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The design of things
Building in IoT connectivity

The Internet of Things in product design: A research collaboration between Deloitte and IBM

CONTENTS

Introduction

Product connectivity has been part of our daily lives for decades. An automated door is connected because a pressure sensor detected the presence of foot traffic and instructed the door to open accordingly—an example of an open-loop connected system. A thermostat is connected because a sensor detected that room temperature was above or below a set point, thereby instructing a furnace to turn on or off depending on the temperature—an example of a closed-loop connected system.[1] In the pre-IoT days, these systems were connected in that they performed limited functions based on what a sensor detected. But they did not typically communicate with other parts of a larger ecosystem, and thus companies had trouble collecting data about usage, customer behavior, and performance.

The Internet of Things (IoT) has ushered in an age of connectivity, one that enables objects to function in new, expanded ways. IoT technology allows objects to communicate with each other continuously, forming large, interconnected systems capable of creating, communicating, aggregating, analyzing, and acting on data.[2] This, in turn, opens up a world of opportunity for connected objects that can better serve customers' individual needs[3] and gather data to drive the development of more tailored services.[4] Developers can use data gathered via IoT-enabled devices for a range of applications, from consumer goods that make a home more efficient to industrial systems that can enhance asset management.[5]

The casual observer may see nothing different about a product once it becomes "smart." But that product is fundamentally different: It is now a member of a larger community of products, processes, and stakeholders, expected to do more and fill more roles than ever before.[6] IoT technology transforms the product and everything within it.

As connectivity expands a product's role and functionality, it only makes sense that its original design might prove limiting. And new smart products need to incorporate IoT technology from the beginning. So product design is a way not only to fashion smart products but also to create an effective connected system. An industrial sensor must generate a much broader range of data than pre-IoT models and, then, be able to securely communicate that information. A fitness tracker needs to incorporate sufficient memory and sensors to collect useful data as well as a reliable connection to a smartphone or computer—all while looking and feeling attractive to shoppers.

This article examines four significant ways in which IoT technology has transformed the nature of products and, by extension, product design. We will also identify the accompanying organizational transformations—in terms of people, process, and technology—that are crucial to successful product design in the IoT age.

THE INFORMATION VALUE LOOP

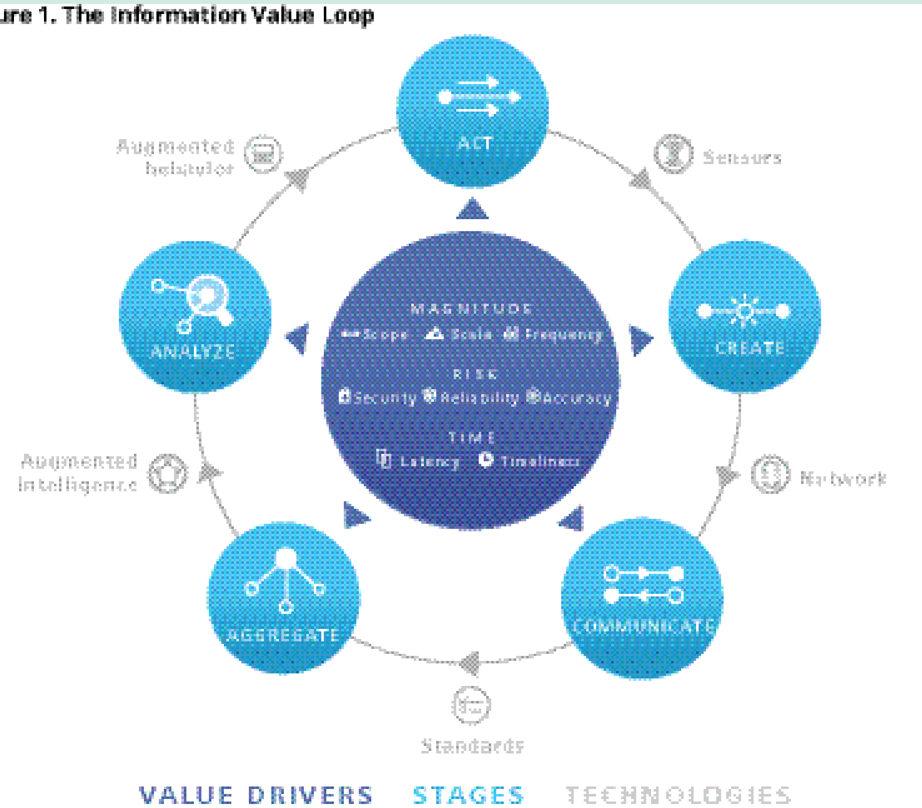
The Internet of Things is a technology architecture. It is a specific way of stitching together a suite of new and existing technologies to turn almost any object into a source of information about that object. This creates both a new way to differentiate products and services and a new source of value that can be managed in its own right. At the same time, it creates challenges for product designers as they seek to create useful—and usable—objects that can accommodate the added complexity that goes along with connectivity.

In order to understand the full nature of those design challenges, we must first understand exactly how IoT technology enables those new products and services. Since the value in connected products comes from their information about the world, modeling the flow of information through the system is a good way to illustrate the architecture. Deloitte's Information Value Loop illustrates how IoT technology links together enabling technologies to create new value for companies and customers (see figure 1).

Note first that the Value Loop is a loop: An action—the state or behavior of things in the real world—generates information, which then gets manipulated in order to inform future action. For information to complete the loop and create value, it passes through the loop's stages, each enabled by specific technologies. A sensor creates information and is communicated within a network, and standards—technical, legal, regulatory, or social—allow the data to be aggregated across time and space. Analytical support is collectively used to analyze information. The loop is completed via augmented behavior technologies that either enable automated autonomous action or shape human decisions in a manner that leads to improved action.

The amount of value created by information passing through the loop is a function of the value drivers identified in the middle, which fall into three general categories: magnitude—how much data is needed; risk—how reliable and accurate must that data be; and time—how quickly the data is needed. These value drivers may offer a good starting point for product designers as they begin to unravel what customers truly need in an IoT product, and what may be extraneous features.

Figure 1. The Information Value Loop



Source: Deloitte analysis.

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Connectivity brings fundamental changes

Even in the world before IoT connectivity, a product designer had many things to consider: who would be using the product, how, when, and why—and, perhaps, how it might look in a TV ad or on a store shelf. The object's desired lifespan and any risks associated with its use could also shift design requirements.

IoT connectivity adds to the process an additional layer of complexity and, thus, challenge. Connectivity reshapes the challenges and complexity of product design; the interconnectedness that defines the technology imposes new requirements. We can begin to categorize the impact of IoT technology on products—and product design—into four main transformations:

- Marrying physical and digital worlds
- Staying "always on" and constantly connected
- Moving from single object to part of a larger system
- Constantly evolving uses—and life cycles

In this section, we examine these transformations and the ways in which they impact product design.

Marrying physical and digital worlds

With IoT enablement of a physical product, embedded sensors are able to capture and transmit data about that product over a network. The system then analyzes the data and, based on that analysis, takes action. The information the product generates is as important as the physical product itself. In that sense, there is a marriage of the physical and digital worlds: Each component is equally essential to the function, and value proposition, of the connected object.

While this union of the digital and physical brings with it a host of user benefits—including more efficient products tailored to the user's behavior and demonstrated preferences[7]—it significantly complicates the design process. Connectivity means the product must be able not only to create and communicate information but to act on it autonomously—in turn creating and communicating new information that enables it to learn and adjust.[8] Incorporating these capabilities seamlessly into a physical object such that the object can reliably interact with a digital network while still remaining user-friendly—or outwardly relatively simple—is critical to designing a smart object.[9]

Indeed, the importance of user-friendliness and simplicity cannot be overstated. Even while making an object smart, the designer cannot lose sight of the customer, her mind-set, and how she will use the product. One particular concern that derives from the convergence of the physical and digital may be some customers' wariness of smart objects; IoT-enabled objects can inspire strong psychological reactions in users, who may fear or overcomplicate a high-tech object that is, practically speaking, no more difficult to use than an unconnected object.[10] Even the need to learn a few extra steps or deviate from current habits may deter users from purchasing a connected product, much less signing up for the IoT-based system of which the object is a component.[11] Thus, keeping the product simple to use—even while its capabilities expand—is a crucial aspect of design. An IoT-enabled thermostat must still function as a traditional device; a smartphone must still serve as an easy-to-use cell phone no matter how many new features developers add; a connected car must drive normally even if the owner elects not to subscribe to all the available navigation and entertainment options.

Staying "always on" and constantly connected

In the world of connectivity, no product is an island. An IoT-enabled object will necessarily stay connected to a network to facilitate the communication of data. Indeed, that ability to stay connected and communicate data regularly—if not constantly—constitutes much of a smart product's value proposition. At one level, connectivity invokes purely technical issues for the product designer: choice of network, power-consumption considerations, and interoperability. Designers creating an IoT-enabled object will thus need to account for the need to stay connected.

> In the world of connectivity, no product is an island.

At a higher level, when a product becomes a part of a larger IoT ecosystem, the components that make connectivity possible are as much a part of the user experience as the physical object itself—and must be as secure and reliable. For all of the value it adds, connectivity significantly adds to the ways that a product experience can fail. If the components in a connected product that communicate information fail, it does not matter that the rest of the device might function perfectly.

And the stakes are higher: Many consumers find malfunctions in IoT-enabled objects particularly disconcerting; they may appreciate the benefits of physical-digital convergence, but they expect connected products to function as reliably as previous versions,[12] especially since connectivity implies new susceptibility to outside interference. Individuals may be relatively tolerant of periodic failures in now-familiar web browsers, voice-over IP, or apps—for which periodic service interruptions can seem contextually appropriate—but they tend to apply their same high expectations about the reliability of previously unconnected objects to their newly IoT-enabled counterparts.[13]

Beyond its impact on customers' mind-set, expectations of always-on connectivity mean that the implications of failures or compromises in connectivity are dramatically more far-reaching and can have more serious consequences than unconnected counterparts.[14] With a connected medical device monitoring patients' vital signs and informing decision making of remotely located health care professionals, a failure in connectivity could place lives at risk. A connected piece of factory machinery may serve as the linchpin of an automated manufacturing process, and a dropped connection might shut down the entire factory.[15] A smart lock that loses its connection may refuse to unlock, leaving a homeowner unable to open his front door.

When a product is connected and expected to be always on, product designers must prepare for the consequences of malfunction and connectivity loss. They must do so across multiple dimensions—not only the object itself but its components and, potentially, even the entities with which it interacts. Designers cannot break down the design process and treat each component separately. Rather, they must understand each component's actions, interactions, and even security and legal implications as a part of the larger whole.[16]

Moving from a single object to part of a larger system

If the constant connectivity of an IoT system makes it difficult to separate a product's physical makeup from its digital components, it also introduces wider interactions that complicate design even further. For example, consider just the communications protocols needed to establish the always-on connectivity that IoT technology demands. The manufacturers of a connected product may assemble the hardware and even write some software code. However, in nearly every case they will use an established communications protocol owned by another company or foundation. In many cases, this can mean using third-party signals to take advantage of that protocol.[17] As connectivity is central to the function of an IoT-enabled product, this means that most connected products are dependent upon external groups simply to work as designed.

But this external dependency extends far beyond just communication protocols. Even core customer interactions may be mediated by external elements. With typical products—say, a traditional lightbulb—the interaction between customer and company typically ends at the sales counter. A connected lightbulb, by contrast, may be a part of a larger web of interactions between manufacturer, distributor, third-party developers, and customer.[18] These new interactions are integral to the function of the product—indeed, the whole value proposition of an IoT-enabled lightbulb in the first place.

This increases the level of contact the company must have with the customer, as well as all the other stakeholders in the system. This, in turn, ups the ante considerably for the manufacturer: Not only must its designers create a product that can interface with digital systems created by many others outside its direct control—they must design a product and process capable of sustaining continuous, ongoing customer-to-company engagement. In this way, the object changes from simply a product into a product and a service—or, increasingly, multiple services.[19]

The Amazon Echo, for example, is an audio device with a speaker and set of microphones—in other words, a traditional home entertainment gadget. Echo's value lies in its connected web service and software platform, which, using voice recognition and artificial intelligence capabilities, act as a virtual assistant that engages digital services and other smart home devices upon command. (Devices expected to launch in late 2016 aim for similar functionality.[20]) Thus, a user can play music, control a connected thermostat, or summon a car via Uber.[21] These external connections are core to Echo's function and value: If the connection to Uber and other services is dropped, the device ceases to "function." This enhancement of a physical product with diverse—and expanding—digital capabilities is just one such example of how consumers will shift to engage with smart objects and, also, how designers should account for multiple demands and stakeholders. In this case, the value shifts from the physical object to its operating system—and its ability to interact with other connected systems.

Nor are these issues limited to the world of consumer products. Consider Flowserve, which manufactures valves and other fittings for hydraulic lines. Where customer interactions once ended with valve sales, Flowserve now offers sensor-enabled valves along with as-a-service valve status monitoring.[22] As with the consumer-oriented Echo, this shift relies on a host of external interactions beyond the physical valve.

With all of these external connections being critical to a connected product's functionality, its boundaries extend beyond the physical plastic case or steel valve to encompass communications protocols, APIs, and other components that may not be under designers' direct control. Regardless, designers may need to consider—or at least take into account—these services as they develop products.

Constantly evolving uses—and life cycles

In the pre-connected world, a manufacturer designed a product and released it. Based on market conditions, user feedback, and competitive forces, the manufacturer could subsequently design and release updated versions of that product, or discontinue it altogether.[23] In the connected world, that sense of control and predictability changes: Now, not only can a manufacturer potentially change the core function of its product at any time via an update—third-party partners can do the same thing to key components, such as apps.[24] The forces of change and product evolution are faster, more complex, and further outside the hands of the manufacturer.

For their part, designers are now tasked with designing an object that can not only adapt to unforeseen updates that can change the function completely but can also accommodate mismatched life cycles. This challenge is particularly acute for IoT-enabled objects. While a traditional product's components may have differing life cycles—particularly in the case of objects with electronic components—the manufacturer has some level of control and predictability, along with component lifespans of at least several years.[25] With connected objects, component lifespans can vary much more widely. Take, for example, the connected car. Individuals typically keep newly purchased vehicles for at least five or six years[26]—the average car on an American road is nearly a dozen years old[27]—but digital developers push updates every few months, or even more frequently. Automakers should therefore take into account the full spectrum of life cycles as they consider the design of a connected car, from its durable frame to its ability to accommodate regular technology updates. Designers must even anticipate technological developments that won't arrive for several years—and, when they do get here, may alter various car features and functions considerably beyond the initial intended use.[28] With digital product update cycles becoming ever more compressed, this problem will likely only intensify.[29] Many manufacturers no longer have the luxury of time and predictability in attempting to sort out the complex ecosystems in which their products exist. Evaluation and adaptation of design must be a continuous process.[30]

Across each of these transformations, a common theme emerges: Connected products are part of complex and ever-changing ecosystems that extend well beyond the product itself. Designing IoT-enabled products, therefore, challenges organizations to think beyond the object to understand exactly how those complex ecosystems work. It requires them to adapt—and to develop new capabilities to keep up with the pace of change.

From analog to digital: Preparing the organization for connected design

The issue of "designing for the IoT" moves beyond the contours of product design to touch on organizational design. To effectively design a connected product, the organization should first consider how it will handle the transformations that IoT technology imposes on product design. These new requirements can, in turn, result in a shift in design mind-set, responsibilities, and design and management workflows.[31]

To accommodate these shifts, the organization needs to evolve, which can manifest in three broad ways: people, process, and technology. It is important to note that the changes occurring throughout the organization need not be exclusive to just one of these pillars—particularly with a comprehensive technology such as the IoT. Rather, evolutions can span all three, and each can bleed into the other.

People: Changing talent needs

As designers begin to think about developing a connected, smart object—or adding intelligence to a previously unconnected product—they will need to develop new skills to enable them to do so. These can include programming capabilities[32] or app design—or at least, the ability to consider the need for those features in a product, and the means to find an expert resource to bring those features to life. To this end, organizations will need to develop networks of reliable experts, either within the organization or via external specialists.

IT and product design skills don't always overlap, and a traditional consumer products company looking to incorporate IoT technology for the first time may need to bring in a wider range of digital skills such as programmers, engineers specializing in artificial intelligence, and other related skill sets.[33] On the other hand, a software company looking to launch its first connected object may need industrial designers, materials scientists, or human-factor specialists to deal with the physical aspects of the new product. Always helpful: individuals who can visualize the design in big-picture terms and understand how the components fit together holistically.

As these skill sets and talent needs come to life within an organization, it will then be important to consider how these experts and specialties will work together, and how their design processes will evolve to accommodate new IoT-specific design requirements.

Process: Changing mind-sets—and design approaches

In a connected environment, designers' concerns hardly stop at the object itself. They should consider the data that usage of the object generates—the lifeblood of an IoT system. The product's objective is no longer purely physical, and the information it generates helps shape a new value proposition—and can even result in new, ongoing data-based service offerings.[34] Reorienting the design process to focus on that data output as a key design objective may also mean working cross-functionally with teams that understand once-arcane principles—for example, data analytics. These teams can thus provide insights as to what data characteristics—frequency, scale, scope, and others—are most important to consider. This can enable design teams to create products capable of creating and communicating the right data effectively and efficiently.[35]

Sharing and thinking collaboratively and cross-functionally can require shifts that go beyond individual skills to the organization itself. Indeed, management may need to institute processes to enable broader communication across teams, backgrounds, and even geographies.[36] This can also impact leadership: Senior executives may need to reconsider how they manage cross-functional teams, think beyond their own areas of expertise, and create a culture that prioritizes innovative product design.[37] These changes in team organization, design considerations, and necessary skill sets can encourage designers to incorporate and update venerated design philosophies to accommodate the new demands of IoT technology. (See sidebar, "Applying design philosophies to the IoT.")

Technology: Broadening capabilities to accommodate data flows

Manufacturers that have traditionally focused on developing purely physical objects—or objects that may be connected in only limited ways—may need to develop or acquire new capabilities to incorporate IoT technology into designs. They can do so on multiple fronts.

First, organizations will need to have the technological resources and capabilities to enable the design of objects containing IoT hardware—such as sensors and other physical components for connectivity—and capable of running the requisite software.

APPLYING DESIGN PHILOSOPHIES TO THE IOT

There are nearly as many design philosophies as there are designers. No single philosophy is intrinsically more valid than any other; the decision to use any particular philosophy depends on the context, and sometimes a design calls for more than one approach. Several philosophies are particularly salient to IoT design:

- **Systems thinking.** To bring order to complexity, designers may turn to a design philosophy called systems thinking, which allows engineers and designers to understand the boundaries between different parts of a product, even when those parts can be separated by thousands of miles and owned by different organizations. Systems thinking focuses on looking at the object as part of a larger ecosystem rather than discrete and independent.[38] For this reason, systems thinking is well suited to deal with complex ecosystems such as an IoT-enabled system.
- **Design thinking.** If systems thinking is fundamentally about understanding the complex ecosystem in which a product operates, design thinking takes this concept a step further, urging designers to picture that system but place a human at its center.[39] In doing so, designers can assess the needs, wants, and dislikes of their product's likely user and meet those needs not only with the product itself but with everything around it: how it is made, packaged, and sold, and all of the other connections that support it.
- **Lean startup.** Based on the concept of "fail fast, succeed sooner," lean startup focuses on rapid iteration—or agile approaches—to better meet customers' needs.[40] In his eponymous book, Eric Ries describes how designers should Build-Measure-Learn quickly and repeatedly in order to meet ever-changing customer needs with the smallest amount of overhead.[41] Indeed, one of the principles of lean startup is to produce an optimized design quickly, with minimal waste.

No matter which design philosophy best suits the organization, the transformative challenges of IoT technology guide the approach. These design philosophies are like parallel roads to the same city: The exact paths may be different, but the ultimate destination is the same. In IoT product design, that destination means realizing that organizational change is required to meet the complex, changing demands of connected products.

Beyond the object itself, companies should consider how they will manage the resulting information flows: how they will aggregate, analyze, and act on any data these smart objects generate on an ongoing basis as they move from selling simple products to selling products *and* services.[42] Furthermore, because of that potentially valuable user data, products and solutions may at some point need to connect to or communicate with other systems within the organization, such as customer accounts or order management systems, to enable more tailored services or customer behavior-based pricing structures.[43] In the case of connected machinery, companies may need to aggregate data with that of other machines to better enable capabilities such as predictive maintenance[44]—or to inform future designs of the same object.[45] Thus, designs may need to be integrated and interoperable with other core IT systems, increasing both design complexity and technological capabilities necessary for not only design and production but ongoing function as well.

Companies can also use these information flows to realize new opportunities, such as continuous improvement of products. Product development does not stop once a product transitions from R&D into manufacturing, and engineering teams have traditionally used reliability testing combined with analysis of field failures to identify design weaknesses that need to be addressed in future releases. Adding connectivity to a product gives designers the opportunity to monitor product performance and failures in real time in their actual environment. By incorporating the ability to monitor critical performance and environmental metrics such as temperature, battery condition, and wireless signal strength, designers can correlate specific conditions with specific failures. The company can then use that data to issue a firmware update to fix the problem in the field, or to construct a targeted set of lab tests that duplicate the conditions that caused the failure. Connectivity gives designers a window into how, what, why, and where failures occur and makes sustaining a product easier—if they have the appropriate technological and organizational capabilities in place to act on the information.

The rapid rate of change in IoT technology and the potential to realize design benefits—such as continuous improvement—suggest that organizations may need additional technological capabilities to push regular software updates to objects as well receive data from them. This is yet another factor for which designers should account as they grapple with multiple life cycles within just one product.

Conclusion

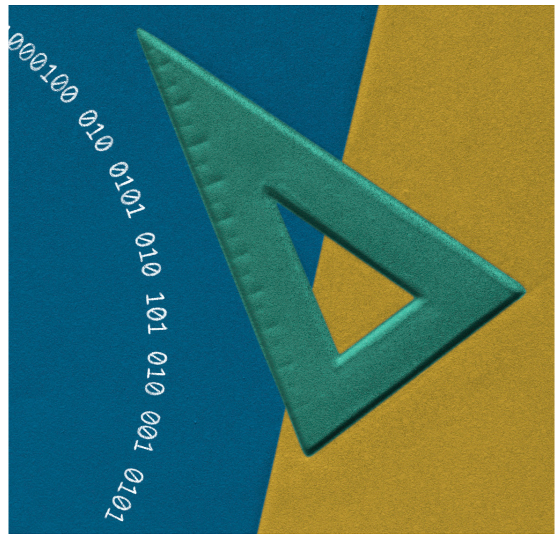
In changing the nature of products, IoT technology unavoidably guides their design. If an organization wants to meet the new challenges imposed by these transformations and successfully design connected products, it should rise to the challenge. As companies focus on readying themselves to design and develop IoT-enabled objects, they can consider the following actions:

- **Build a talent pool** capable of addressing digital and physical issues, such as artificial intelligence, app design, programming, and big data analytics. By combining two disciplines—the digital and the physical—designers can reorient their thinking to account for new, IoT-specific requirements. This may involve upending the design process to start from the premise of the desired information outcome rather than the desired physical form.

- **Coach designers** to know their limitations and recognize when they should engage experts outside their traditional teams. Knowing the possibilities—but also where help is needed—will be important for changing designers' mind-set so they feel comfortable looking to experts with unfamiliar skill sets.[46]

- **Encourage cross-functional collaboration** to ensure that designers and engineers can share expertise and focus on solving the design challenge together. Rather than continuing to focus on functional specialization—a tenet of traditional design—organizations can promote the creation of design teams with representatives from each function.[47] This may help design teams cope with unexpected changes internally and much more rapidly and effectively.[48]

- **Train managers** to lead cross-functional teams and encourage collaboration. Organizations can consider rotational programs in which leaders and other high-potential employees can gain experience in multiple areas crucial to IoT product design, providing the skills to more effectively manage diverse teams and projects.



- **Stress simplicity** through a digital design approach, even as the object necessarily grows more complex. Designers and engineers should consider expanding their thinking to incorporate a digital approach, including CX/UX approaches used in website and app design. They can include regular testing throughout the design process to help ensure that connected objects, while expanding functionality, retain simple interfaces that make them easy to use.

- **Bring IT into the picture early and often.** In keeping with the more collaborative, cross-functional model of effective IoT product design, including IT experts on the design team can provide much-needed expertise about incorporating often-complex technologies. As Eric Libow, the CTO of Internet of Things Lab Services and Support at IBM, explains, "we recommend that companies considering IoT start with a use case for a line of business but involve the IT group from the start, because you almost always want to use or interface with at least some legacy systems."[49]

- **Develop a plan** for accommodating future technological advancements in current designs. To account for future developments, engineers may incorporate modularity in some components, enabling service providers to swap outdated hardware for updated options capable of accommodating next-generation software as it becomes available. Thus, objects meant to have long lifespans—such as automobiles, appliances, grids, buildings, and industrial machinery—can assimilate new technologies with shorter life cycles.

As companies adapt existing products—and create new ones—for a connected world, no single solution or approach is correct in all situations. And since IoT technology is still in a nascent stage of development, the future of connected objects will get only more interdependent and complex, and organizations should consider and prepare for the changes that smart connectivity can bring to their products and their designs.

ENDNOTES

1. Dimitris Kiritsis, "Closed-loop PLM for intelligent products in the era of the Internet of things," *Computer-Aided Design* 43(5), May 2011, pp. 479–501.
2. Michael Raynor and Mark J. Cotteleer, "The more things change: Value creation, value capture, and the Internet of Things," *Deloitte Review* 17, July 27, 2015, http://dupress.com/articles/value-creation-value-capture-internet-of-things/.
3. Eleonora Borgia, "The Internet of Things vision: Key features, applications and open issues," *Computer Communications* 54(1), December 1, 2014, pp. 1–31.
4. Irene Ng, Kimberley Scharf, Ganna Pogrebna, and Roger Maull, "Contextual variety, Internet-of-Things and the choice of tailoring over platform: Mass customisation strategy in supply chain management," *International Journal of Production Economics* 159, January 2015, pp. 76–87.
5. Oleksiy Mazhelis et al., "Internet-of-things market, value networks, and business models: State of the art report," University of Jyväskylä Department of Computer Science and Information Systems, 2013, http://internetofthings.fi/extras/IoTSOTAReport2013.pdf, accessed August 18, 2016.
6. Brenna Sniderman and Michael Raynor, "Power struggle: Customers, companies, and the Internet of Things," *Deloitte Review* 17, July 27, 2015, http://dupress.com/articles/internet-of-things-customers-companies/.
7. Raynor and Cotteleer, *The more things change*.
8. Ibid.
9. Susan H. Higgins and William L. Shanklin, "Seeking mass market acceptance for high-technology consumer products," *Journal of Consumer Marketing* 9(1), pp. 5–14, 1992, www.emeraldinsight.com/doi/abs/10.1108/EUM0000000002592.
10. According to recent research, the most common type of fear among consumers when facing new technology is fear of technical complexity. For more, see Higgins and Shanklin, "Seeking mass market acceptance for high-technology consumer products."
11. For examples of how consumers (and workers) can be resistant to change old habits, and what strategies can effectively mitigate that resistance, see James Guszcza, "The last-mile problem: How data science and behavioral science can work together," *Deloitte Review* 16, January 26, 2015, http://dupress.com/articles/behavioral-economics-predictive-analytics/.
12. Claire Rowland, "What's different about user experience design for the Internet of Things?", O'Reilly, September 20, 2015, www.oreilly.com/learning/whats-different-about-user-experience-design-for-the-internet-of-things.
13. Ibid.
14. Irfan Saif, Sean Peasley, and Arun Perinkolam, "Safeguarding the Internet of Things: Being secure, vigilant, and resilient in the connected age," *Deloitte Review* 17, July 27, 2015, http://dupress.com/articles/internet-of-things-data-security-and-privacy/.
15. Ibid.
16. Gerd Kortuem, Fahim Kawsar, Vasughi Sundramoorthy, and Daniel Fitton, "Smart objects as building blocks for the Internet of Things," *IEEE Internet Computing* 14(1), December 2009, pp. 30–37, www.fahim-kawsar.net/papers/Kortuem.IEEEInternet2010.Camera.pdf.

17. Dan Rhodes, *Choosing the right mobile communications technology for IoT*, Deloitte Digital blog, May 23, 2016, www.deloittedigital.com/blog/choosing-the-right-mobile-communications-technology-for-iot.

18. David D. Clark, John Wroclawski, Karen R. Sollins, and Robert Braden, "Tussle in cyberspace: defining tomorrow's internet," IEEE/ACM Transactions on Networking (TON) archive 13(3), June 2005, pp. 462–75.

19. Paul Daugherty, Prith Banerjee, and Allan Alter, "5 ways product design needs to evolve for the Internet of Things," *Harvard Business Review,* November 14, 2014, https://hbr.org/2014/11/5-ways-product-design-needs-to-evolve-for-the-internet-of-things.

20. Dieter Bohn, "Google Home: A speaker to finally take on the Amazon Echo," *Verge*, May 18, 2016, www.theverge.com/2016/5/18/11688376/google-home-speaker-announced-virtual-assistant-io-2016.

21. IFFFT, "Amazon Alexa Channel," https://ifttt.com/amazon_alexa, accessed August 18, 2016.

22. OSIsoft, "OSIsoft's connected services enables Flowserve's global rotating equipment monitoring solutions," presented at 2015 EMEA User's Conference, www.osisoft.com/uploadedFiles/Pages/Solutions/Business_Solutions/Enhance_Aftermarket_Services/customer-brief-flowserve.pdf, accessed August 18, 2016.

23. For an example of how consumer feedback contributed to design in a pre-IoT world, see Peter H.Bloch, "Seeking the ideal form: Product design and consumer response," *Journal of Marketing* 59(3), 1995, pp. 16–29.

24. The most recent and most notable example of this is Nest's recent decision to disable all of its Revolv home hubs. If a product had been designed to operate expressly with the Revolv hub, that product too would now be rendered inoperable. For more information on the shutdown of Revolv hub and the related issues, see Aaron Tilley, "Nest's Revolv shutdown debacle underscores business model challenges for 'Internet of Things,'" *Forbes*, April 12, 2016, www.forbes.com/sites/aarontilley/2016/04/12/nests-revolv-shutdown-debacle-underscores-business-model-challenges-for-internet-of-things/.

25. James R. Bradley and Héctor H. Guerrero, "Product design for life-cycle mismatch," *Production and Operations Management* 17(5), September–October 2008, pp. 497–512.

26. IHS, "Average age of light vehicles in the U.S. rises slightly to 11.5 years, IHS reports," *BusinessWire*, July 29, 2015, http://press.ihs.com/press-release/automotive/average-age-light-vehicles-us-rises-slightly-2015-115-years-ihs-reports.

27. Simon Ninan, Bharath Gangula, Matthias von Alten, and Brenna Sniderman, "Who owns the road? The IoT-connected car of today—and tomorrow," Deloitte University Press, August 18, 2015, http://dupress.com/articles/internet-of-things-iot-in-automotive-industry/.

28. Ibid.

29. Peter Stephan, Markus Eich, Jörg Neidig, Martin Rosjat, and Roberto Hengst, "Applying digital product memories in industrial production," in Wolfgang Wahlster, *SemProM: Foundations of Semantic Product Memories for the Internet of Things* (Berlin: Springer, 2013), pp. 283–304.

30. For more information on continuous engineering, see Zach Jory, "The impact of the Internet of Things on product development," IBM Big Data & Analytics Hub, October 5, 2015, www.ibmbigdatahub.com/blog/impact-internet-things-product-development.

31. Avan R. Jassawalla and Hemant C. Sashittal, "An examination of collaboration in high-technology new product development processes," *Journal of Product Innovation Management* 15(3), 1998, pp. 237–54.

32. Rick Delgado, "5 IT skills you'll need as the Internet of Things becomes a reality," Tech.co, June 28, 2015, http://tech.co/it-skills-internet-things-2015-06.

33. Sudarshan Krishnamurthi, "Addressing the IoT skills gap," presentation to IoT Talent Consortium, March 2016, https://workspace.iiconsortium.org/kws/public/download/5208/IIC_Cisco_IoT_Talent_Consort_Preso_March2016.pdf, accessed June 14, 2016.

34. Brenna Sniderman, Monika Mahto, and Mark J. Cotteleer, *Industry 4.0 and manufacturing ecosystems: Exploring the world of connected enterprises*, Deloitte University Press, February 22, 2016, http://dupress.com/articles/industry-4-0-manufacturing-ecosystems-exploring-world-connected-enterprises/.

35. Delgado, "5 IT skills you'll need as the Internet of Things becomes a reality."

36. Avan R. Jassawalla and Hemant C. Sashittal, "Building collaborative cross-functional new product teams," *Academy of Management Perspectives* 13(3), 1999, pp. 50–63.

37. Jassawalla and Sashittal, "An examination of collaboration in high-technology new product development processes."

38. Herbert Simon, "The architecture of complexity," *Proceedings of the American Philosophical Society* 106(6), December 12, 1962, pp. 467–82, http://pespmc1.vub.ac.be/books/architectureofcomplexity.pdf.

39. Tim Brown, "Design thinking," *Harvard Business Review*, June 2008, https://hbr.org/2008/06/design-thinking.

40. Stephen Jordan, "Lean startup, design thinking & open innovation for the enterprise," Design Management Institute, August 21, 2015, www.dmi.org/news/247277/Lean-Startup-Design-Thinking--Open-Innovation-for-the-Enterprise.htm.

41. Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses* (N.Y.: Crown Business, 2011).

42. Kiritsis, "Closed-loop PLM for intelligent products in the era of the Internet of things."

43. Joe Mariani, Evan Quasney, and Michael E. Raynor, "Forging links into loops: The Internet of Things' potential to recast supply chain management," *Deloitte Review* 17, July 27, 2015, http://dupress.com/articles/internet-of-things-supply-chain-management/.

44. Sniderman, Mahto, and Cotteleer, *Industry 4.0 and manufacturing ecosystems*.

45. Mark J. Cotteleer, Stuart Trouton, and Ed Dobner, *3D opportunity and the digital thread: Additive manufacturing ties it all together*, Deloitte University Press, March 3, 2016, http://dupress.com/articles/3d-printing-digital-thread-in-manufacturing/.

46. Jassawalla and Sashittal, "Building collaborative cross-functional new product teams."

47. Sang M. Lee, David L. Olson, and Silvana Trimi, "Co-innovation: Convergenomics, collaboration, and co-creation for organizational values," *Management Decision* 50(5), 2012, pp. 817–31.

48. Michael A. Hitt, Robert D. Nixon, Robert E. Hoskisson, and Rahul Kochhard, "Corporate entrepreneurship and cross-functional fertilization: Activation, process and disintegration of a new product design team," *Entrepreneurship: Theory and Practice* 145, spring 1999, June 7, 2016.

49. Conversation with authors, October 1, 2015.

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