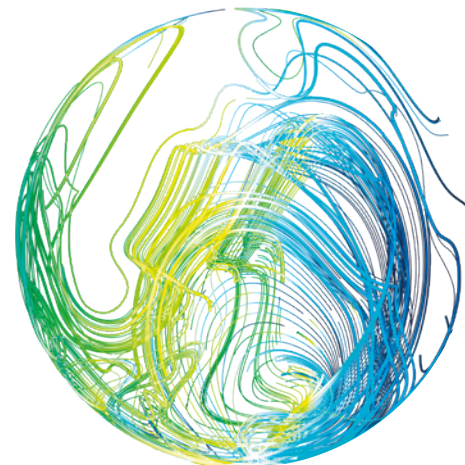


The future of the smartphone: the era of invisible innovation



Deloitte Global predicts that by the end of 2023, penetration of smartphones among adults in developed countries will surpass 90 percent,¹² a five-percentage-point increase over 2018. Smartphone sales will be 1.85 billion per year in 2023, a 19 percent increase over 2018 and equivalent to over five million units per day.

The main driver of higher adoption rates in each market will be take-up among older age groups. We would expect ownership among 55-to-75-year-olds to reach 85 percent in developed countries in 2023, a 10-percentage-point increase over 2018.¹³

We further predict that owners will interact with their phones on average 65 times per day in 2023, a 20 percent increase over 2018.¹⁴ This will reflect the wider range of applications used by the mainstream smartphone owner, such as enterprise applications and in-store payment options, and more intensive use of existing applications such as photography.

We expect the percentage of smartphone owners who use their devices daily to increase from 93 percent in 2018 to 96 percent by 2023.¹⁵ This implies that 86 percent of all adults will use a smartphone on any given day in 2023, versus 79 percent in 2018.

Deloitte Global predicts that by the end of 2023, penetration of smartphones among adults in developed countries will surpass 90 percent, a five-percentage-point increase over 2018.

This usage frequency is likely to be significantly higher than for any other digital device, and it is likely to drive upgrades and, ultimately, total sales and the rising value of those sales. The frequency of smartphone usage is likely also to spur an ever-greater degree of smartphone-centric content creation and process redesign.

We expect about 180 million units to be sold in retail for \$1,000 or more. This category alone will generate over \$200 billion in revenue and, in unit and dollar terms, will be significantly larger than the entire tablet market.¹⁶ In Q3 2017, one-eighth of smartphones in Western Europe sold for \$900 or more, double the proportion a year prior.¹⁷

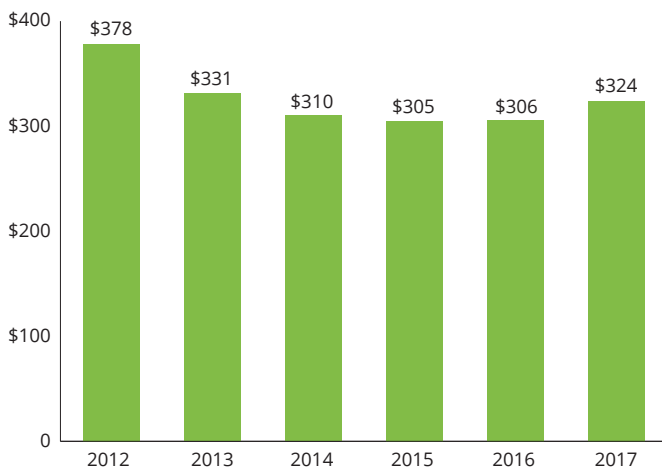
We forecast an average selling price (ASP) for smartphones of \$350 in 2023, implying a total market value of \$650 billion. Global smartphone revenue increased by 10 percent between 2016 and 2017, from \$434 billion to \$478 billion.¹⁸ Smartphone ASPs rose from \$302 in 2015 to \$324 in 2017 (ASPs had declined between 2012 and 2015).¹⁹ We expect ASPs to continue to rise as users' valuation of their handsets increases (see Figure 1).

12. Adults are, for the purposes of this survey, those aged 18 to 75. In most developed countries, this represents the vast majority of all adults. If we were to include 16-to-17-year-olds as well, the penetration would increase a little. The data is from Deloitte's Global Mobile Consumer Survey across 16 developed markets, with a total sample of 29,056 respondents. The countries surveyed are Australia (2,002), Belgium (2,002), Canada (2,002), Denmark (1,003), Finland (1,002), Germany (2,000), Ireland (1,036), Italy (2,000), Japan (2,003), Luxembourg (1,000), the Netherlands (2,000), Norway (1,002), Spain (2,000), Sweden (2,002), the UK (4,002) and the US (2,000). Deloitte's Global Mobile Consumer Survey (GMCS) refers to individual Deloitte member firms' 2017 GMCS surveys, conducted between May and July 2017. For more details, see <https://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/gx-global-mobile-consumer-trends.html>.

13. Ibid.

14. Ibid. The average views for 2017, based on survey responses, were 46. Our view is that people in general underestimate the number of times they interact with a phone, as most people do not count how many times they do it. As of 2016, iPhone mobile device owners unlocked their phones an average of 80 times per day. Apple's Penchant for Consumer Security, Tech.pinions, 18 April 2016: <https://techpinions.com/apples-penchant-for-consumer-security/45122>.

15. Ibid. As of 2017, this was 92 percent.

Figure 1. Evolution of smartphone ASP, 2012-17

Source: GfK (for further information on the sources, see endnotes)

In short, we predict that over the next five years, the smartphone market should continue to grow in penetration, usage, unit shipments, total value and ASP.

Additionally, the smartphone will consolidate its position as the primary access to digital service and content. This is despite the fact that a 2023 smartphone is likely to look, on the outside, very similar to a 2018 model.²⁰ The majority of the models shipped in 2023 are likely to feature a single 5- or 6-inch high-definition rectangular touch screen, have two cameras, weigh 130 to 200 grams, and have a lithium-ion battery with a capacity roughly similar to that of today's smartphones.

The secret to the smartphone's success over the next five years is likely to be the introduction of an array of innovations that are largely invisible to its users but whose combined impact should feel tangible in the form of greater ease of use (such as facial recognition based on depth maps) or improved functionality (for example, for maps and photos).

The smartphone's invisible upgrades

The 2023 smartphone should offer superior performance across a range of business and consumer applications, thanks to enhanced connectivity, processors, sensors, software, artificial intelligence and memory.

By 2023, 5G networks should have launched in most developed markets, offering much greater capacity and connectivity speeds. Over a billion 5G users are forecast for China alone by 2023.²¹ Furthermore, advanced 4G networks, which can also support peak download speeds of over 1 Gbit/s, should have rolled out in most of the remaining markets.

Dedicated artificial intelligence (AI) chips are likely to have become standard across smartphones by 2023 and will be most commonly used to assist machine-learning (ML) applications, and in so doing take load off the main CPU for these tasks. 2017 was the first year in which premium smartphones (about 300 million, or 20 percent, of shipments for that year)²² started incorporating AI chips.

According to Deloitte's research, about two-thirds of adult smartphone owners in developed countries are using at least one application that features ML, and 79 percent are aware of applications with ML (see Figure 2). Through 2023, dedicated AI chips are likely to become standard in smartphones at all price points, as happened with fingerprint readers; these were initially included in only flagship models but are now available in \$100 phones. Over time, and as the base of smartphones with dedicated AI chips increases, the range and utilization rate of ML applications should steadily increase.

Premium handsets are always likely to have the latest AI chips in the same way that they include the most powerful CPUs and GPUs.

Field-programmable gate array (FPGA) chips are also likely to have become standard (an FPGA chip can be programmed multiple times to undertake specific tasks after manufacture). An FPGA takes the load off the main processor for certain tasks, such as optimizing reception on a cellular network, particularly in congested areas.²³

The CPUs and GPUs in smartphones are likely to be upgraded on a regular basis over the next five years, in tandem with developments with other more specialized chips.

16. Deloitte Global estimates that there will be 180 million units of smartphones sold by multiple vendors retailing at \$1,000 or more (in US dollars, or when converted into US dollars) in 2023. We estimate that the average selling price will be \$1,250 for this category, with the most expensive devices priced at close to \$2,000. Deloitte Global's forecast for global tablet sales in 2017 was 165 million, a 10 percent decrease from the prior year, and significantly lower than the 2014 peak of 230 million units. See Deloitte Global's TMT Predictions 2017 – Have we passed peak tablet? Deloitte Touche Tohmatsu Limited, 11 January 2017: <https://www2.deloitte.com/uk/en/pages/press-releases/articles/technology-trends-for-2017.html>.

17. The figures are obtained by leveraging various press releases by GfK. See Smartphone average selling price sees record year-on-year growth in 3Q, GfK, 24 October 2017: <http://www.gfk.com/insights/press-release/smartphone-average-selling-price-sees-record-year-on-year-growth-in-3q/>; Global smartphone sales hit a quarterly high in Q4 2015, GfK, 3 March 2016: <http://www.gfk.com/insights/press-release/global-smartphone-sales-hit-a-quarterly-high-in-q4-2015/>; Strongest Q3 smartphone sales on record driven by demand in China, MEA and emerging APAC, GfK, 25 November 2015: <http://www.gfk.com/insights/press-release/strongest-q3-smartphone-sales-on-record-driven-by-demand-in-china-mea-and-emerging-apac/>; Global smartphone sales exceed 1.2b units in 2014, GfK, 17 February 2015: <http://www.gfk.com/insights/press-release/global-smartphone-sales-exceed-12b-units-in-2014/>.

18. Ibid.

19. Ibid.

20. Deloitte Global expects the majority of smartphones shipped in 2023 are likely to feature a single 5-to-6-inch touch screen (measured on the diagonal) and two to four cameras, weigh 150 to 200 grams, and have a lithium-ion battery (the same composition as used in a 2018 model). By 2023, the majority of screens are likely to be OLED; in 2018, about a third are likely to incorporate these screens.

There is likely to be an increased range of sensors included on smartphones in 2023, and existing sensors are likely to be upgraded. One additional sensor that may become mainstream over coming years is a forward-facing infrared camera, which is likely to be rolled out on a range of devices in 2018 and may end up usurping the fingerprint reader as the primary biometric authenticator.²⁴ Smartphones that retain a fingerprint sensor are likely to feature upgraded components, and by 2023 these may be ultrasonic, enabling them to work through glass and metal and even when fingers are wet or greasy.²⁵ The GPS receiver in smartphones may also be upgraded to enable it to deliver more precise location information – to within 30 centimeters, versus 5 meters in 2017.²⁶

AI delivered via better software is likely to become increasingly used across all smartphone applications by 2023, and it will be an ever more prominent differentiator. The main benefit of AI will be to make applications work more slickly, delivering, for example, better recommendations on routes, more realistic augmented reality or more compelling photos. AI, while not tangible per se, is likely to be a heavily marketed core feature.

As of mid-2017, usage and awareness of applications featuring ML were still quite modest, but we expect both indicators to improve through 2023 as AI capabilities steadily improve (see sidebar: AI and smartphones).

By 2023, 5G networks should have launched in most developed markets, offering much greater capacity and connectivity speeds.

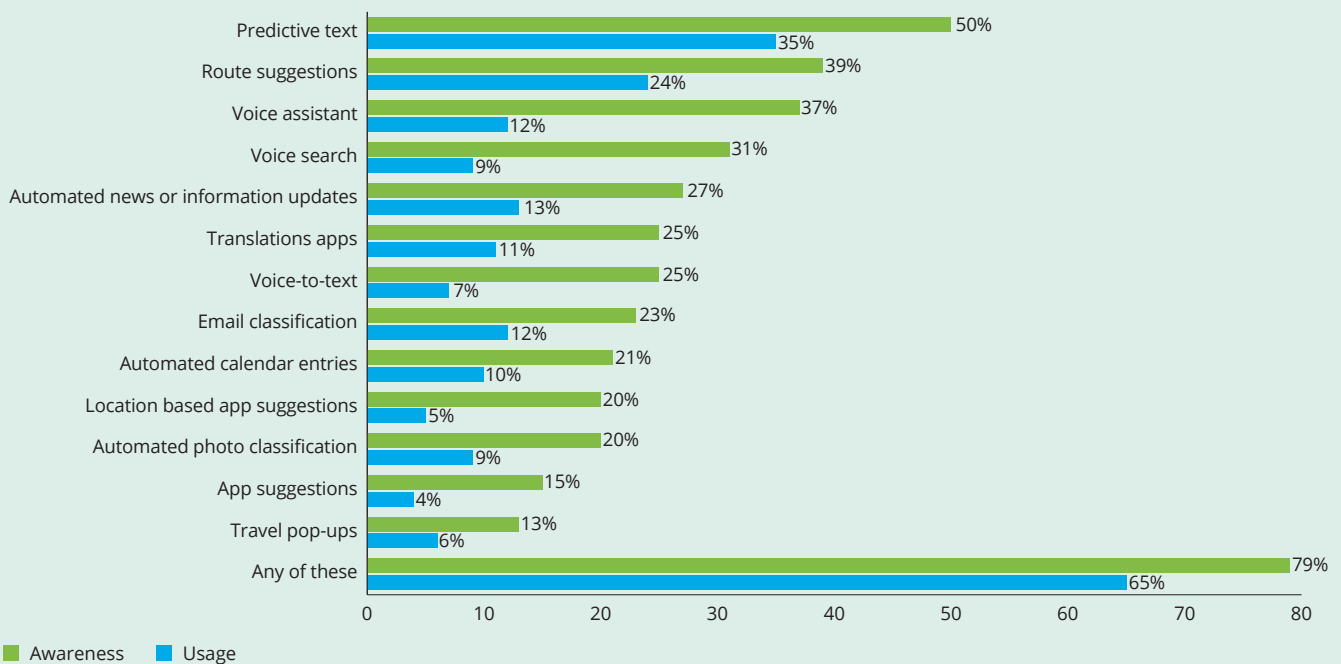


AI and smartphones

According to Deloitte’s research, in which we asked respondents about their awareness and usage of a range of AI-enhanced applications, the most commonly used application was predictive text, followed by route suggestions (see Figure 2). Voice recognition applications saw a large cleft between awareness and usage. We expect that as the quality of applications improves, thanks to better algorithms, data sets and AI hardware, users will increasingly depend on AI-infused tools.

For example, in 2017, a quarter of smartphone owners used route suggestions. We expect the proportion to exceed 60 percent by 2023, thanks to more personalized and faster suggestions (due in part to the onboard AI chip, which can learn, for example, the device owner’s walking pace according to the time of day) and more accurate recommendations (courtesy of better data sets and better location-tracking capability).

Figure 2. Awareness and usage of applications featuring ML (developed markets)



Weighted base: Smartphone owners in 16 developed markets (24,563 respondents). The figure is the average of 16 countries in our study, namely Australia, Belgium, Canada, Denmark, Finland, Germany, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Spain, Sweden, the UK and the USA. Source: Deloitte’s Global Mobile Consumer Survey, developed countries, May-July 2017

The average smartphone sold in 2023 will have 128 GB or more storage, compared with about 32 GB in 2018. Most of this space will be occupied by photos and videos, but greater memory capacity will provide more space for apps, some of which will be many gigabytes in size. RAM memory is likely to range from 2 GB to 16 GB.²⁷ Both upgrades should make smartphones more useful and valuable.

One upgrade unlikely to come through is a new and better battery formulation. By 2023, lithium ion is likely to remain the basis of almost all batteries used in smartphones. As of late 2017, there were no battery technologies on the horizon that appeared to be sufficiently stable and mature to be tested and factored into supply chains that could displace lithium ion.

However, all is not lost. Processors are likely to become more efficient. Splitting off processing tasks to other chips aside from the CPU helps reduce battery usage. Using multiple processors of varying power, some optimized for power and others for efficiency, also improves power usage.²⁸ Second, wireless battery charging should help users top up devices when they're out and about. The major smartphone vendors have agreed on a wireless charging standard known as Qi that is likely to be rolled out in multiple environments, from coffeehouses to office waiting rooms and from bedside tables to cars. Qi is used in smartphone brands that are likely to represent collectively over a billion smartphones shipped in 2018.²⁹

By 2023, lithium ion is likely to remain the basis of almost all batteries used in smartphones. As of late 2017, there were no battery technologies on the horizon that appeared to be sufficiently stable and mature to be tested and factored into supply chains that could displace lithium ion.

The smartphone's lengthening list of applications

These invisible innovations should enable the smartphone to continue "absorbing" the functionality of an ever-broader array of physical objects, and to displace further the PC as the preferred device for a growing range of digital applications.

The smartphone's expanding scope among smartphone users in the UK can be seen in Figure 3. Between 2016 and 2017, the smartphone became the preferred device for video calls across all users, the preferred device for search among 18-to-34-year-olds and the preference among 45-to-54-year-olds for reading news. It was not all one-way traffic; the games console became the preferred device for playing video games among males, possibly reflecting the rising market penetration by latest-generation consoles.

21. China to blaze connectivity trail with a billion 5G users by 2023, TechRadar, 18 October 2017: <http://www.techradar.com/news/china-to-blaze-connectivity-trail-with-a-billion-5g-users-by-2023>.
22. As of 2017, multiple vendors had launched handset models with dedicated AI chips. These include proprietary chips, which shows the importance being placed on this processor as a differentiator. For more information, see Why are smartphone chips suddenly including an AI processor? Android Authority, 30 September 2017: <https://www.androidauthority.com/smartphone-ai-processor-803019/>.
23. Huawei boosts smartphone 4G reliability and performance with lattice semiconductor tunable antenna solution, Lattice Semiconductor, 7 July 2015: <http://www.latticesemi.com/About/Newsroom/PressReleases/2015/20150707Huawei.aspx>.
24. Android phone makers set to follow Apple's lead with Face ID, TechRadar, 8 October 2017: <http://www.techradar.com/news/android-phone-makers-set-to-follow-apples-lead-with-face-id>.
25. In June 2017, Qualcomm announced a fingerprint sensor that can scan through glass, aluminium and metal. Qualcomm announces advanced fingerprint scanning and authentication technology, Qualcomm, 28 June 2017: <https://www.qualcomm.com/news/releases/2017/06/28/qualcomm-announces-advanced-fingerprint-scanning-and-authentication>.
26. Superaccurate GPS chips coming to smartphones in 2018, IEEE Spectrum, 21 September 2017: <https://spectrum.ieee.org/tech-talk/semiconductors/design/superaccurate-gps-chips-coming-to-smartphones-in-2018>.
27. At the end of 2017, the largest-size phone in terms of RAM was 6 GB. 2017 Smartphone Comparison Guide, New Atlas, 9 May 2017: <https://newatlas.com/best-smartphones-specs-features-comparison-2017/49418/>.
28. For an explanation of how this works, big.LITTLE, arm Developer, as accessed on 6 November 2017: <https://developer.arm.com/technologies/big-little>.

Figure 3. Device preference for various activities, UK (2016 versus 2017)
 Question: Which, if any, is your preferred device for each of the following activities?

	Total	Male	Female	18-24	25-34	35-44	45-54	55-64	65+
Browse shopping websites									
Make online purchases									
Online search									
Watch short videos									
Check bank balances									
Video calls									
Check social networks									
Read the news									
Play games									
Voice calls using the Internet (VoIP)									
Take photos									
Record videos									
Stream films and/or TV series									
Watch TV programs via catch-up services									
Watch live TV									

Weighted base: Smartphone owners in 16 developed markets (22,929 respondents). The figure is the average of 16 countries in our study, namely Australia, Belgium, Canada, Denmark, Finland, Germany, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Spain, Sweden, UK and USA
 Source: Deloitte’s Global Mobile Consumer Survey, developed markets, May–July 2017

By the end of 2023, the smartphone is likely to have assimilated various additional non-PC functions, serving as keys; office entry cards; and credit, debit and other stored-value cards (including for transport). This will lead to smartphones being increasingly used to authenticate access to physical and digital environments, including homes, offices and hotel rooms,³⁰ cars,³¹ buses,³² trains and planes; corporate information systems; and e-commerce and banking sites.

Deloitte Global predicts that by 2023, over three-quarters of all smartphone owners in developed countries will use some form of biometric authentication, and 80 percent of smartphones will have at least one dedicated biometric sensor, such as a fingerprint reader or a 3-D facial scanner.³³ This compares with about 29 percent of owners who will use fingerprint authentication in 2018, and a base of about 42 percent of devices with a dedicated fingerprint sensor.

29. For more information, see Qi (standard), Wikipedia, as accessed on 6 November 2017: [https://en.wikipedia.org/wiki/Qi_\(standard\)](https://en.wikipedia.org/wiki/Qi_(standard)).

30. Hotel room access via smartphone is already available in some hotels as of 2017, but rollout is currently minimal. For more information, see “Frustrating” hotel room key cards could disappear within five years, The Telegraph, 7 July 2017: <http://www.telegraph.co.uk/news/2017/07/07/frustrating-hotel-room-key-cards-could-disappear-within-five/>.

The smartphone’s deepening applications

In addition to being used for new functions, smartphones are likely to be used by more people and more often for functions they have already absorbed: as MP3 and CD players, GPS navigation systems and maps, fitness bands and pedometers, compact and single-lens reflex (SLR) cameras,³⁴ handheld game players and puzzle books, boarding passes, and entertainment tickets.

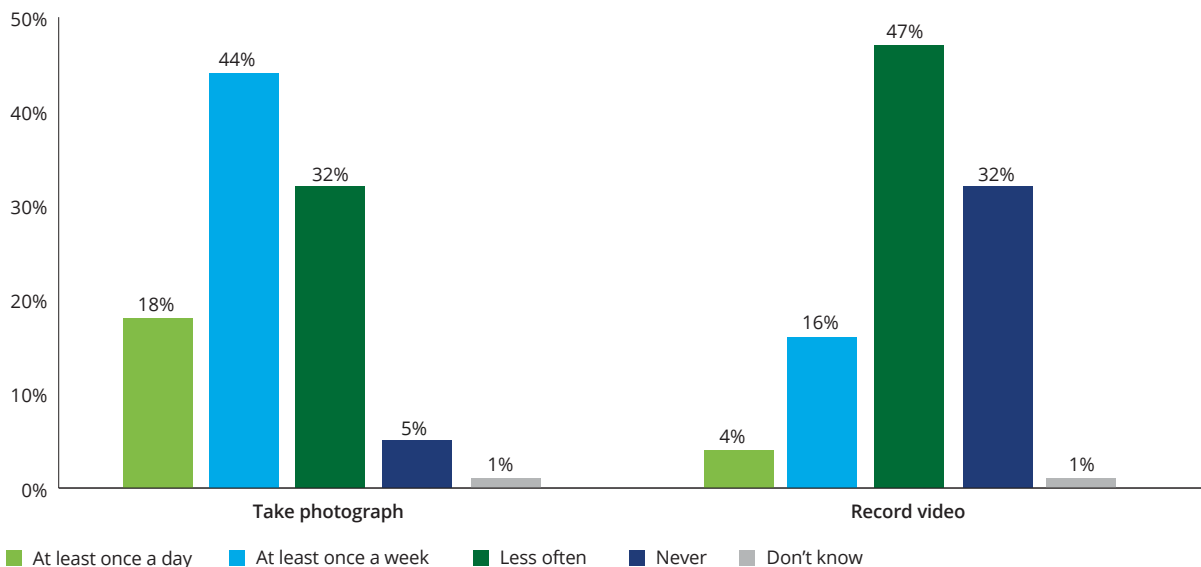
The caliber of photos and videos captured on a smartphone should steadily improve through 2023 (see sidebar: The evolution of the smartphone camera), increasing device usage and utility in both consumer and business contexts.

In the medium term, a major – and for some, a principal – factor in choice of phone, whether premium or budget, new or used, is likely to be the quality of its photo app and hardware.³⁵ As of mid-2017, 18 percent of smartphone owners in developed countries took photos at least daily, and an additional 44 percent took photos at least weekly (see Figure 4).³⁶ This proportion should rise over time as the photo capability of a smartphone steadily increases and the possibility of taking a low-quality snap (one not worth sharing) falls.

31. As of 2017, there were a few car manufacturers, including Volvo and Tesla, that supported or planned to support smartphone entry. Volvo’s truly keyless entry: your smartphone, Extreme Tech, 15 March 2016: <https://www.extremetech.com/extreme/224665-volvos-truly-keyless-entry-your-smartphone>; Tesla’s Model 3 doesn’t come with a key, Mashable, 29 July 2017: <http://mashable.com/2017/07/29/tesla-model-3-keyless-smartphone-app/>.

Figure 4. Frequency of taking photos and recording videos (developed markets average)

Question: Please state how often you do each of these (take photographs/record video). Do you do this...?



Weighted base: Smartphone owners in 16 developed markets (22,929 respondents). The figure is the average of 16 countries in our study, namely Australia, Belgium, Canada, Denmark, Finland, Germany, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Spain, Sweden, UK and USA
 Source: Deloitte Global Mobile Consumer Survey, developed markets, May-July 2017

As the range of travel options (such as walking and public transport, in addition to driving) on a smartphone’s maps app expands, this function is likely to be used, and relied upon, even more. Over the next five years, we expect smartphone map apps to integrate more large indoor locations (such as shopping malls, office blocks

and transport hubs) and become more accurate (thanks to additional location data points from Wi-Fi hotspots, beacons and cell towers). Machine learning, too, is likely to play a major role in generating better routes for each individual.

32. This system was already available as of 2017 but had been rolled out in only a few cities, including London. Mobile payments, Transport for London, as accessed on 3 November 2017: <https://tfl.gov.uk/fares-and-payments/contactless/other-methods-of-contactless-payment>.

33. There are likely to be an increasing number of smartphones that incorporate 3-D facial recognition. Android phone makers set to follow Apple’s lead with Face ID, TechRadar, 8 October 2017: <http://www.techradar.com/news/android-phone-makers-set-to-follow-apples-lead-with-face-id>.

The smartphone transforms the workplace

A further major driver of increased smartphone usage and value is its wider and deeper usage in a business context.

Over the past 10 years, smartphones have redefined how people live and interact with each other; over the next five, it is likely to be enterprises' turn to use mobile even more than they already do to transform the way work gets

done in settings from retail store operations, health care, restaurants, sales and field maintenance to dozens of other services and processes.

We estimate that in the European Union alone, 45 percent of the workforce (about 100 million people) could use a mobile device as a primary (or only) work device (see Figure 5).

Figure 5. Number of tasks that can be done primarily on a mobile among people in work in the European Union, by type of role

Type of role	Employees (thousands)	Total amount of tasks that can be done primarily on mobile (average)	Amount of work that can be replaced by mobile					
			Timesheet management	Job allocation	Office software suite processing	Communication (with peers, employer, clients)	Access to information (job-related or company data)	Stock and third party suppliers management
Lower status employees	42,479				N/A			N/A
Skilled industrial employees	35,999				N/A			
Clerks and skilled service employees	32,009							
Small entrepreneurs	24,442							
Technicians and associate professional employees	32,227							
Professionals	42,912							
Managers	13,502							

Source: Deloitte analysis 2017, based on European union employment data as of 2016

Note: To arrive at the average for the total amount of tasks that can be done on mobiles, we have taken into account the importance of certain tasks to the role and the amount of people in work within the category

As of mid-2017, about half of workers in developed countries used their smartphone to email and make calls, yet only 7 percent submitted a timesheet, only 5 percent posted expenses using their phone,³⁷ and only 10 percent accessed their company's intranet via their phone.

This lack of smartphone usage for work purposes is not due to a lack of scope.

Workers whose job requires them to walk a lot or does not require them to be tethered to a desk – from retail sales staff to traffic officers – would be encumbered by carrying a laptop or a tablet and would probably not need a full keyboard or a PC's processing power.³⁸ In most markets, at least half of the employees are rarely or never at a desk.

Hundreds of millions of workers around the world do not need to process or analyze information, but they do need to receive contextual information on a timely basis so they can respond to it rapidly based on better information. The smartphone is the ideal device for this.

The enterprise app or mobile-optimized website would appear to offer a huge opportunity that may have been overshadowed by the allure of developing consumer smartphone apps or websites. Yet there are significant dividends in making the world's workforces more productive by making relevant business processes available via a smartphone.

In some regards, 2018 is reminiscent of the early days of the internet era, when enterprises started adopting browser solutions to transform how employees work and changed how they engaged with core enterprise applications – thereby improving substantially the speed and quality of their access to data.

As the underlying nature of work for many professions is unlikely to change fundamentally over the next five years – roofers will fix roofs, chefs will cook – technology's role may be more about improving existing processes than about redesigning them.

For roofers, one benefit of a well-designed mobile app would be being able to submit invoices faster and with more information (such as photos showing work done) rather than waiting until they are back in a PC-equipped office. In a small restaurant, one of the most common needs for a chef may be to order ingredients; again, this could be done via a well-designed website or app, and does not require a PC.

However, there are even deeper opportunities for mobile, as has been shown in some professions such as delivery services. Hundreds of businesses and processes are operating under old models, with some employees unnecessarily tethered to workstations or point-of-sale devices, or disconnected from real-time information. In most cases mobile should, through better efficiency, make companies more competitive, but in a few cases mobile will enable entire business models to be reinvented and industries to be disrupted fundamentally.

Workers whose job requires them to walk a lot or does not require them to be tethered to a desk – from retail sales staff to traffic officers – would be encumbered by carrying a laptop or a tablet and would probably not need a full keyboard or a PC's processing power.

34. Single lens reflex (SLR) cameras have a construction materially different from that of smartphones and are likely to maintain their lead over smartphones in terms of image quality. There is always likely to be a need for SLR cameras. However, we also expect a growing number of photography enthusiasts to use a smartphone instead of an SLR when the highest-resolution images are not required. For those who view and share photos mostly via a smartphone, the SLR is likely to become increasingly eschewed. This is a trend similar to that for music; traditional hi-fi setups, occasionally including vinyl records, are likely to continue to offer the highest-fidelity reproduction. But smartphones streaming high- or standard-resolution audio files to single box speakers are likely to be increasingly used for music instead of traditional hi-fi. This is because it is convenient and the combination of streaming and single speaker is continuously improving.
35. Review: iPhone 8, TechCrunch, 19 September 2017: <https://techcrunch.com/2017/09/19/review-iphone-8/>.
36. The data is from Deloitte's Global Mobile Consumer Survey across 16 developed markets, with a total of 29,056 respondents. The countries surveyed are Australia (2,002), Belgium (2,002), Canada (2,002), Denmark (1,003), Finland (1,002), Germany (2,000), Ireland (1,036), Italy (2,000), Japan (2,003), Luxembourg (1,000), the Netherlands (2,000), Norway (1,002), Spain (2,000), Sweden (2,002), the UK (4,002) and the US (2,000). Deloitte's Global Mobile Consumer Survey (GMCS) refers to individual Deloitte member firms' 2017 GMCS surveys, conducted between May and July 2017. For more details, see <https://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/gx-global-mobile-consumer-trends.html>.
37. Ibid.
38. Some tablets now have the processing power of midrange PCs.
39. A standard 50mm lens for an SLR camera alone weighs more than most smartphones.



The evolution of the smartphone camera

One of the primary differentiators for all smartphones is the camera or, more precisely, the image displayed on a phone's screen once an array of post-processing actions – often using proprietary hardware and software – have taken place.

Improvements in photo quality over the next five years are likely, thanks to better, highly integrated software and hardware, with the role of software becoming increasingly significant. This should enable smartphones to get closer to the quality and characteristics of images captured by much larger, heavier and bulkier traditional cameras.³⁹

One type of photographic effect that had been unique to traditional SLRs was “bokeh,” where the subject is in focus and the background is blurred, highlighting the subject more prominently.⁴⁰ On a standard smartphone, the entire image ordinarily would be in focus.

The bokeh function in smartphones was first introduced in 2016, but it has since advanced markedly, and as of late 2017, most vendors' flagship models supported this effect.⁴¹ The first phones with a bokeh capability blend images from two lenses taking a photo at the same time. Software is then used to create a composite image, with the major challenge being to distinguish and separate precisely the subject from the background. Over time, the quality of the bokeh effect should steadily improve; ML enables more refined algorithms that become more accurate at splitting foreground from background. And more powerful and dedicated processors should enable these composite images to be generated ever faster.

By 2023, convincing bokeh effects should be attainable with a single lens. The first model with this capability was launched in 2017.⁴² The device distinguishes between the foreground and the background and creates the composite image from multiple images taken at the same time.⁴³ This advance is significant, as in a smartphone size is paramount, and the removal of a lens leaves room for other components or a larger battery.

Another innovation that is likely to become ubiquitous in smartphones over the next few years is optical image stabilization, which integrates hardware (the lens), sensors (the gyroscope) and processors to mitigate the impact of the device shaking when a photo is being taken. If the gyroscope detects the phone is moving (perhaps due to the press of a finger on a shutter), it adjusts the direction of the lens slightly to counteract the device's movement.⁴⁴ The result is no or reduced blur in a photo.⁴⁵

The smartphone's camera is likely to be increasingly used in work contexts, again with software at the fore. A common administrative task in a work context is capturing information, which may be in the form of business cards, receipts or brochures. Any camera can copy these images; software can remove excess content (such as the underlying table surface when photographing a business card)⁴⁶ or shadows.

One type of camera that may be integrated into some handsets used in a work environment is a back-facing IR camera, which detects heat (IR energy). A camera with integrated IR would be compact and portable, and could readily be carried by tradespeople, including in confined spaces or up ladders. Thermal imaging can be used in a wide range of contexts, such as tracing the source of leaks in a home, analyzing faulty motor engines or checking home appliances.⁴⁷

There are likely to be many more techniques incorporated into smartphones that increase the proportion of quality photos, with the benchmark for quality likely to be photographs that elicit a positive response when shared. There are likely to be many more techniques deployed to increase the likelihood that the image that appears on a phone's screen after the shutter has been pressed is the one you wanted to take, even if it was not the one that you actually took.

40. On SLR cameras, this effect is most likely to occur when using telephoto or macro lenses, as they create shallow depth of field. For an explanation of what the bokeh effect is and how this looks, see Bokeh, Wikipedia, as accessed on 3 November 2017: <https://en.wikipedia.org/wiki/Bokeh>.
41. For a list of smartphones with this capability, see 2017 is the year of dual-camera phones, but the best cameras are still single, The Verge, 1 August 2017: <https://www.theverge.com/2017/8/1/16074480/dual-camera-phones-2017-best-image-quality>.
42. Portrait mode on the Pixel 2 and Pixel 2 XL smartphones, Google, 17 October 2017: <https://research.googleblog.com/2017/10/portrait-mode-on-pixel-2-and-pixel-2-xl.html>.
43. The camera takes two lower-resolution photos and combines them. This mimics the process used by phones with two cameras but achieves it with just one. Google says Pixel 2 is so good, it doesn't need dual cameras, Cnet, 4 October 2017: <https://www.cnet.com/news/pixel-2-is-so-good-it-doesnt-need-dual-cameras-google-says/>.
44. More information and some examples of photographs taken with optical image stabilization are shown here: <https://www.androidauthority.com/ois-optical-image-stabilization-explained-677976/>.
45. This type of functionality is likely to have become mainstream by 2023, in the same way that techniques such as HDR (high dynamic range) have rapidly rolled out. HDR is software that creates a composite image with a high dynamic range based on multiple shots at different exposures taken in close sequence. HDR was first introduced in 2010 on iOS devices. HDR photography with iPhone 4 and iOS 4.1: how good is it? ArsTechnica, 13 September 2017: <https://arstechnica.com/gadgets/2010/09/hdr-photography-with-iphone-4-and-ios-41/>. The iPhone 8 mobile device and Google Pixel are two smartphones that as of October 2017 had HDR on by default. iPhone is a trademark of Apple Inc., registered in the US and other countries. Deloitte Global's TMT Prediction 2018 report is an independent publication and has not been authorised, supported or otherwise approved by Apple Inc.



The bottom line

The role of the smartphone in society, for tech vendors, screen manufacturers, enterprises and government, is likely to become ever more central. There are multiple implications for all; the smartphone is a once-in-a-generation innovation whose full potential is far from realized yet.

The scale of the market, overshadowing any other device currently available or likely to be available, is likely to have multiple ramifications for all device manufacturers. For one thing, vendors will need to remain relentlessly focused on identifying and acquiring the next big idea or differentiator for smartphones. Adopting a technology too early – be it a new battery technology or screen formulation – could prove very costly. Integrating niche functionality, whether in the form of projectors or IR keyboards, should be avoided. Making a commercial success of modular phones is likely to be challenging. Failing to allocate sufficient resources to improving a specific feature, such as the photo capability, could also be significantly detrimental. Given that the camera is so critical, vendors should consider doubling the size of their teams and deploying thousands to the task.

The smartphone's trajectory looks strong through 2023. But should vendors also be developing a new growth engine for when the smartphone's momentum eventually peters out? Or might a focus on a new device distract resources from the smartphone?

Many vendors have bet on the emergence of new form factors, from smart glasses to virtual reality, but the smartphone has so far remained dominant. It has steadily absorbed more digital and physical functionality. Attempts to launch adjuncts to the smartphone have had only modest success.

Members of older generations are rapidly adopting smartphones and may start to rely on them as more processes, from access to public transport to paying for parking, shift to smartphones. Industry and government should create training programs to enable this age group to take full advantage of smartphones. School curricula should place as much focus on familiarity with creating content and coding for smartphones as is currently done for PCs.

IT departments at companies should evaluate how best to integrate smartphones into their IT strategies and their way of thinking. They should consider which device is best for each type of employee and how best to utilize smartphone biometric authentication to improve security.

46. How to use Apple's terrific document scanner in iOS 11, The Verge, 26 September 2017: <https://www.theverge.com/2017/9/26/16362386/apple-ios-11-notes-document-scanner-how-to-use>.
47. For more examples, see FLIR ONE tips & tricks, FLIR, as accessed in 2017: <http://www.flir.com/flirone/support/tips/>.



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