technology or business model problem is solved.

The answers will come from the use cases we identify through our in-depth interviews and qualitative analysis. ■

The four-part framework of the Mobile Innovations Forecast

As noted, the Mobile Technologies Index is just the starting point for our ongoing forecasting efforts in mobile innovation. Wireless devices and their supporting services will continue to run applications faster, store more data, create better pictures, and display information in brighter and more compelling images. New capabilities, creative use cases and imaginative business models, are more likely than the seven components (individually or collectively) to produce game-changing mobile innovation.

Taking a closer look, there are two parts to mobile innovation: how things are evolving and moving up the curve and the big “gotchas”.

To anticipate the “gotchas” and track their progress from idea to commercial reality, we constructed the broader framework of the Mobile Innovations Forecast. Predictably, future component performance levels at acceptable price points will support even “heavier” applications that are not feasible today. But other types of innovation are harder to predict and the consumer, and even some established vendors, can find it hard to anticipate them.

A domain of technology with this amount of innovation poses a challenge for applying a useful framework on its evolution: which attributes should be included? Add the complexities of personal, enterprise, national, service provider and global perspectives, and the problem becomes nearly unsolvable. The framework must be flexible enough to account for continuous introduction of the new. And it must separate innovations into meaningful categories while retaining an explicit expectation of emergent interdependencies.

The historical context must also be considered. There was a time when most functions now standard in smartphones were too expensive or unusable due to the immaturity of the underlying

technologies. Such functions included integrated imaging, general purpose operating systems, downloading applications, location awareness, motion sensing and others. How long after the technical capability existed did it take for these to become mainstream features, and what happened that allowed them and the use models they support to become standard?

From this perspective, more interesting questions about the future of mobile devices can be considered. What features and functions are coming, but are not commercially possible today due to current technology limitations, cost, wireless network speeds, business model imperfections or other barriers? What constraints prevent their appearance? When will these constraints dissipate enough to allow the capability to flourish? Can we predict when mobile devices will incorporate potentially disruptive capabilities they don’t have today, based on future engineering advances?

New business models

When, where and how will the next disruptions to mobile business models happen? Perhaps a social networking site becomes a virtual network operator? Or a healthcare provider resells wireless devices and services as part of a chronic disease management solution. Maybe a carrier launches vertical service and application packages to industry segments. We're already seeing announcements by carriers and credit card companies that portend major business model shifts.

How will the cloud figure in mobile business models? Does the newly emerging wholesale wide area network "pipe" business make sense? Will more electronics retailers offer branded devices and service? How far below the \$100 price point might the full-featured smartphone drop?

These are among the topics we will examine when we do additional research into business models in future reports. We anticipate considerable innovation over the next five years.

Today there appears to be very little variation in the mobile communications industry. Phones are starting to have similar features and service offerings. However, this environment is when there's potential for business model disruption.

Operators, OEMs, retailers, automobile companies, healthcare providers and insurers, web-based entrepreneurs, the entertainment industry and any number of segments we haven't considered yet, will seek new ways to monetise mobile innovation. New business models have the potential to disrupt as much as technologies do.

In this ongoing series of articles, PwC will periodically offer answers to those types of questions through the framework of the four categories of the Mobile Innovations Forecast:

- The seven enabling technologies of the Mobile Technologies Index, plus the OS, as explained above, are the subject of this current report and a series of articles to appear in the coming weeks.
- The new capabilities of various emerging and existing technologies. [see sidebar, "New capabilities," and the subject of a series of articles scheduled for later this year]
- New use cases that arise from performance improvements or entirely new mobile technologies including the extension of the mobile ecosystem into the cloud. [see sidebar, "New use cases," and the subject of future articles]
- New business models built on all of the above, and that might increasingly rely on industry dynamics outside of the mobile industry itself. [see sidebar, "New business models," and also the subject of future articles]

We do not intend to develop an encyclopedic description of all existing or potential capabilities, emerging technologies, use cases and business models. In many cases we expect there will be an explicit hierarchy in the new—a new capability, relying on further improvements in enabling components, creates the potential for new use cases that, in turn, create new business models.

The broader business impact

As noted, this introductory article and the individual component articles in the weeks ahead are just the beginning of a much longer project to track mobile innovation across a broad front. One hope is that, over time, the community of readers will offer their own ideas and insights into this process, and begin to understand how mobile innovation itself is only one key element in a broader evolving technology ecosystem.

The Mobile Innovations Forecast exists within PwC's framework for understanding various dynamics driving the broader technology sector today, a framework that suggests ways technology companies might navigate disruptions that are rich in opportunity. In this context, there has been little research that describes the mobile ecosystem as we are describing it, and then analyses the ecosystem parts to forecast innovations likely to reach commercial adoption.

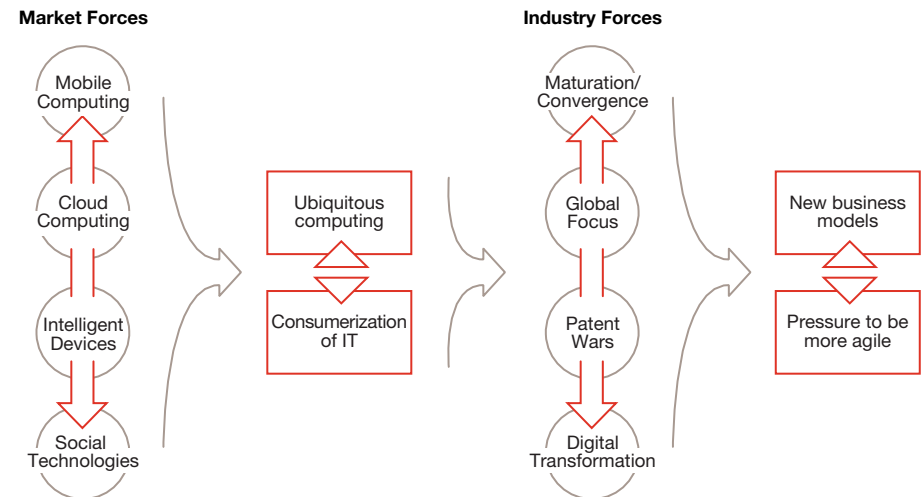
It is a truism that technology innovation never stops, and technology companies can never rest on prior success. In this regard, the disruptive forces in mobile computing are familiar—as friend and foe. But there is something different this time. PwC sees major market and industry forces co-mingling in ways that paint a forward-looking picture that is starkly, even radically, unlike the past. Incremental change this is not.

As noted earlier, mobile innovation is one of four market forces that, individually and collectively, are redefining customer demand, expectations and business opportunity for technology companies; the others are cloud computing, social technology and the emergence of intelligent devices. Individually, each is turning the rules of the broader technology sector upside down. [see Figure 3] For examples, consider the following:

- Enterprise computing device strategies focused solely on desktop PCs and laptops ignore at their peril the 24x7 reality of fully engaged knowledge workers and customers on mobile devices.
- The lack of agility in typical legacy data centres destroys enterprise value relative to cloud options.
- Email and Web portal strategies are siloed and tone-deaf if they aren't embracing many-to-many social technologies.
- Networked, digital intelligence will be emanating from billions of smart, networked "things" operating without direct human oversight and offering data for purposes limited only by the imagination.

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Figure 3: The interplay of market and industry forces and how they are driving technology companies to consider new business models and more agile operations



Source: PwC

For example, when Apple launched the iPhone in 2007 it injected a new dynamic to the OEM and wireless carrier relationship, changing the standard business model. For the first time a carrier allowed an OEM to dictate design and functionality of the handset because it believed the innovations would jumpstart the adoption of its 3G service.

Concerned about being disrupted by others, wireless operators in particular are looking to evolve business models. Operators are struggling to find ways to add value. They are not only competing against other operators, but content providers, OEMs and app developers. They are continuously trying to find ways to differentiate themselves.

The technologies in the Mobile Technologies Index and in new capabilities will suggest new use cases, which in turn can inspire new business models. And the whole cycle is likely to turn around on itself when new business models create demand for or accelerate the development of new technologies.

Business models are not part of the Index, which is why our future analysis of them will rely on interviews with leading industry visionaries and other research to identify and analyse where new business models are possible, are being tried or thought about and where current business models are most likely to be disrupted. ■

Mobile, cloud computing, social media and the network of intelligent devices through the Internet are several disruptive changes affecting technology, communications and media industries. Individually, their disruptive nature could impact established vendors and create new customer value propositions. Combined, their impact as mobile engages with smart objects without user intervention, personal data stored in the cloud and socialize commerce. As seen in the mobile ecosystem, we expect to see the same level of disruption played out in all corners of the technology industry.

PwC views these four trends as delivering on the long-time promise of ubiquitous computing, a phenomenon predicted two decades ago by Xerox PARC. Today, Wikipedia captures it well: “Ubiquitous computing (ubicom) is a post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities.” When our customers and employees live and work in this ubiquity they have disruptive expectations that their work lives will be as “thoroughly integrated” as their private lives—hence the “consumerization of IT” that every enterprise is grappling with today.

As if these market forces weren’t enough, the tech industry itself is experiencing major internal disruptions: maturity and convergence, globalization, patents as an arms race and digital transformation of business ecosystems. Market forces are driving some of these disruptive developments. Cloud totally redefines compute infrastructure. Everyone is in everyone else’s markets—hardware companies go into retail and services, while retailers introduce their own hardware and software companies become retailers and hardware vendors. And mobile computing is establishing heated competition for the future of the end-user devices, a battle that reverberates throughout the value chain, from chips to applications. Inevitably the migration of major powers towards overlapping customers is resulting in IP battles, even as globalization is bringing new players onto the landscape—largely made possible by digitally transformed product development teams, supply chains distribution channels and customer experience management.

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Creating the Mobile Technologies Index

The Mobile Technologies Index is a method PwC developed to analyze the rate of improvement in key enabling technologies that are fundamental to mobile innovation, and to help forecast new use cases and business models.

In the spring of 2011, PwC began to research whether there was a way to forecast mobile capabilities. In addition to seeking credible data about the technological drivers of mobile capabilities, we sought a shared vision that mobile capabilities could be forecast. After an extensive review and discussion with various market research firms, PwC partnered with IHS.

IHS, an Englewood, Colorado-based global information and analytics provider, has a comprehensive database of each sector of the high technology industry value chain, from analogue and digital circuit designers through the chip foundries, as well as the original equipment manufacturers and the telecom network operators.

More than 130 subsectors of the high tech industry are included in its databases of prices, production capacities, capital spending, component features, average selling prices and numerous other metrics. More than 140 analysts have compiled these historical data points going back 10 years, and have prepared forecasts extending through 2015. The IHS iSuppli products and services include information from teardowns of various phones and tablets over the years, along with a continuing series of surveys, vendor roadmaps, market share analyses and other sources.

PwC mobile computing and high tech industry practice leaders and IHS analysts reviewed the databases and identified several metrics that drove mobile capabilities in the past, and would be expected to drive the devices and services in the future. We eventually chose seven components for the Mobile Technologies Index: device connectivity speed, infrastructure speed, processor speed, memory, storage, display and image sensor. [See story, "Making sense of the rapid change in mobile innovation"]

Through a series of back testing and other calculations, we determined that the relative performance of these Mobile Technologies Index components has consistently followed a pattern of at least 30 per cent compounded annual growth. The components, and therefore the Index's performance, appear likely to continue in the same upward path for the next five years.

In addition to the analysis of the data, PwC practice leaders interviewed leading mobile industry visionaries to review the data and provide their perspectives on the future capabilities of smartphones, tablets, wearable computers and other portable devices.

We concluded that five technologies will continue to serve as the basic building blocks of mobile innovation: device connectivity speed, infrastructure speed, processor speed, memory and storage. Over the five-year forecast period, each of the five will continue to progress along a Moore's Law type price-performance curve, which makes them a natural starting point for a numerical and predictive index.

Based on our analysis, we added two other technologies to the Index: display and image sensor. Both are progressing along a Moore's Law-style price-performance curve, which we expect will continue for the five-year forecast period. Currently both are nearly as important to mobile innovation as the five core technologies.

The display, with its multi-touch capability, has been one of the most disruptive qualities of smartphones. Over the next five years we anticipate that touch sensitivities will improve, and the physical display will become thinner, tougher and less expensive per square inch. Resolution and power efficiency are also expected to improve. As for the image sensor, not only will the smartphone continue to disrupt the digital camera market, this technology will be integral to next generation social networking, which is expected to consume video the way today's social networking consumes still photos.

We decided to weight these two at less than the value of the five core technologies. Each core building block technology accounts for 16 per cent of the Mobile Technologies Index, and image sensor and display account for 10 per cent each.

We examined several other technologies, some with meaningful metrics and some without. Among the more important ones were Wi-Fi, Bluetooth and operating systems (OS).

Wi-Fi and Bluetooth have already achieved wide adoption. By the end of 2011, Bluetooth was found in an estimated 81 per cent of handsets and its estimated CAGR is only 3 per cent in Mbps/\$ through 2015. Sixty per cent of handsets will have Wi-Fi capability by 2015, including virtually 100 per cent of smartphones. Its CAGR is 18 per cent Mbps/\$ through 2015. Given these factors, we decided to exclude them from the Index.

We would like to have included the OS in the Index, but we have observed that the OS does not trend along a predictable evolutionary curve similar to the other components. Rather, it tends to lurch forward in disruptive ways with qualitative enhancements to the user experience. User experience can be measured through usability testing, but such studies of mobile devices are not widely conducted and tend to test for basic functions, making them a bit simplistic. The OS can also be benchmarked for standard criteria, but we are unaware of anyone issuing benchmark or usability data covering the past five years or forecasting the next five years for mobile operating systems.

Despite these barriers to including an OS metric of some sort in the Index, the OS is central to innovation, and so we will include a qualitative analysis of it in this first series of reports, which are focused on the enabling technologies. ■

Given this landscape, vendors are looking at business models through a different lens. They recognize the need for more of a dynamic business model, one in which products and experiences are at opposite ends of the spectrum and vendors are somewhere in the middle. Easier said than done, this of course means a real investment in enterprise agility to have a successful business model evolution.

By examining mobile innovations in the framework outlined above, PwC hopes to create common understandings from which will emerge the launch points for disruptive innovations. In the weeks and months ahead, we will offer forecasts of the innovations positioned for near-term commercial success and around which others can build their own value propositions. We have not reached the end of dramatic changes through mobile innovation. We are only at the beginning.

Let's talk

If you have any questions about the Mobile Innovations Forecast or would like to discuss any of these topics further, please reach out to us.

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