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Industry Agenda

Industrial Internet of Things (IIoT): Unleashing the of Connected Products and Services

TelnT next generation IIoT real-time wireless artificial intelligence platforms

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September 2017

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REF TeInT230917

Executive summary

During the past 15 years, the Internet revolution has redefined business-to - consumer (B2C) industries such as media, retail and financial services. In the next 10 years, the Internet of Things revolution will dramatically alter manufacturing, energy, agriculture, transportation and other industrial sectors of the economy which, together, account for nearly two-thirds of the global gross domestic product (GDP). It will also fundamentally transform how people will work through new interactions between humans and machines.

Dubbed the Industrial Internet (of Things), this latest wave of technological change will bring unprecedented opportunities, along with new risks, to business and society. It will combine the global reach of the Internet with a new ability to directly control the physical world, including the machines, factories and infrastructure that define the modern landscape. However, like the Internet was in the late 1990s, the Industrial Internet is currently in its early stages. Many important questions remain, including how it will impact existing industries, value chains, business models and workforces, and what actions business and government leaders need to take now to ensure long-term success.

To address these and other questions facing business and government leaders, the TelnT's IT Governors launched the Industrial Internet initiative at internet of things("IoT") Meeting 2016 in Israel. During the last eight months, the project team has developed a guiding framework and conducted a series of research activities, including in-person workshops, virtual working group sessions, interviews of key thought leaders, and a survey of innovators and early adopters around the world (information about this research can be found in Appendix A).

Key research findings

Our research concludes that the Industrial Internet is indeed transformative. It will change the basis of competition, redraw industry boundaries and create a new wave of disruptive companies, just as the current Internet has given rise to Amazon, Google and Netflix. However, the vast majority of organizations are still struggling to understand the implications of the Industrial Internet on their businesses and industries. For these organizations, the risks of moving too slowly are real.

Opportunities and benefits

Our research reveals that disruption will come from new value creation made possible by massive volumes of data from connected products, and the increased ability to make automated decisions and take actions in real time. The key business opportunities will be found in four major areas:

- Vastly improved operational efficiency (e.g., improved uptime, asset utilization) through predictive maintenance and remote management
- The emergence of an outcome economy, fuelled by software-driven services; innovations in hardware; and the increased visibility into products, processes, customers and partners
- New connected ecosystems, coalescing around software platforms that blur traditional industry boundaries
- Collaboration between humans and machines, which will result in unprecedented levels of productivity and more engaging work experiences

As the Industrial Internet gains broader adoption, businesses will shift from products to outcome-based services, where businesses compete on their ability to deliver measurable results to customers. Such outcomes may range from guaranteed machine uptimes on factory floors, to actual amounts of energy savings in commercial buildings, to guaranteed crop yields from a specific parcel of farmland.

Delivering such outcomes will require new levels of collaboration across an ecosystem of business partners, bringing together players that combine their products and services to meet customer needs. Software platforms will emerge that will better facilitate data capture, aggregation and exchange across the ecosystem. They will help create, distribute and monetize new products and services at unprecedented speed and scale. The big winners will be platform owners and partners who can harness the network effect inherent in these new digital business models to create new kinds of value. For instance, Qualcomm Life's 2net platform supports a wide range of connected devices that can all contribute patient health data to improve hospital-to-home health and economic outcomes.

Our research also shows that the Industrial Internet will drive growth in productivity by presenting new opportunities for people to upgrade skills and take on new types of jobs that will be created. An overwhelming majority of executives we surveyed believe that the growing use of "digital labour" in the form of smart sensors, intelligent assistants and robots will transform the skills mix and focus of tomorrow's workforce.

While lower-skilled jobs, whether physical or cognitive, will be increasingly replaced by machines over time, the Industrial Internet will also create new, high-skilled jobs that did not exist before, such as medical robot designers and grid optimization engineers. Companies will also use Industrial Internet technologies to augment workers, making their jobs safer and more productive, flexible and engaging. As these trends take hold, and new skills are required, people will increasingly rely upon smart machines for job training and skills development.

Risks and challenges

To realize the full potential of the Industrial Internet, businesses and governments will need to overcome a number of important hurdles. Chief among them are security and data privacy, which are already rising in importance given increased vulnerabilities to attacks, espionage and data breaches driven by increased connectivity and data sharing. Until recently, cyber security has focused on a limited number of end points. With the advent of the Industrial Internet, these measures will no longer be adequate as the physical and virtual worlds combine at a large scale. Organizations will need new security frameworks that span the entire cyber physical stack, from device-level authentication and application security, to system-wide assurance, resiliency and incidence response models.

Another crucial barrier is the lack of interoperability among existing systems, which will significantly increase complexity and cost in Industrial Internet deployments. Today's operational technology systems work largely in silos. However, in the future, a fully functional digital ecosystem will require seamless data sharing between machines and other physical systems from different manufacturers. The drive towards seamless interoperability will be further complicated by the long life span of typical industrial equipment, which would require costly retrofitting or replacement to work with the latest technologies.

In addition, other notable barriers and risks include uncertain return on investments on new technologies, immature or untested technologies, lack of data governance rules across geographic boundaries and a shortage of digital talent. Overcoming these challenges will require leadership, investment and collaborative actions among key stakeholders.

Summary of recommendations

To seize near-term opportunities, capitalize on the long-term structural shift and accelerate the overall development of the Industrial Internet, our research recommends the following actions:

—— Technology providers should begin to inventory and share best security practices, perhaps by establishing a global security commons. They should participate in the development of technology test-beds to demonstrate how solutions from different organizations can work together. And they need to focus on brownfield innovation1 to support existing equipment in the field, and raise the market awareness on successful use cases and implementations.

—— Technology adopters should first reorient their overall business strategy to take full advantage of the latest developments in the Industrial Internet. They also need to identify their new ecosystem partners, and determine whether they should join a partner's platforms or develop their own. Companies that still are new to the Industrial Internet should identify one or two relevant pathfinder applications that can be piloted within the next six months to create necessary momentum and learning.

—— Public policy-makers must re-examine and update their data protection and liability policies to streamline trans-border data flow. They also need to revisit the current regulations on such industries as utilities and healthcare to encourage investment and the adoption of new digital processes.
In emerging markets, governments will need to increase investment in digital infrastructure (e.g. embedded sensors, broadband connectivity) to take advantage of the leapfrogging potential of the Industrial Internet in accelerating regional economic development. And policy-makers need to learn more about societal and policy implications of the Industrial Internet, and function as role models in advocating and supporting high-potential applications such as smart cities.

—— All stakeholders need to work together in three important areas. Industries, governments and academia need to collaborate on long-term R&D to solve fundamental technology challenges related to security, interoperability and management of systemic risks. They need to conduct joint lighthouse projects to demonstrate the real benefits and raise the profile of the Industrial Internet among the general public. They also need to implement new training programmers, and provide policy incentives to employers and workers to encourage reskilling for high-demand job categories.

The Internet of Things is ground zero for a new phase of global transformation powered by technology innovation, generating significant economic opportunities and reshaping industries.

Marc Benioff, Chairman and Chief Executive Officer, Salesforce.com, USA

General findings

2.1 The state of the market

Analyst firm Gartner recently declared that the Internet of Things (IoT) was the most hyped technology in 2017 Much of this hype centers on consumer applications, such as smart homes, connected cars and consumer wearables like wristband activity trackers. However, it is the IoT's industrial applications or the Industrial Internet", which may ultimately dwarf the consumer side in potential business and socioeconomic impacts. The Industrial Internet will transform many industries, including manufacturing, oil and gas, agriculture, mining, transportation and healthcare. Collectively, these account for nearly two-thirds of the world economy.[3] As society evolves towards an integrated digital-human workforce, the Industrial Internet will redefine the new types of new jobs to be created, and will reshape the very nature of work. Given the greater significance, this report focuses exclusively on the Industrial Internet.

The Industrial Internet is still at an early stage, similar to where the Internet was in the late 1990s. Our survey results underscore this point: the vast majority (88%) of respondents say that they still do not fully understand its underlying business models and long-term implications to their industries. While the evolution of the consumer Internet over the past two decades provides some important lessons, it is unclear how much of this learning is applicable to the Industrial Internet given its unique scope and requirements. For example, real-time responses are often critical in manufacturing, energy, transportation and healthcare. Real time for today's Internet usually means a few seconds, whereas real time for industrial machines is often sub-millisecond. The engineering rule of thumb dictates that a 10x change in performance requires an entirely new approach, not to mention the 100x change that the Industrial Internet will likely need.

Another important consideration is reliability. The current Internet embodies a "best effort" approach, which provides acceptable performance for e-commerce or human interactions. Unexpected server glitches at Google or Amazon cause delays in email or streamed video. However, the failure of the power grid, the air traffic control system or an automated factory for the same length of time would have much more serious consequences. This strong bias towards real time and reliability, which has contributed to a conservative culture among industrial companies in embracing change and new technologies, together with the high cost and long life span of typical industrial products, are all critical factors in shaping how the Industrial Internet will evolve.

Despite these barriers, adoption of the Industrial Internet is accelerating. During the past three years, for example, the number of sensors shipped has increased more than five times from 4.2 billion in 2012 to 23.6 billion in 2017.[4] Much attention is drawn to the efforts by large companies such as Cisco, GE, and Huawei, and government initiatives like Industry 4.0 in Germany. The second Internet of Things World Forum hosted by Cisco featured more than 250 real-world deployment examples showing how companies and municipalities from around the globe are already applying the Industrial Internet to drive efficiencies, create new revenue streams and improve quality of life for citizens and consumers. In addition, the event's steering committee, comprising more than 100 leading organizations from the user and provider communities, introduced a seven-layer IoT reference model as a common framework and vocabulary to drive efficient collaboration and future deployments.[5] In another example, GE announced that it has realized more than $1 billion in incremental revenues in 2017 by helping customers improve asset performance and business operations through Industrial Internet capabilities and services.[6] Outside of the US, Huawei recently announced the acquisition of Neul -- the UK-based Industrial Internet startup that was one of the key supporters of the Weightless standard for low-power M2M communications.

In Europe, the German government is sponsoring Industrie 4.0, a multi-year strategic initiative that brings together leaders from the public and private sectors as well as from academia to create a comprehensive vision and action plan for applying digital technologies to the German industrial sector. China has also recently proposed its "Made in China 2025" strategy to promote domestic integration of digital technologies and industrialization. High-level dialogue is underway between the German and Chinese governments on how the two manufacturing powerhouses can work together to accelerate the realization of the Industrial Internet in their two countries.[7]

Workshop Highlights - San Jose, California, USA, 23-24 July, 2016

- The near-term opportunity lies in operational efficiency and productivity gains.
- Over the long-term, new business models around products-as-a-service, pay-per-use models and monetization of data will emerge.
- Industry verticals will blur through shared relationships with customers, partners and data.

New data aggregation will fuel the platform economy.

- Increase in automation will take over lower-wage and lower-skilled jobs that are repetitive and unsafe for humans.
- The required education level will rise and necessary skillsets will shift. Demand for higher- skilled and higher-wage resources will increase.
- There will be a heightened need for engineers to develop robots, and for data scientists and managers to analyze data and draw insight.
- At the current stage of development, government regulations should be designed to spur innovation and be responsive to changing market conditions.

Another sign of strong industry momentum is the emergence of consortia to address the growing need for industry collaboration on common concerns such as security and interoperability. Among these are the Industrial Internet Consortium (IIC), the AllSeen Alliance and Open Interconnect Consortium (OIC). While AllSeen and OIC focus on device-level connectivity, the goal of the IIC is to accelerate the adoption and deployment of Industrial Internet applications through technology test-beds, use cases and requirements development. Since its establishment in March 2017, IIC has expanded its member base to include more than 100 organizations, with one -third from outside the US. The rapid growth and diversity of IIC membership shows both the value of and strong need for high-level industry collaboration in this area.

The Industrial Internet has also attracted increasing levels of venture capital, with an estimated $1.5 billion in 2017.[8] Unlike in other technology sectors, venture capital funding for the Industrial Internet comes primarily from large corporate venture funds, such as GE Ventures, Siemens Venture Capital, Cisco Investments, Qualcomm Ventures and Intel Capital.

Siemens, for example, recently launched a new $100 million "Industry of the Future Fund" to fund early-stage start-ups in industrial automation and other digital technologies that can transform future manufacturing.[9] Meanwhile, dedicated and hybrid funds are also emerging in this market. McRock Capital is one of the first such funds devoted to start-ups in advanced manufacturing, grid automation, smart cities and digital oil fields. And GE recently announced a partnership with big data incubator Frost Data Capital to create Frost I3, which will fund and incubate 30 Industrial Internet technology start-ups in the next three years.[10]

2.2 The four phases of the Industrial Internet evolution

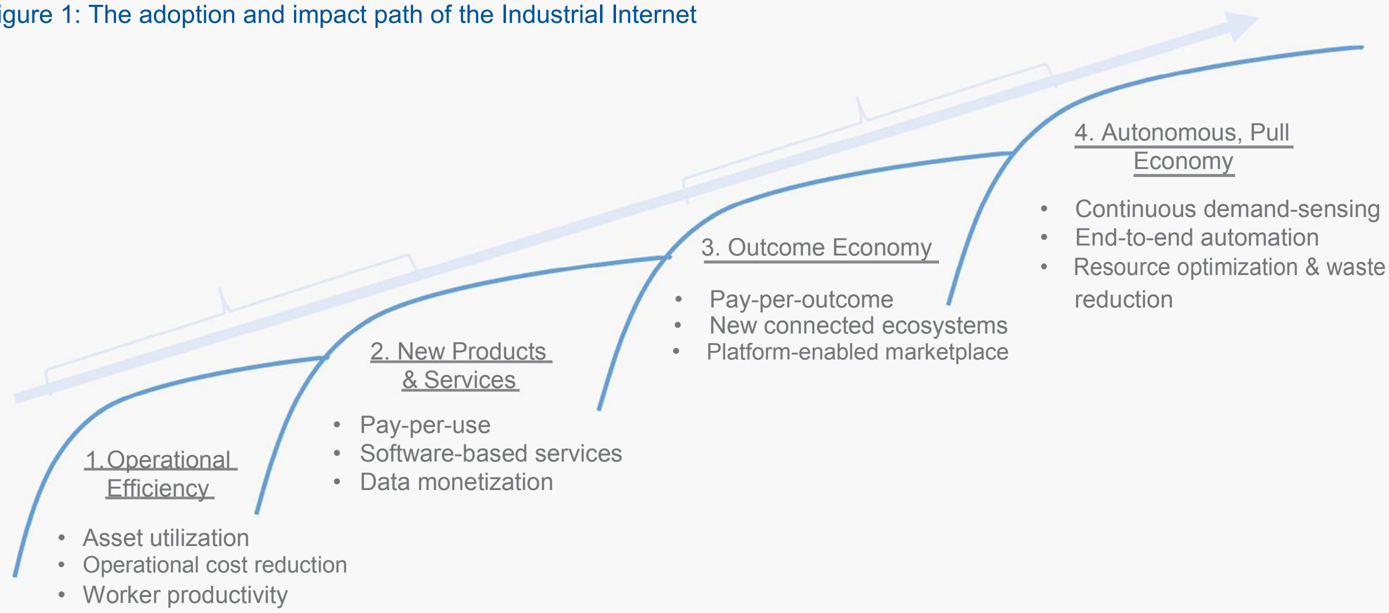
As depicted in Figure 1, research shows that the future evolution of the Industrial Internet will likely follow four distinct phases. Phases 1 and 2 represent immediate opportunities that drive the near-term adoption, starting with operational efficiency. These activities are happening now, and will likely accelerate in the next two years.

Phases 3 and 4 include long-term structural changes that are roughly three years away from mainstream adoption. Survey results support the view that the impact of the Industrial Internet is incremental in the near-term (see Section 2.3 for details) but transformative over the long-term: 72% of respondents believe that the development of the Industrial Internet will be disruptive to their businesses and industries, and more (79% of respondents) think those disruptions will occur within the next five years. These disruptions will manifest themselves in Phases 3 and 4 in the form of the outcome economy and an integrated human-machine workforce.

The outcome economy will be built on the automated quantification capabilities of the Industrial Internet. The large-scale shift from selling products or services to selling measurable outcomes is a significant change that will redefine the base of competition and industry structures. Delivering outcomes will require companies to forge new ecosystem partnerships centred on customer needs rather than individual products or services. Because of the rising importance in data, software and platforms, incumbent players will need to expand their capabilities and ecosystems in these areas to compete in this new marketplace. (See Section 3, "Convergence on the Outcome Economy", for more details.)

As the Industrial Internet becomes more ingrained in every industry, it will ultimately lead to a pull-based economy characterized by real-time demand sensing and highly automated, flexible production and fulfilment networks.[11]

Figure 1: The adoption and impact path of the Industrial Internet



This development will call for a pervasive use of automation and intelligent machines to complement human labor (machine augmentation). As a result, the face of the future workforce will change dramatically, along with the skill sets required to succeed in a much more automated economy. (See Section 4, "Shift towards an Integrated Digital and Human Workforce", for more details.)

2.3 Key near-term opportunities and benefits

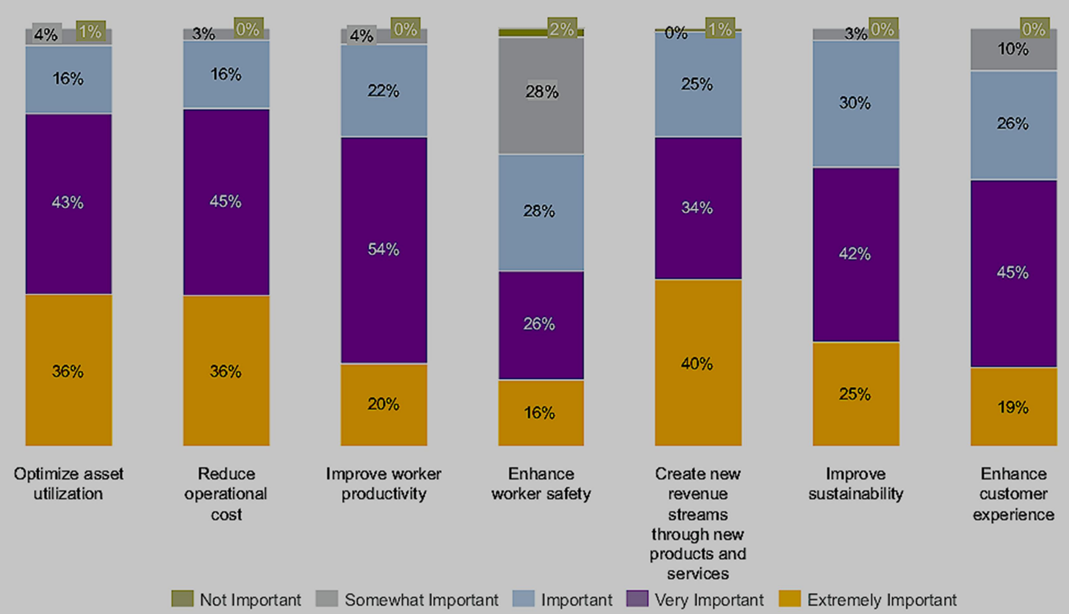
For most incumbent manufacturers, energy companies, agriculture producers and healthcare providers, the initial business case to justify the adoption of the Industrial Internet is based on incremental results in increased revenues or savings. As shown in Figure 2, our survey indicates that companies are turning to digital technology either to drive down cost or increase top-line growth: 79% of respondents indicate that "optimizing asset utilization" is a "very to extremely important" driver for adoption, while 74% say the same about creating alternative revenue streams through new products and services.

Accordingly, the most widely cited application of the Industrial Internet is predictive maintenance and remote asset management, which can reduce equipment failures or unexpected downtime based on the operational data now available. Early Industrial Internet adopters such as ThyssenKrupp, Caterpillar and Thames Water are already reaping these types of benefits. Specifically, Thames Water, the largest provider of drinking and waste -water services in the UK, is using sensors, analytics and real-time data to anticipate equipment failures and respond more quickly to critical situations, such as leaks or adverse weather events.[12]

Another key opportunity that early adopters of the Industrial Internet are pursuing is the improvement of worker productivity, safety and working conditions. Examples include using unmanned aerial vehicles (UAVs) to inspect oil pipelines, monitoring food safety using sensors, and minimizing workers' exposure to noise, chemicals and other hazardous gases, especially in traditional heavy industries like oil and gas, manufacturing and chemicals. Schlumberger, for example, is now monitoring subsea conditions using unmanned marine vehicles, which can travel across oceans collecting data for up to a year without fuel or crew, moving under power generated from wave energy.[13] Leading mining companies such as Rio Tinto have increasingly turned to new, more autonomous mining equipment to enhance mine productivity. By introducing remote monitoring and sensing technologies, these industries can dramatically decrease safety-related

Figure 2: Business benefits for driving near-term adoption

Q: How important are the following benefits in driving businesses to adopt the Industrial Internet?



incidents, while making mining in harsh locations more economical and productive.

Many organizations see great potential in leveraging the Industrial Internet to offer differentiated customer experiences. In healthcare, hospital errors are still a leading cause of preventable death and patient suffering. Many of these errors are caused by false alarms, slow response and treatments based on inaccurate information. By networking distributed medical devices, alarms can become smarter, triggering only when multiple devices indicate danger to a patient. Connecting measurements to treatments further enables smart drug delivery systems to react to patient conditions much faster and more reliably than busy hospital staff. As a result, organizations can improve patient safety and experiences, and more efficiently use hospital resources.

For society at large, the Industrial Internet will provide many opportunities for citizens and governments at all levels to improve government services and enhance the quality of life. For example, ShotSpotter uses connected microphones to determine when gun shots are fired in public and helps police identify where the gun that fired them might be located. The city of Oakland, California, saw the largest drop in homicides among all major cities in the US in 2013, in part, as a result of the deploying such a system.[14] Dozens of cities around the world are already turning to smart parking solutions, such as Streetline, to help drivers quickly and conveniently find available parking spaces. Governments can also use the Industrial Internet to support sustainability efforts by providing transparency on the utilization of resources like water, energy, fuel, fertilizers and pesticides. Such initiatives can ultimately lead to less waste and more accountability through public policies and market pricing designed to incentivize compliance and good stewardship.

2.4 Major challenges and risks

Despite the great promise and new opportunities of the Industrial Internet, many factors could hinder future growth. Figure 3 shows our survey results on perceived adoption barriers. Not surprisingly, almost two-thirds of respondents agree with the widely-held view that security and interoperability are the two biggest hurdles. Other significant barriers cited include the lack of clearly defined return on investment (ROI) (53%), legacy equipment (38%) and technology immaturity (24%). In addition, survey respondents and workshop participants cite several other concerns and potential challenges based on their experiences, including:

—— Lack of vision and leadership
—— Lack of understanding of values among management or C-level executives
—— Lack of proven business models (e.g. outcome-based revenue sharing or profit sharing)
—— Rapid evolution of the technology causing companies to delay large investments
—— Requiring heavy upfront capital investment
—— Requiring business process change

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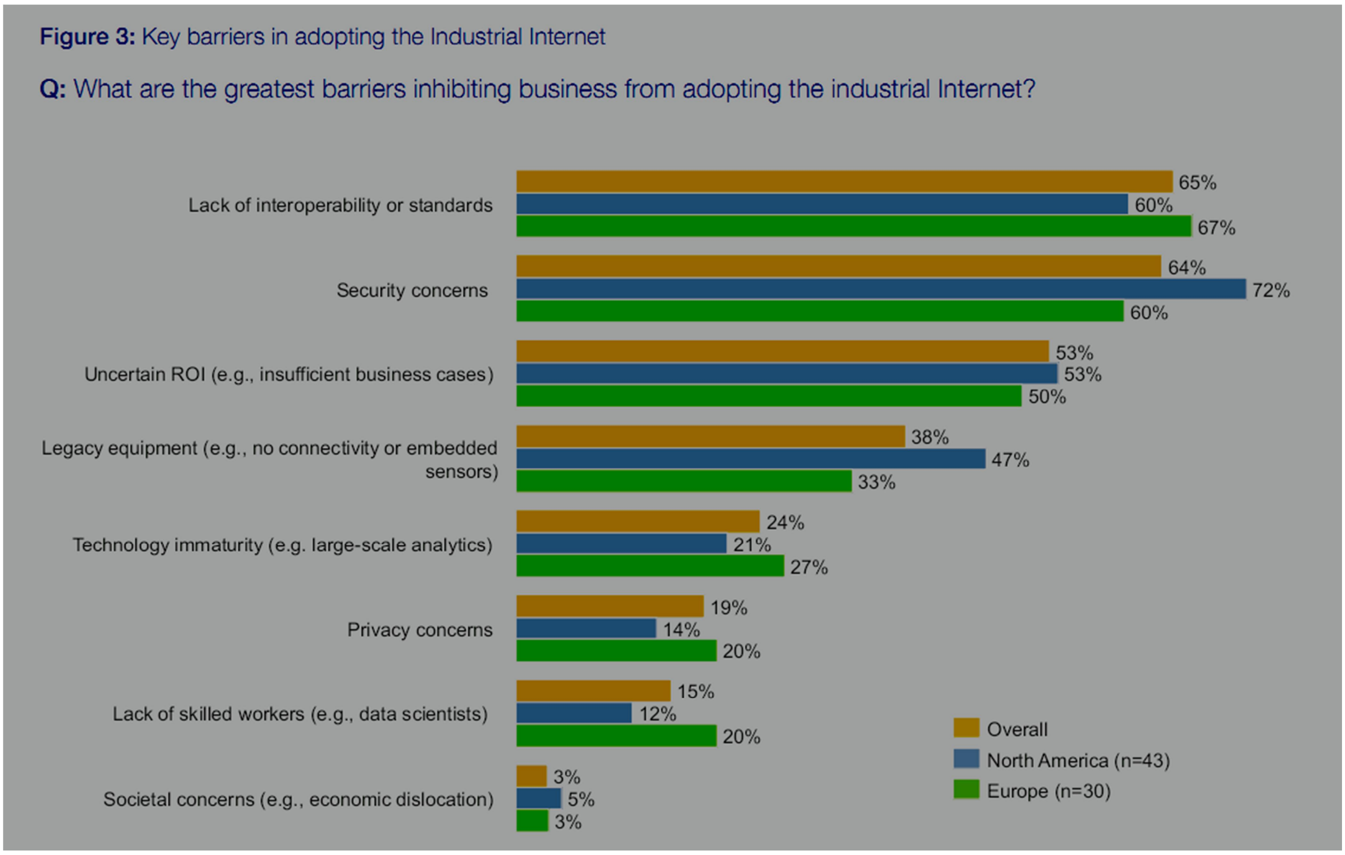


—— Not enough awareness about the current state of technology
—— Inadequate infrastructure
—— Lack of application development tools
—— High cost of sensors.

Regarding risk, respondents single out vulnerabilities for cyber-attacks as their most important concern, as more physical systems come online. As shown in Figure 4, 76% of respondents indicate that they believe the likelihood of such attacks is "very or extremely high." A related but slightly different risk is privacy breaches of personal data, which are also ranked high (68%). Both are justified when one considers such impacts as attacking a power plant to deny electricity and the loss of public trust that could occur when any Industrial Internet- enabled system is compromised. A 2017 TelnT report estimated $3 trillion in potential economic loss from cyber-security issues by 2020. In the first half of 2017 alone, hackers accessed approximately 195 million identities from records associated with utilities, medical devices, transportation and more.[15] Investments in countermeasures are increasing as a result. Gartner says more than 20% of enterprises will invest in security specifically for business initiatives using IoT devices by 2017.[16]

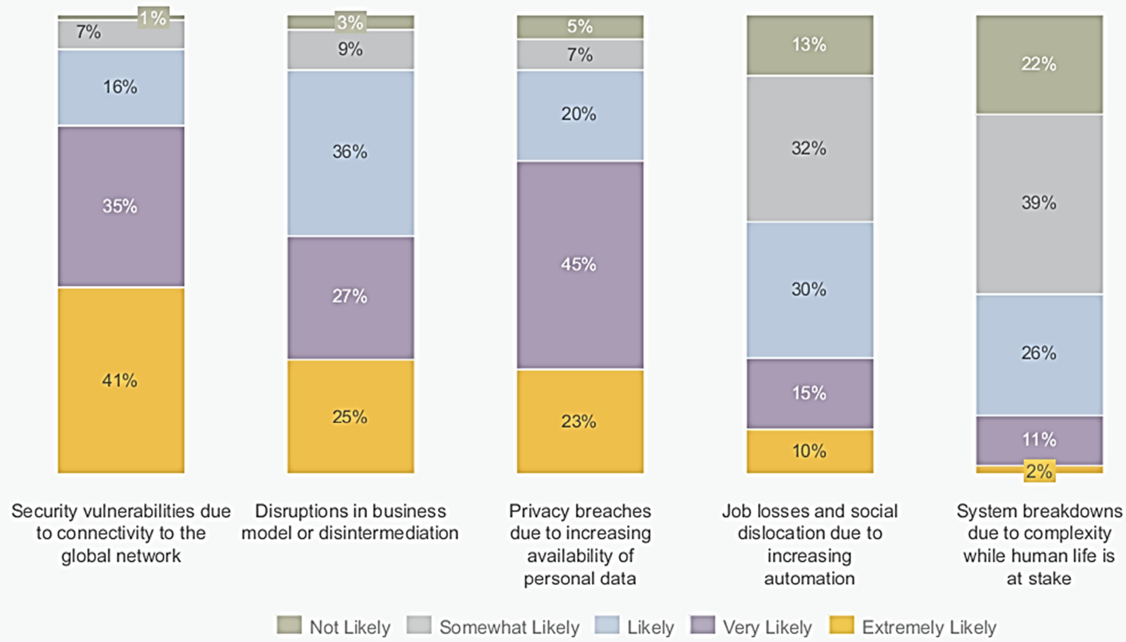
For many incumbent players, potential disruption to existing business models constitutes another significant risk, as noted by a vast majority of respondents (88%). The shift from products to services to outcomes will not only disrupt internal operations, but will impact how they go to market. Since access and control points are more open and fluid in a digital marketplace than in traditional markets, companies will face competition from a broader set of players, including digital pure plays founded on new models and platforms from their very inception. At the same time, companies will have the flexibility and opportunity to partner with many organizations across the ecosystem. In fact, such collaboration will be an imperative if companies want to meet the growing customer expectations around delivering results, i.e., it is difficult to see how one company can master the entire digital value chain.

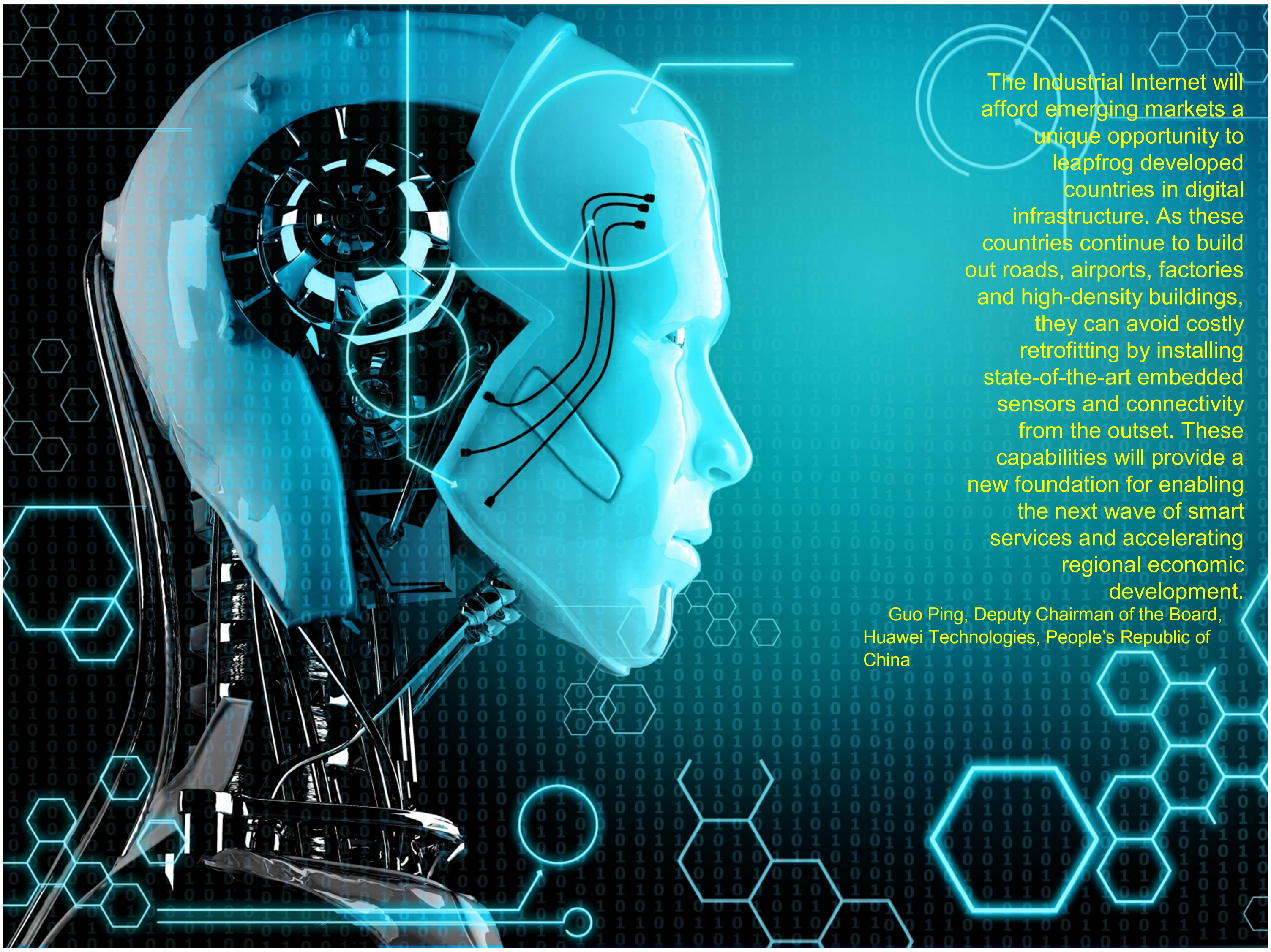
At a societal level, it is important to consider potential job displacement that will occur in some sectors due to increased automation. This process is similar to what happened in the communications industry when switchboard jobs were replaced by technology solutions. As intelligent machines become more widespread, more jobs will be impacted, even the ones long considered distinctively human. For example, with the current pace of technology improvement, self-driving cars may replace heavy truck drivers in the next 20 years.[17] However, it is equally important to anticipate that many new and different types of jobs will be created – jobs that will require unique human attributes, such as creativity, critical thinking and collaboration. (See Section 4, "Shift towards an Integrated Digital and Human Workforce", for more details.)

For industry and government leaders, it is important to note that technology is constantly raising the bar for low-skilled jobs. As a result, the need for continuous skills upgrade is real. Actions are urgently needed to refocus attention on education, adapting the current educational systems and approaches to better prepare younger generations for the upcoming digital workplace.

Figure 4: Likely risks for adopting the Industrial Internet

Q: How likely are the following risks or negative consequences associated with the Industrial Internet?




The Industrial Internet will afford emerging markets a unique opportunity to leapfrog developed countries in digital infrastructure. As these countries continue to build out roads, airports, factories and high-density buildings, they can avoid costly retrofitting by installing state-of-the-art embedded sensors and connectivity from the outset. These capabilities will provide a new foundation for enabling the next wave of smart services and accelerating regional economic development.
Guo Ping, Deputy Chairman of the Board, Huawei Technologies, People's Republic of China

Convergence on the outcome economy

Product companies have traditionally built their reputations by providing high-quality products at competitive prices, helping retail or commercial customers meet their needs more efficiently or effectively: aircraft that carry more passengers but burn less fuel; tractors that plant hectares of farmland faster; and light bulbs that last longer but consume less energy. In recent years, pressure has been mounting for manufacturers to look downstream to uncover new value creation opportunities by helping customers use their products to meet specific outcomes, such as optimizing transportation of people across long distances, increasing crop yield and providing lighting only when it is needed. This focus on solving the why behind the buy is a key driver in the ongoing evolution from products to services. The increasing availability of smart products will accelerate this process.

This new world is called the "outcome economy," where businesses compete on their ability to deliver quantifiable results that matter to their customers in a specific place and time. To achieve these goals, companies will increasingly rely on business partners, connected ecosystems, advanced analytics and new data streams from smart products in the field to gain timely insights about customer needs and behaviors.

3.1 From connected products to software-driven services

In his Wall Street Journal essay "Why Software Is Eating the World,"[18] Marc Andreessen points out software's growing importance and disruptive potential to non-technology industries. As more products become smart and connected, software is emerging as the connective tissue for value creation, even for companies that sell physical goods. The convergence of the physical and digital worlds begins with sensors and sensory data, which automates and quantifies pattern tracking for both product distribution and customer behaviours in the physical world. Such data is becoming the currency of the Industrial Internet economy, and the foundation for new software-enabled services.

Ongoing improvements in sensor technologies – including miniaturization, performance, cost and energy consumption – are making intelligent products more accessible. These sensors are increasingly being installed in industrial equipment, such as GE's latest locomotives, which are equipped with more than 250 sensors that measure 150,000 data points per minute.[19] As this level of digital infrastructure develops, companies will be able to take advantage of growing data streams to apply powerful analytics for insights that can enhance existing services, enrich customer experiences and create alternative revenue streams, not only through new products but also through entirely new business models.

With the Industrial Internet, manufacturers are already using new software capabilities to improve operational efficiency through predictive maintenance, and achieving results such as savings on scheduled repairs (12%), reduced maintenance costs (nearly 30%) and fewer breakdowns (almost 70%).[20] For example, ThyssenKrupp AG, which makes and maintains elevators in buildings around the globe, uses networked sensors for its predictive maintenance system designed to reduce down time and unnecessary trips by service personnel for elevator repair. Data from the sensors travels to the cloud, where analytics software identifies anomalies to determine what problems need immediate attention versus those that can wait for scheduled maintenance.[21]

Similarly, product companies increasingly rely on software to differentiate their products and customer experiences. For example, automotive supplier ZF Friedrichshafen AG's intelligent transmission system continuously monitors and analyses a commercial driver's behaviour, along with topographical data, to signal vehicle transmissions when to shift gears. As a result, truck transmissions last longer and use less fuel.[22]

3.2 The emergence of the outcome economy

In the outcome economy phase, companies will shift from competing through selling products and services, to competing on delivering measurable results important to the customer. This is a much more challenging prospect. Among other things, providers will require a deeper understanding of customer needs and contexts in which products and services will be used. Value based on output also entails quantifying results in real time. Both of these requirements have been nearly insurmountable obstacles to scale – until now.

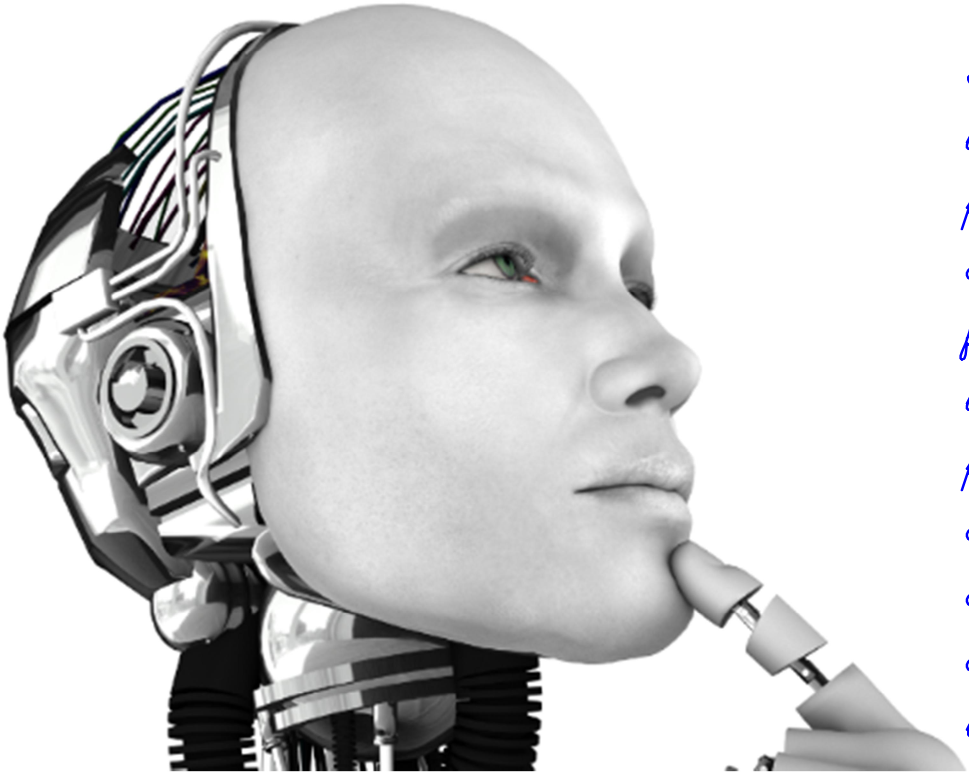
It is the digital age that makes the outcome economy possible. With the proliferation of connected sensors, the physical world is moving online, becoming increasingly quantified and accessible. Similar to the data logs that show web trails, sensory data streams from connected machines contain detailed traces about product usage and customer behaviours. By applying advanced analytics to such data, along with the right external data and domain models, companies can gain a better understanding of interactions among input variables, and optimize what it takes to achieve desired business outcomes.

For example, agricultural companies now have the data necessary to calculate how many bushels of wheat can be produced on a given piece of farmland with a particular mix of seed, fertilizer, water, soil chemistry and weather conditions. By combining analytics software with connected tractors, tillers and planters, they can apply the precise mix of seed and fertilizer to maximize crop yield at harvest. (See sidebar on "Outcome-based Agriculture.") Similarly, a building management company can deliver a defined level of energy savings through sensors, controls and software to analyze the data on when and where people work, and thus optimize the lighting and temperature levels required to support them.

Industrial Internet outcomes typically revolve around the product or the business. Product outcomes measure how well a product performs according to its intended purpose. For example, target outcomes might relate to the operations or maintenance of a product (e.g. reliability), or to the savings generated from the use of a product or piece of equipment. In general, product outcomes are fairly straightforward because they typically involve only the product supplier and user. For example, Rolls-Royce's Total-Care provides a suite of predictive maintenance and repair services for its jet engines, including monitoring engine health, and modifying engines to increase reliability and durability. Customers pay for product reliability. As the product-service provider, Rolls-Royce assumes the entire risk of time-on-wing and shop visit cost.[23]

Workshop Highlights – Tianjin, China 11 September, 2016

- Cross-industry partnerships are essential in enabling new business models in the Industrial Internet
- New opportunities exist in monetizing consumer data but safeguarding privacy is a prerequisite
- Best practices and technological advances from the development of the consumer IoT could be leveraged for the Industrial Internet but the economic potential will be far greater on the industrial side
- Rather than replacing old infrastructure, new technological innovation will emerge to bridge the old and new
- While the developed world will focus mostly on cost reduction and operational efficiency, more opportunities exist in emerging markets in creating new services and solving pressing societal problems
- Increase in productivity would ultimately reduce unemployment even though certain existing jobs could be at risk in the near term
- Many workers will need to be more specialized in areas of data science and engineering.



"Industrial Internet of Things
is everything that has been promised to be. It has the clear ability to impact the fundamental needs of the industry and has the potential to rejuvenate certain industry segments and economies. It can connect and evolve the silo views of assets to a system of assets and eventually to a system of systems, leading
to the fundamental redefinition of businesses."

Anant Gupta, President and Chief Executive Officer, HCL Technologies

Business outcomes, on the other hand, are quantitative measures that address the why behind the buy. One example of business outcomes is from Taleris America LLC. Unlike Rolls-Royce's TotalCare service, which focuses on the uptime of one product (e.g. Rolls-Royce jet engines), Taleris tackles the larger issue of airline delays and cancellations caused by equipment failures. To accomplish this goal, it focuses on airline fleet optimization far beyond the operational condition of a specific piece of equipment. By servicing the entire fleet, Taleris can impact overall maintenance schedules. This systemic approach means less disruption, lower costs, better spare-parts inventory management and more satisfied travellers.[24]

The outcome economy will have many implications for businesses. Companies will need more and better data to calculate costs, manage risks and track all the factors required to deliver the promised value. Provider risk will increase, too, as markets move to value based on outcomes, but so will the reward. New financial instruments and forms of insurance will emerge to help enterprises manage the risks associated with guaranteeing outcomes. Pricing practices will also change, as it becomes possible to model the probability of delivering outcomes. Success in this environment will require greater cooperation among businesses than ever before, which will call for a far more connected world, comprising new market ecosystems and technology platforms that can support and serve the Industrial Internet economy.

3.3 Delivering outcomes through connected ecosystems and platforms

Traditional industry supply chains focus on the efficient movement of physical goods. They are typically linear and often siloed. As companies shift focus from products to outcomes, these models will become liabilities. New digital entrants will increasingly disrupt established structures and relationships by bringing the power of software, the speed and scale of the Internet and nimble business models. To compete effectively, incumbent companies will need to shift their business practices and begin thinking in terms of ecosystems.

Developing the technology and related capabilities to deliver business outcomes is a challenging task. Few companies, even the world's largest ones, are in a position to own emerging digital value chains. That is why ecosystems are critical to the success of the outcome economy. Since delivering outcomes often demands problem-solving above the level of an individual product or solution, companies must work together to meet the needs of customers. The other advantage an ecosystem provides is speed. Since digital markets evolve at a much faster rate than physical industries, being part of an ecosystem allows participating companies to specialize in their core competencies and work together to quickly adapt to changes in external environments.

Digital lighting is one industry leading this transition to ecosystems. For example, Philips has developed smart LED bulbs and wireless switches powered by kinetic energy, and is now creating an ecosystem of partners to provide a wide variety of digital lighting solutions. It has partnered with design studios WertelOberfell and Strand+Hvass to co- create 3D -printed luminaires, with carpet manufacturer Desso to develop light-transmitting carpets and with AliCloud, a Chinese cloud services and wireless service provider, to support smart lighting control systems. Meanwhile, industry consortiums, such as the Connected Lighting Alliance, are bringing together lighting, electronics and controls companies to promote open standards and global growth for interoperable wireless lighting solutions.[25]

Workshop Highlights – Munich, Germany, 4 November, 2016

- Software platforms within ecosystems can enable the aggregation and brokerage of data and the collaboration across industries, which can create unexpected business relationships and expertise.
- The supply chain will become more flexible, allowing more on-demand customization and real-time access to information.
- Digital manufacturing will affect the design process of a product, and its lifecycle will be shorter since technology will enable quicker change and modification.
- Production of goods will happen closer to consumption and service delivery will drift further away from consumption as services can increasingly be performed remotely.
- The Industrial Internet will create new complexities and moving parts that will all need to be managed by new positions--leading to the creation of jobs.
- Start-ups are often considered outsourced R&D. Many feel that the start-up environment is stronger in the US when compared to that in Europe.


Industrial Internet is the core of this digital economy. Its adoption and resulting predicting capability will drive the new growth paradigm for every business.
Natarajan Chandrasekaran, Chief Executive Officer and Managing Director, Tata Consultancy Services

One hallmark of a mature ecosystem is the presence and wide acceptance of anchor software platforms, which connect and align all parties to achieve desired outcome by providing rules, structures and incentives. A platform can collect and analyze data from all participants, including customers and ensure that outcomes commitments are met. In time, the top-tier platforms will comprise extended networks of innovators, including software developers, start-ups, customers, partners, suppliers and competitors turned "co-opetitors," which collectively amplify the value creation opportunities for all participants, and solve problems and apportion liability if one or more parts of the system fail.

Across many industries, the battle to become the dominant Industrial Internet platform is already underway. In healthcare, for example, Qualcomm Life is currently leading the connected health market with the 2net platform. The picture for industrial markets is still murky. The exceptions are GE and Siemens. Both have been investing heavily in building out their software platforms, initially supporting only their own business units and brands of equipment, but slowly expanding to include others. For example, GE recently announced it will make its Predix platform available to third parties beginning in 2017 to develop custom apps and create innovation within the ecosystem.26 Oil and gas is still lagging behind, and no clear platform favorite has emerged yet. Given the growing importance of software platforms, most large equipment manufacturers are expected to attempt to build or maintain their own platforms, though third parties will emerge to help make such platforms work together.

In sum, the outcome economy is transforming how companies create value for customers and how they compete. To be successful, companies will need to have a clear strategy on how they want to participate in emerging industry platforms and ecosystems. There are a number of possible lead and supporting roles: platform owner, data supplier, service aggregator and so on. Many factors influence these choices as well, including the businesses' existing market positions, IT capabilities, risk tolerance and internal cultures. Because the Industrial Internet market is still in its early stage, and will evolve significantly in upcoming years, organizations must be ready to adapt in response to constant change.

Case study: Outcome-based Agriculture

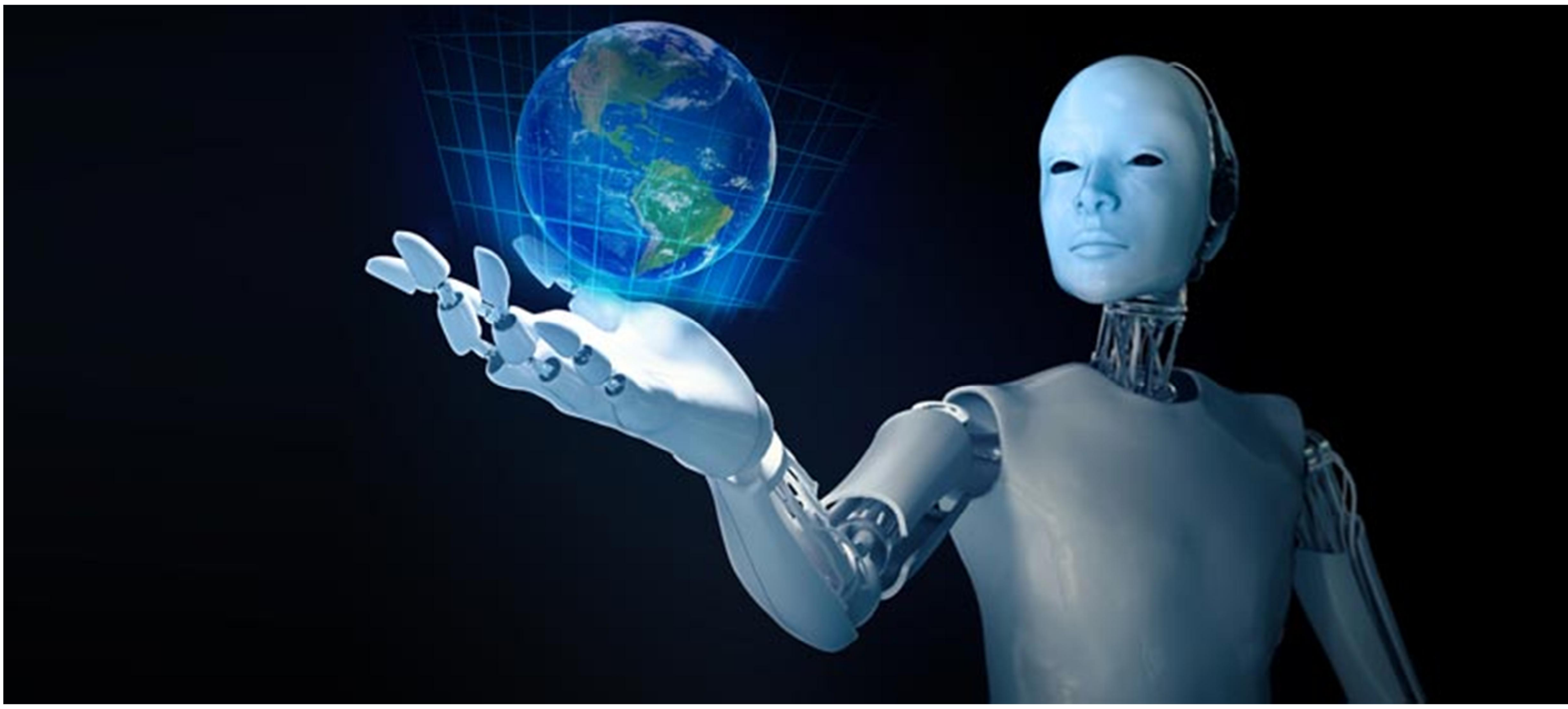
One industry at the forefront of the evolution to outcome-based services is agriculture. By connecting farm equipment to geo-location data, agricultural companies and farmers can now coordinate and optimize farm production in ways never before possible. For instance, automated tillers can inject nitrogen fertilizer at precise depths and intervals, as seeders follow, placing corn seeds directly in the fertilized soil. Ultimately, turning such data into actionable insights will improve crop yield to help feed the world's growing population.

One example of such "smart farms" comes from Monsanto, a multinational agrochemical and agricultural biotechnology company.[27] To help farmers increase crop productivity while conserving water and energy, Monsanto purchased Climate Corporation, a company which has used remote sensing and cartographic techniques to map all 25 million farming fields in America by field shape, type of crop, crop yields, soil capacity and other critical metrics.[28] By adding Climate Corporation's data to Monsanto's data on seed yields, farmers can better understand which seeds will grow best in which fields and under what conditions.

Outcome-based agriculture requires connected ecosystems and platforms. In Europe, the 365FarmNet[29] brings together farm equipment makers Claas, Rauch, Horsch and Amazonen-Werke, financial service giant Allianz, chemical company Bayer, seed producer KWS Saat, agricultural software service provider LACOS, agricultural advisory service company Agravis, and the European Global Navigation Satellite Systems Agency. This ecosystem provides farmers with easy access to data and analysis on geo-location, diagnostics, crops, fertilizers, weather and other factors, over smartphones or through direct connections with farm equipment.

Farm equipment manufacturers are also taking an active role in developing their own ecosystems. John Deere is building intelligence into its large combines, tractors and sprayers through sensors that make the machines into mobile platforms. The company is also vying to become a trusted source of agriculture data by forming digital partnerships with companies such as DuPont, Pioneer, Dow Chemical and others to supply precision agriculture solutions to growers. And John Deere and AGCO are working together to connect irrigation systems, soil and nutrient sources, with information on weather, crop prices and commodity futures to optimize overall farm performance.[30]

While prescriptive agriculture offers many potential benefits, there is also potential for conflict among stakeholders. Many farmers, for example, do not trust companies that offer prescriptive agriculture systems since they fear that the stream of detailed data they are providing on their harvests may be misused. They also worry that these firms could buy underperforming farms and run them in competition, or use the data on harvests to trade against farmers on the commodity markets.[31]



"*Humans must adapt to collaborate with machines, and when that collaboration happens, the end result is stronger*."

Erik Brynjolfsson, Director, MIT Initiative on the Digital Economy, Massachusetts Institute of Technology, USA

Shift towards an integrated digital and human workforce

Our survey research shows that the broad adoption of the Industrial Internet in many industries will lead to a structural shift in employment (see Figure 5). A vast majority (94%) of respondents believe that the increasing use of smart products, intelligent assistants and robots will fundamentally transform what skills and jobs are required in the future.
As machines become more intelligent, they will play new and more important roles in many types of work situations. Companies will use machines and network systems to automate tasks that can be done at lower costs and higher quality levels. At the same time, such automation will free up people to focus on the more human elements of their jobs like creative problem-solving and collaboration. The combination of humans and machines will be the winning formula, yielding higher overall productivity and a more dynamic, engaging human work experience.

In time, the Industrial Internet will drive the world towards a blended workforce, where it is no longer humans versus machines but humans with machines, working together to deliver outcomes that neither could produce alone.[32] By designing and applying technology to empower rather than replace people, this "human-centred automation"[33] or augmentation can redefine existing jobs and give rise to new ones. It will also reshape how skills will be acquired – an area that will become critical as a result of the rapid pace of change in digital technologies.

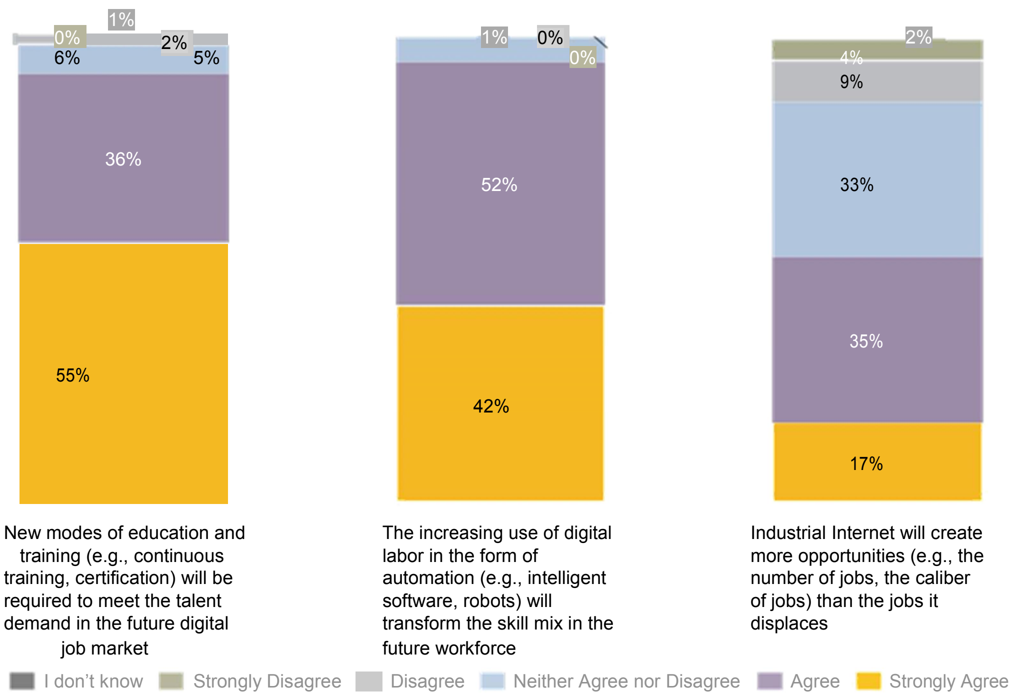
4.1 Enhancing productivity and work experience through augmentation

Computer augmentation of human capabilities, such as GPS-guided navigation and advanced decision support systems, has been available for years. Recent advances in human-computer interfaces have made such capabilities more widely accessible. For example, the combination of speech recognition and wearable displays enables convenient hands-free delivery of context-based information at the point of need. Mitsubishi Electric is experimenting with augmented reality software using Epson's Moverio smart glasses to help air conditioner technicians perform repair services. The glasses let the technician view 3D overlays on physical objects in the field to see how to remove or replace parts.[34] The result is reduced repair time and fewer potential mistakes, especially by less experienced or skilled technicians.

The increasing collaboration between human workers and robots provides another way to improve productivity and work experience. This new blend of labour combines human flexibility and contextual decision-making with robots' precision and consistency to deliver better output. With its recent acquisition of Kiva Systems, for example, Amazon now operates one of the world's largest fleets of industrial robots in its warehouses, where humans and robots work side-by-side, capable of fulfilling orders up to 70% faster than a non-automated warehouse. While robots perform picking and delivery, human workers spend more time on overall process improvements such as directing lower-volume products to be stored in a more remote area. (See sidebar on "The Future of Robots.")

Figure 5: Workforce impact of the Industrial Internet

Q: To what extent do you agree or disagree with each of the following statements regarding talent?



Creating a safer workplace is a top priority in many industries. Wearable and connected sensors are increasingly being used to address worker safety across industries such as oil and gas, chemicals, metals, mining and utilities. At Marathon Oil refineries,[35] for example, employees wear a wireless multi-gas detector that continuously tracks exposure to harmful gases throughout an employee's shift. Plant managers can monitor the status, location and safety of all employees on the site, and, in the event of emergency, individuals need only to press a panic button to trigger an alarm and call for help from a central control centre. Capabilities like this go a long way towards ensuring worker safety beyond simple compliance. This is especially true in some emerging regions where work safety standards are still evolving, and enforcement is not always rigorous.

The Industrial Internet can also help make workplaces more flexible and appealing to new generations of workers, such as the Millennials. Most of today's manufacturing processes, for example, are still organized around large and expensive machines with rigid interfaces. Workers must be physically on the shop floor to operate these machines. With connected factories, a manufacturing engineer can potentially receive notifications on his tablet from hundreds of miles away when a machine is malfunctioning. He can use the same device to resolve the problem remotely, including collaborating with his colleagues on the factory floor if necessary.

This ability to work asynchronously and remotely is significant because mining, agriculture and oil field worksites are often located in isolated areas with few amenities. The decoupling of the worksite and the machines in the field affords a new level of flexibility on where and how work is done. It also transforms the nature of work from the traditional blue-collar work into a knowledge -based role, with real-time access to data from industrial assets, such as fleets of trains, airplanes, power grids or earth-moving equipment. For example, at Rio Tinto's operations centre in Perth, Australia, skilled equipment operators now sit in a remote command centre and work side-by-side with data analysts and engineers to orchestrate the actions of huge drills, excavators, earth movers and dump trucks across multiple mining sites.[36]

4.2 Creating new jobs in hybrid industries

In time, the Industrial Internet will blur industry boundaries, or give rise to new hybrid industries, such as digital medicine, precision agriculture and smart manufacturing, to name a few. These new industries will generate new jobs. Some roles will be familiar, but will require greater analytical abilities and skills in the use of digital technology. As machines assume routine tasks, future jobs will also increasingly rely on certain unique human attributes, such as creative problem-solving, complex forms of communication, large -frame pattern recognition, collaboration and the ability to adapt to unfamiliar situations.

In smart manufacturing, for example, highly automated factories may require fewer blue-collar production workers or machine operators on the shop floors. But at the same time, there will be an increased need for more knowledge-based experts and decision-makers with digital and analytics skills to focus on tasks that cannot be automated, including system planning, engineering, exception handling, coordination and orchestration. By using robots, Marlin Steel – a custom metal products manufacturer based in Baltimore, Maryland – successfully migrated its existing workers from unsafe, routine jobs of bending metal by hand into safer, more interesting jobs of supervising robots. The net result was significantly higher productivity and quality, and the workers hourly pay was more than quadrupled. This has, in turn, led to a growing demand for Marlin Steel's products and the hiring of 25% more workers.[37]

To support these hybrid industries, entirely new categories of jobs will emerge – medical robot designers, grid modernization managers, intermodal transportation network engineers and more. Most of these jobs will demand strong interdisciplinary skills, including deep knowledge about specific industry domains, new technologies, software and data skills, along with soft skills (e.g. leadership, communication, collaboration).

As more traditional companies embrace the Industrial Internet, the demand for traditional IT jobs will grow as well, to include positions in software development, big data analytics, systems integration and security. In particular, user-experience designers will be in high demand, while companies will also need more IT managers and infrastructure specialists to ensure a smooth transition as companies migrate more of their business processes into the cloud. Increasing connectivity and availability of personal data over the global network will also call for new types of security and privacy experts who can help businesses and governments manage and mitigate security risks.

4.3 Reskilling for digital industries

The emerging job market will demand new and different skill sets. Digital-age skills such as data and analytics will become the "new math" in the Industrial Internet. To support an integrated digital and human workforce, society, educational institutions and business will also need to work together to instil a new mind-set on how to collaborate with intelligent machines, which, in some cases, may involve the need to teach and guide the machines as if they were apprentices. It is also important to recognize that machines, however intelligent they might be, are just tools. When in question, human experts must be ready to apply their critical judgment to overrule recommendations from automated systems.

Driven by constantly changing digital technologies, requirements and markets for Industrial Internet skills will be much more volatile. In response, learning and skill acquisition will need to be equally dynamic for individuals who seek employment. For instance, employees will need to perform more specialized tasks earlier in their professions, which will require them to regularly update skills through informal or independent learning, such as participating in massive open online courses (MOOCs). Instead of one-off degrees and technical courses, educational institutions will need to develop platforms for continuous learning, collaborating with students, businesses and governments to produce contents relevant to valued skills.

Job-related training and skills certification will become integrated into business processes and continuous, as there is more emphasis on delivering consistent outcomes and ongoing training across the extended enterprise. Such training will also reduce the length of onboarding time for new employees. TelnT research reveals that 79% of organizations already use just-in-time and social learning to build skills quickly.[38] For example, a newly hired retail sales associate could be given a wearable intelligent assistant on the first day of the job. When a customer asks a question about a product, the tool would use automated speech recognition to detect verbal cues, and deliver relevant product information. This just-in-time delivery of information could enable the associate to learn as he is helping the customer.

The same quantification capabilities that power the outcome economy will also be at work in skills development. Employers will use cognitive training to develop detailed models over time on how workers think and act in specific job situations. Using this data, companies can tailor training programmes to individuals to make them more effective and efficient. Such accelerated learning techniques also offer great potential to align training and skills with content and context, as successfully demonstrated in a military setting. For example, as part of the Accelerated Learning Program, the US Defense Advanced Research Projects Agency (DARPA) uses neuroscience principles to improve sensorimotor and cognitive functions.[39]

The workforce impact of digital technologies will be gradual and profound, as the Industrial Internet transforms industries and business practices. Because system-wide changes take time and planning, business and government leaders and planners will need to act now in preparing for the digital talent market. Some of the initial steps might include examining existing approaches, experimenting with new digital workforce models, and developing a comprehensive strategy on how to reform the education and training system to be more responsive to the demands of the future workforce.

The future of robots

Robots are microcosms of the Industrial Internet. They feature three core capabilities: sensing, thinking and acting. Most industrial robots used in manufacturing today are no more than advanced control arms with limited sensing and reasoning capabilities. Just like the machines around them, these robots are preconfigured to carry out repetitive, structured tasks.

As sensors, hardware and software continue to improve, robots will become more intelligent and autonomous in their capabilities while still working under human direction. For instance, robots will eventually be able to understand the physical world around them, in much the same way as humans do. As a result, robots will appear freely in open environments, such as offices, homes and shopping malls, doing tasks that only humans once did. The use of service robots is expected to grow faster than the use of industrial robots in the near future (e.g. security “guards” from Knightscope).[40]

One distinct capability in the next generation of industrial robots, such as Baxter or Universal Robots, is their ability to work safely alongside humans. New sensors and software enable these machines to detect and avoid collisions with people, and such robots are now also reprogrammable so that they can quickly “learn” from human workers how to perform new tasks. These features, together with lower costs, mean that robots will be deployed more widely.
As human co-workers, collaborative robots are likely to reshape manufacturing processes and workforces. In bringing automation to new applications, robots could also help manufacturers in high-cost countries regain a competitive edge, which might also mean fewer jobs for the lower-skilled workers but more higher-skilled jobs instead.

At the technology level, robotics represents one of the most exciting areas of innovation among corporate R&D labs, start-ups and university research centers. Here are just a few examples:

- Qualcomm is designing a new brain-inspired chip called Neural Processing Units (NPUs), which will be both highly scalable and power efficient. The new chip promises to redefine the cost/performance ratio for robots, just as mobile chips have done for smartphones.[41]

- Google continues to advance machine learning by acquiring a series of robotics and artificial intelligence start-ups.[42]

- At Cornell University, researchers are building a large-scale, cloud-based knowledge repository called Robobrain, which can be used over the Internet to teach robots like Baxter how to comprehend (sense) their environments and quickly take on new tasks.[43]

Similar to the advancement of mobile technology 15 to 20 years ago, the robotics revolution is just beginning. Over the next 20 years, it will likely lead to profound impacts on businesses, the economy and society.

> The Industrial Internet is here and now. Leading companies across multiple industries are already reaping tangible benefits in improving operations, lowering costs, generating revenues and creating competitive differentiation. Major smart cities such as Barcelona, Chicago and Hamburg are also benefiting from reduced crime, improved urban services and better infrastructure integrated with real-time connections, sensors and data. To further accelerate the adoption, industry, technology and government leaders need to work together to address challenges such as security, interoperability, standards and digital talent gaps.

John Chambers, Chairman and Chief Executive Officer, Cisco

Recommended actions for stakeholders

As our research shows, the Industrial Internet is already here, delivering real benefits including improved operational efficiency, flexible work experience and measurable business outcomes. At the same time, our research participants have also pointed out a number of challenges that could potentially slow down the pace and increase the risks of adoption, which include security, interoperability, data policies, and education and talent gaps. To seize the opportunities, overcome key challenges and accelerate the Industrial Internet development, business, technology and government stakeholders need to take immediate actions (see also Figures 6 and 7).

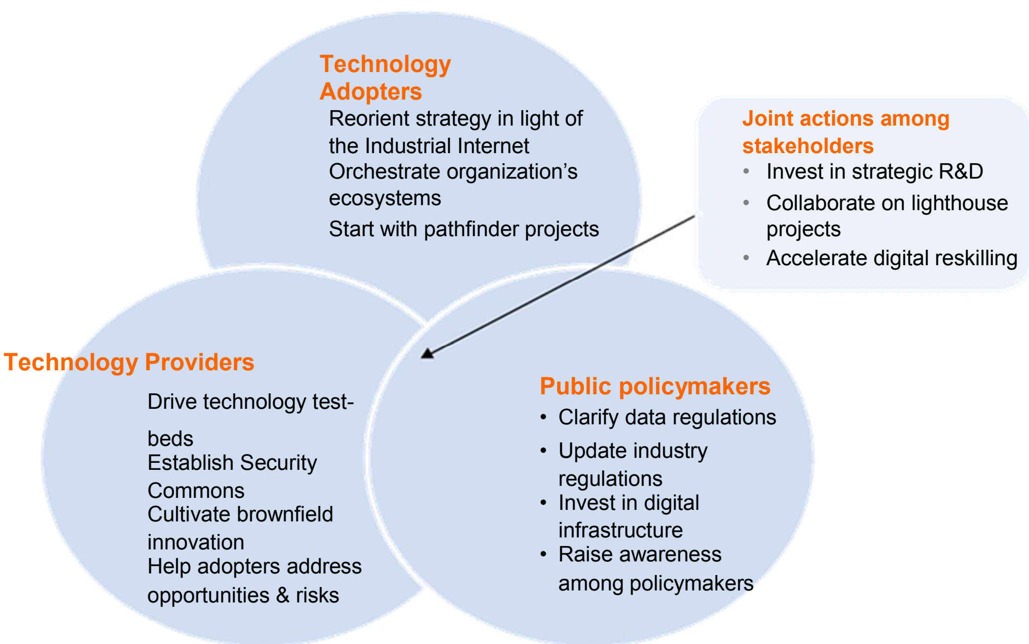
For technology adopters

Reorient the business strategy around the Industrial Internet. Businesses need to evaluate how the shift to an outcome-based economy will disrupt their industry and alter their overall strategies. Where is the industry at right now within the four-phase Industrial Internet evolution model (from products to services to outcomes to the pull economy)? When is the next inflection point? Adopters of the Industrial Internet should develop multiple scenarios about alternative futures and map out the company's possible responses. They must identify the processes and organizational structure required to achieve long-term success. For example, consider how the operational efficiency-focused phase (e.g. asset utilization) can set up the company for later success. Develop a clear roadmap for how to transition between each of the four phases. What are the implications for existing assets and buyer behaviours? What are financial implications of moving from selling products and service agreements to selling outcomes?

Orchestrate the organization's ecosystems. Businesses need to understand the critical importance of ecosystems in the deployment of the Industrial Internet. Multiple providers are required to deliver complex outcomes and share costly investments. If the company has a number of product lines, it must first determine which ecosystem(s) the company should lead, and where it should play a supporting role. What kind of partners will the company need to boost capabilities and deliver the desired outcomes? Are today's partners still the right ones for the future? What does the business need to do to be an attractive partner? Should the business invest in building its own platform (e.g. MyJohnDeere), or join an existing platform to achieve success within the desired timeframe? Whom should the company partner with to move to the next phase while reducing risks? Companies need to look across industry boundaries for emerging opportunities and find the potential partners who will help seize them.

Identify pathfinder projects that the business can drive now. One approach would be to start now with 1-2 validated business cases (e.g. preventative maintenance) to drive near-term measurable benefits for the organization, such as cycle-time reductions, cost savings and business process improvements. Companies may want to balance these implementations with some riskier but low-cost pilots with innovative start-up solutions to provide the valuable learning and insight required for the new strategy. They need to focus on solutions that have new business model implications, such as product/service hybrid or outcome-based services. What are the infrastructural, organizational and legal requirements for conducting such pilots? Can they obtain support from vendors or governments as an early adopter?

Figure 6: Key recommendations for three stakeholders groups



For technology providers

Advance interoperability through test-beds. Technology providers need to develop real-world test-beds to demonstrate how technologies from different organizations can work together to support new use cases and product concepts at scale and at speed. Participating in test-beds gives these companies a direct voice in shaping future Industrial Internet products and services. It will also provide them early mover advantage as they gain a better understanding of the requirements, trends and possible timing around potential market disruptions. Because successful test-beds require close collaboration among stakeholders, they can be an effective way to bootstrap connected industry ecosystems and platforms – two critical components for an outcome economy.

Share best practices through a global security commons. Operational safety and security practices vary greatly across industry domains. They are also significantly different from IT security. For example, human factors engineering is critical in ensuring safe operations. The first step towards building a common security framework for the Industrial Internet is to understand and document existing best practices across industries. This will help identify gaps and requirements for potential innovation, standards or new cyber-security products. A global security commons provides one practical way to bring together these communities by involving key stakeholders across the Industrial Internet value chain. The commons can help raise the collective security awareness by sharing threat intelligence. It can also ensure a unified industry voice when communicating with governments or agencies involving security.

Cultivate brownfield innovation. Industrial products are durable goods "built to last" for years if not decades. Technology providers need to change their "planned obsolescence" product lifecycle mind -set to focus attention on supporting equipment that is now in the field. What sensors or devices can be added without compromising the integrity of the existing machinery? What parts (hardware or software) can be upgraded incrementally? Consider what new value-add services can be provided to make today's equipment and facilities more productive and efficient, or how adding intelligence to existing products opens up new outcome-based opportunities.

Help adopters address market opportunities and risks. The Industrial Internet market is still in a formative stage. So, many potential adopters need to develop a clearer picture of the landscape before they drive through it. It is important to share with them best practices, winning use cases and operational models with customers to get them started in their Industrial Internet journey. What benefits have been demonstrated so far? What are critical barriers (e.g., IT/OT integration, security) that need to be overcome early in the process? What are lessons learned from past implementations? Providers need to think, too, about the most effective ways to share early adopter experiences, such as by leveraging industry consortium like the IIC or events like the IoT World Forum.

For public policy-makers

Clarify and simplify data policies. To realize the promise of the Industrial Internet, global companies need clear legal guidelines over data ownership, transfer and usage. Who owns the data generated by equipment? What information can be shared or sold, and under what circumstance? How will responsibilities among parties be handled when the data originates in one jurisdiction and is used in a different one? In complex global organizations, it is often more difficult to segregate Industrial Internet data than that of consumer Internet based on national boundaries. Until the full impact is better understood, it would be prudent to introduce temporary policies to guide the market and spur innovation. Governments need to collaborate with each other and industry to harmonize compliance requirements in data and liability laws, as the European Commission and the United States are doing on message standards. This will streamline data flow within a jurisdiction and across national boundaries – an issue critical to large, global organizations.

Update industry regulations. Some industries, such as utilities and healthcare, are heavily regulated in many parts of the world. For these industries to benefit from the Industrial Internet, policy-makers will need to revisit and possibly relax existing regulations to provide more flexibility and incentives for companies to invest and innovate. In the utilities industry, governments can now tap into the new power of transparency enabled by the Industrial Internet to encourage more competition, market efficiency and better customer services. Motor vehicle, aviation and workplace regulations may require adjustments to allow experimentation with autonomous cars, unmanned aerial vehicles and robots in warehouses, factories and hospitals. Policy-makers should also review whether insurance regulations will support or hinder the growth of an outcomes guaranty insurance market.

Invest in digital infrastructure. The success of the Industrial Internet depends heavily on the presence of robust infrastructures, such as ubiquitous broadband connectivity and sensors. Through targeted investment, emerging markets will have a unique opportunity to potentially leapfrog developed countries in the Industrial Internet infrastructure. As these countries continue large construction efforts like roads, airports, factories and high-density buildings, they can avoid costly retrofitting faced by developed countries by installing state-of-the-art embedded sensors from the outset. These capabilities provide a foundation for smart cities, enabling more efficient use of natural resources, better public safety and citizen services. Industry can help government leaders to prioritize infrastructure investments that can provide long-term strategic benefits to economic growth, social impact and political success. As part of the Smart Nation infrastructure, for example, Singapore is considering installing Above Ground Boxes as key supplying points for backend fiber access and power. This approach avoids the need for unnecessary groundwork and thus significantly reduces sensor deployment time and cost.

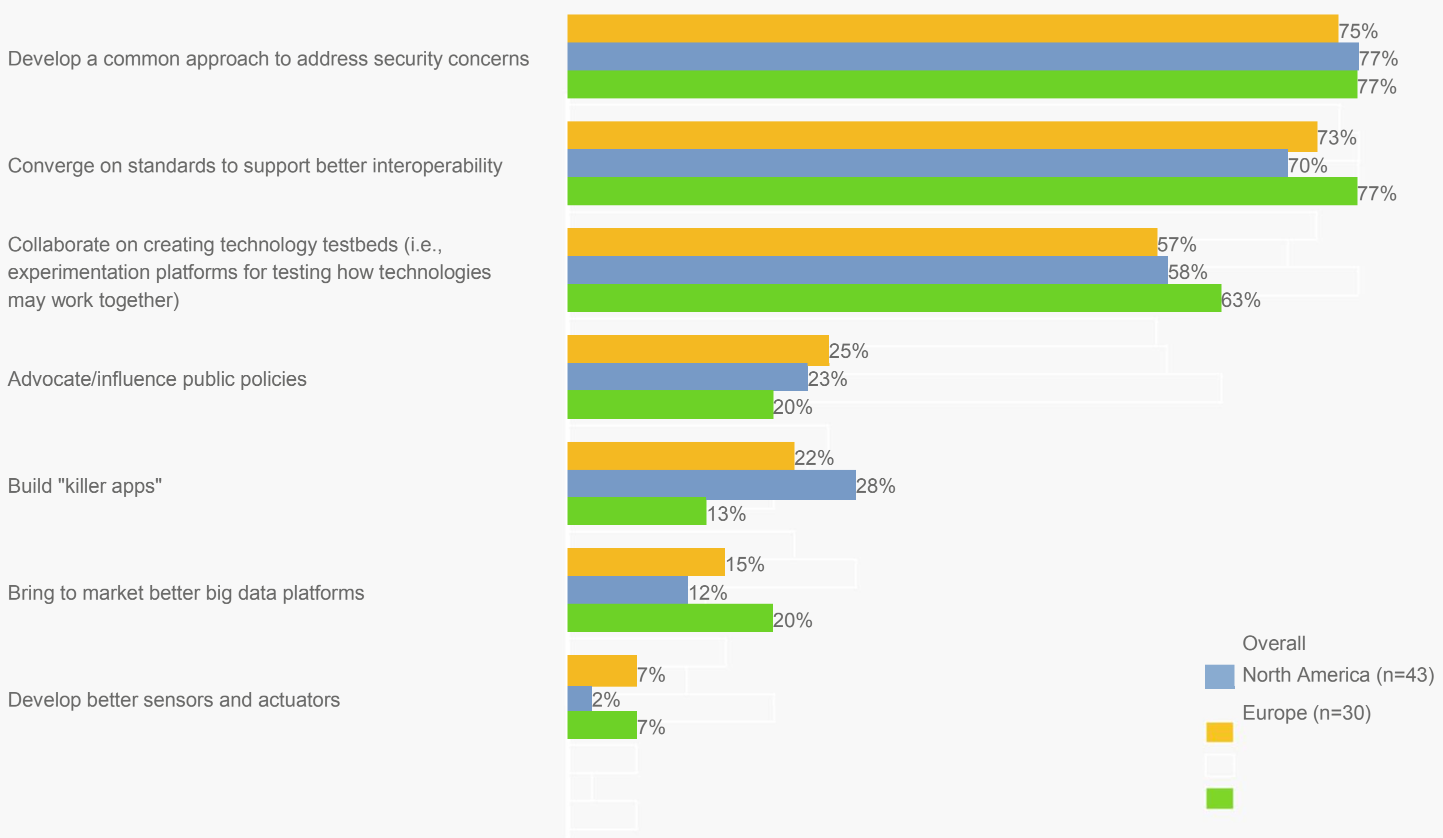
Raise awareness among public policy-makers. Many policy-makers are still not well informed about how the Industrial Internet might impact citizens, industries and governments, and what governments can do to promote the market development and economic growth. There is an urgent need to bring them up to speed on the technology, its societal and policy implications (such as data security, privacy, education and jobs), and impact on government services. For example, the German government was one of the first to recognize this need, and has sponsored the Industrie 4.0 initiative, which includes specific recommendations for German regulators as well as industry to promote the growth of digital industries in the country.

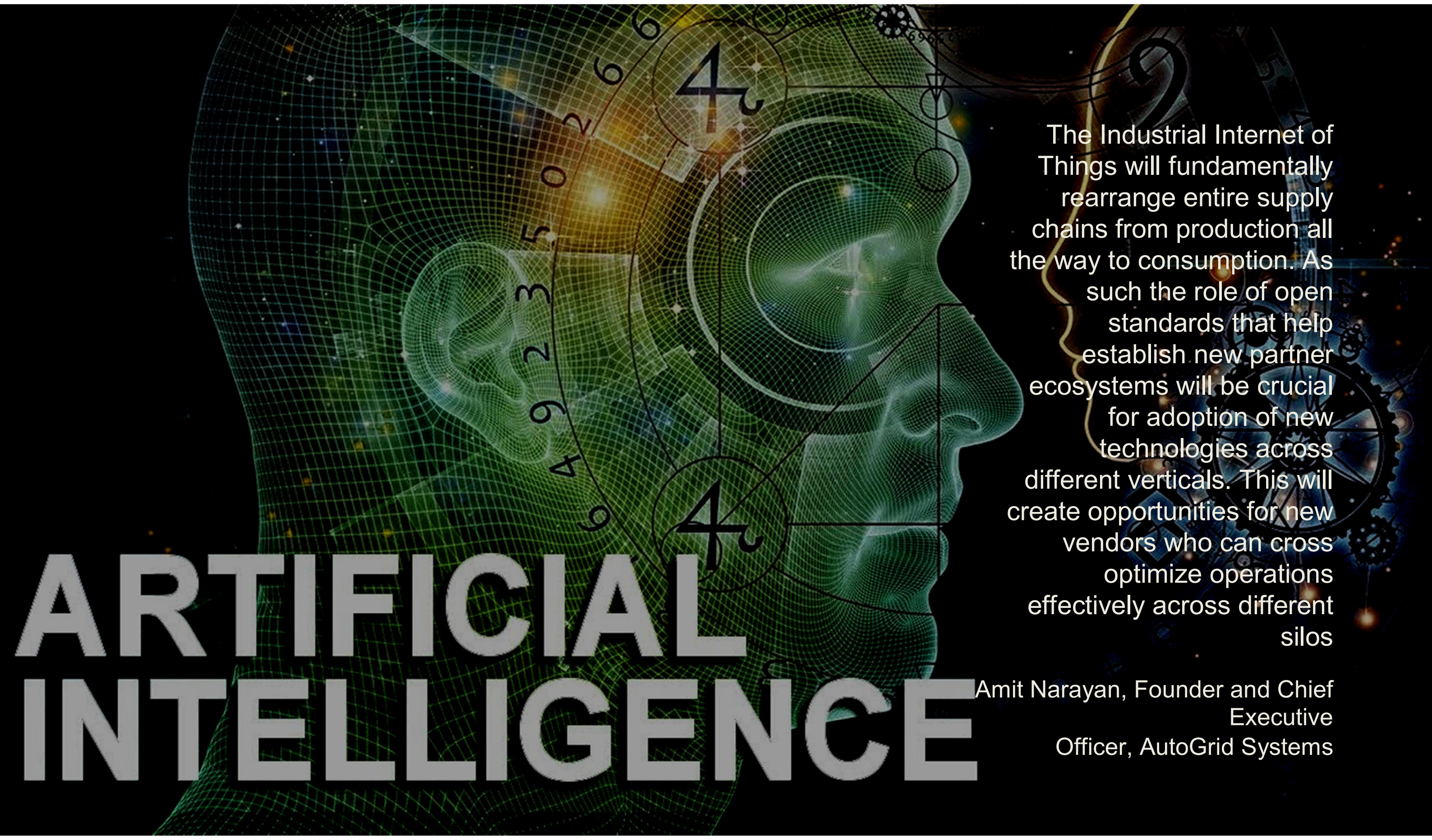
Joint actions among stakeholders

Invest in long-term, strategic R&D. The future development of the Industrial Internet will require large scale multi-stakeholder efforts in boosting security, reliability and interoperability, and in delivering large-scale societal benefits (e.g. smart transportation). In particular, security is one issue that no one industry, business or government can solve on its own. To address these challenges, frontline contributors will come from academia and industry. Government agencies will play critical roles as well. How can they support technology transfer from labs to industry, as the US National Science Foundation's Innovation Corps has done? Funding research into Industrial Internet technology and applications is another option, as the UK government has done. Funding needs will vary significantly by region and maturity, so executives and academics must proactively communicate both current and anticipated challenges.

Figure 7: Top actions for the IT industry

Q: What are the three most important actions the IT industry (e.g., hardware, software and service providers) can take to help accelerate the adoption of the Industrial Internet?



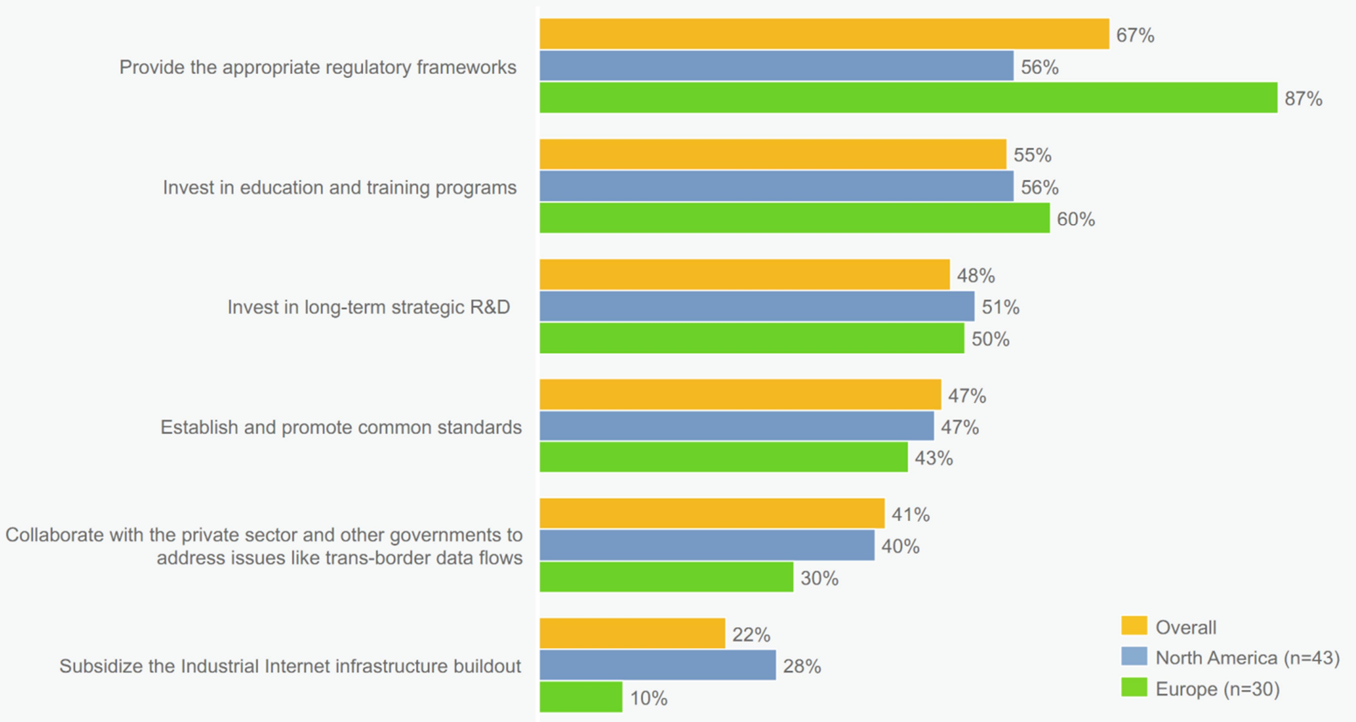

ARTIFICIAL
INTELLIGENCE
The Industrial Internet of Things will fundamentally rearrange entire supply chains from production all the way to consumption. As such the role of open standards that help establish new partner ecosystems will be crucial for adoption of new technologies across different verticals. This will create opportunities for new vendors who can cross optimize operations effectively across different silos
Amit Narayan, Founder and Chief Executive Officer, AutoGrid Systems

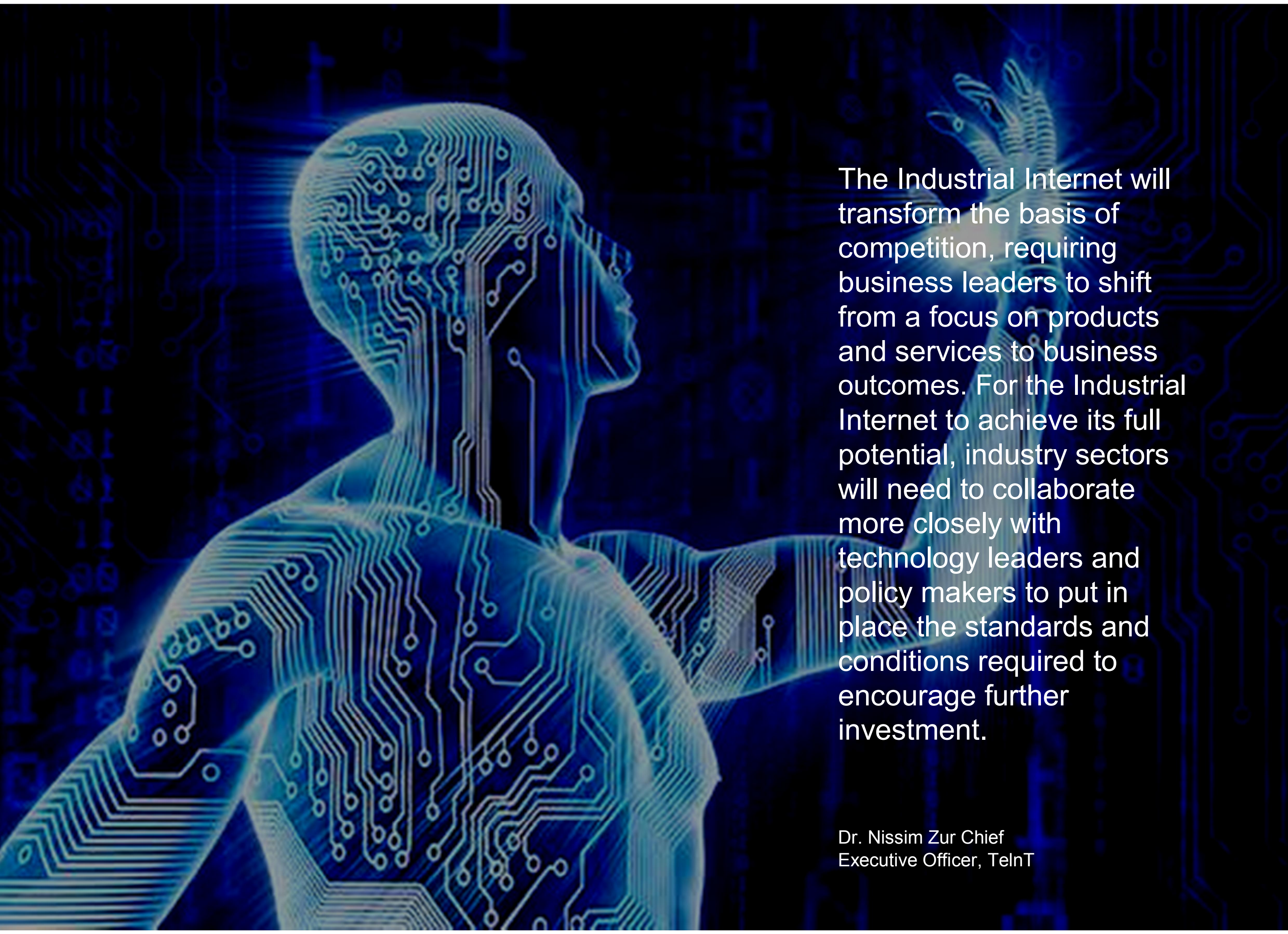
Collaborate on lighthouse projects. To accelerate the uptake of the Industrial Internet, all stakeholders must come together to create large-scale demonstration projects to show how the technology can be used to deliver tangible benefits. Unlike test-beds, which focus heavily on technological issues like interoperability and security, the purpose of these lighthouse projects is to demonstrate the real-world impact by enabling people to experience it at first hand. Many technology providers are already conducting such joint projects. For example, Intel has partnered with the City of San Jose, California, to test its Smart City platform to support San Jose Green Vision initiative. While the initial focus is on air quality, the future plan calls for the use of the same platform to improve the quality of a number of other services, including water, transportation, energy and communications systems. Beyond smart cities, similar projects can be organized around other areas of societal importance, such as healthcare, transportation, food safety and education. One important benefit of these collaborative efforts is the resulting broader awareness among the general public on the vast potential of the Industrial Internet, which will ultimately lead to higher pent-up demand for new smart services.

Accelerate reskilling to meet changing talent needs. The convergence of physical industries and digital technologies will exacerbate the talent gap, especially among workers with both OT and IT skills. The Industrial Internet requires analytical talent, including data scientists, yet most of our research participants agree that current education and training approaches are not up to the challenge. To address the growing shortage of digital talent, industries and academia must come together to define and implement new educational and training and reskilling programmes – both in the classroom and online. For instance, consider pilot programmes where elementary students can work alongside machines or experiment with Arduino boards or littleBits electronic prototyping kits. Governments should consider policy incentives to encourage businesses and individuals to reskill to fill in the talent gaps in high-demand job categories.

Figure 8: Top actions for public policymakers

Q: What are the three most important actions governments can take to accelerate the adoption of the Industrial Internet?





The Industrial Internet will transform the basis of competition, requiring business leaders to shift from a focus on products and services to business outcomes. For the Industrial Internet to achieve its full potential, industry sectors will need to collaborate more closely with technology leaders and policy makers to put in place the standards and conditions required to encourage further investment.

Dr. Nissim Zur Chief
Executive Officer, TelnT

Appendix A: About the research

This report is part of the TelnT's research initiative on the Industrial Internet launched in early 2017

This project to establish a clearer understanding of the transformative opportunities and new risks arising from the Industrial Internet. Further objectives of the project included helping business and government leaders envision the new world resulting from the introduction of the Industrial Internet, and identifying potential implications to the workforce (e.g. employment, skill distribution and productivity). Lastly, the project team set out to determine key recommended actions for stakeholders to accelerate the uptake of the Industrial Internet while mitigating challenges and risks.

Approach and framework

The project team followed a combined top-down and bottom-up approach by first taking a macroeconomic view of key drivers and trends across industries, and then conducting further analysis on select industries. A macro-level framework (see Figure 9) was developed to provide a structure for the analysis, and to identify enablers and inhibitors of the Industrial Internet along with key opportunities and disruptions. The project team conducted extensive research by gathering insight from industry experts around the world to discern the implications of such shifts for businesses and governments. The team also reviewed existing use cases to understand current developments of the Industrial Internet and completed a deep-dive assessment where the framework was applied to the manufacturing industry.

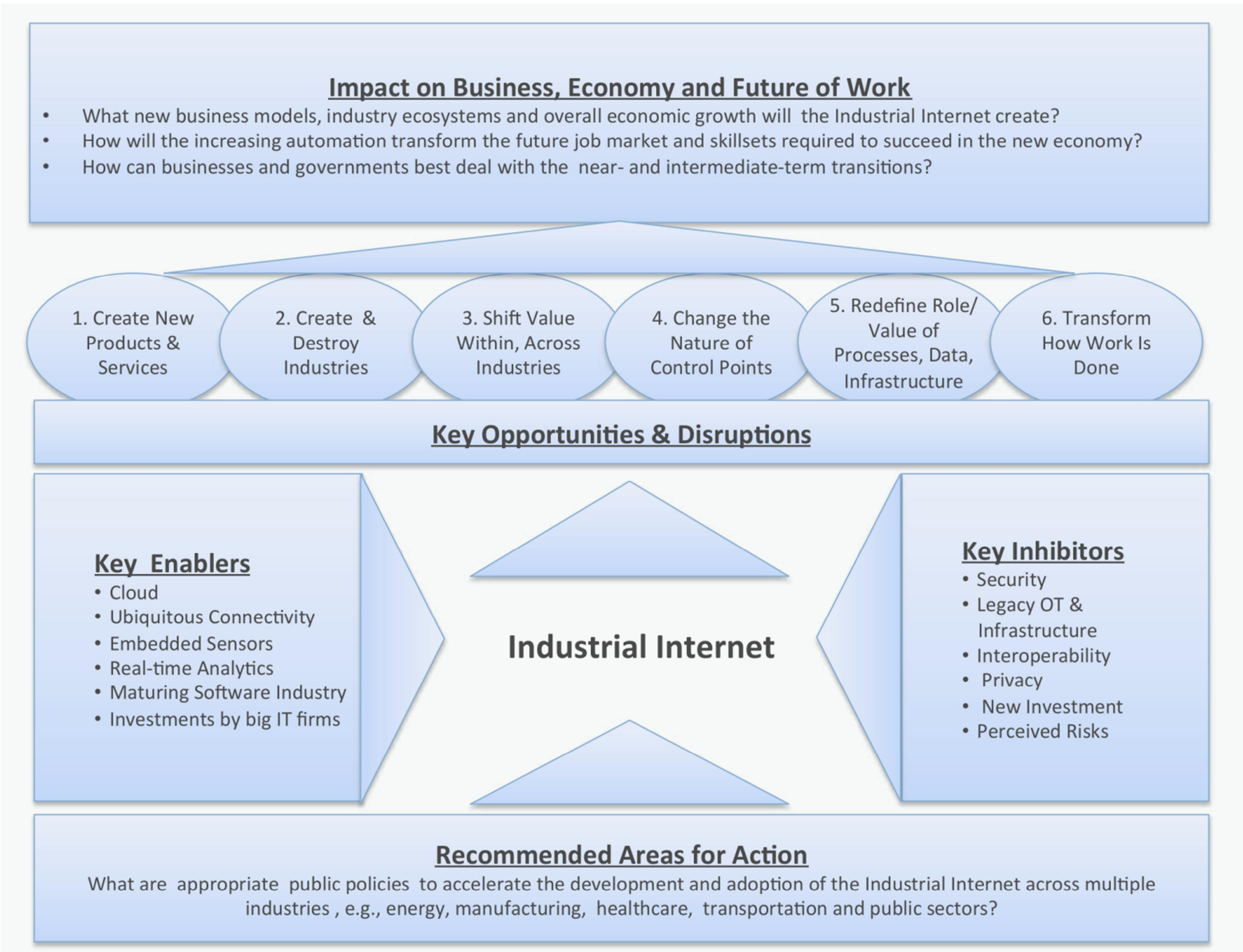
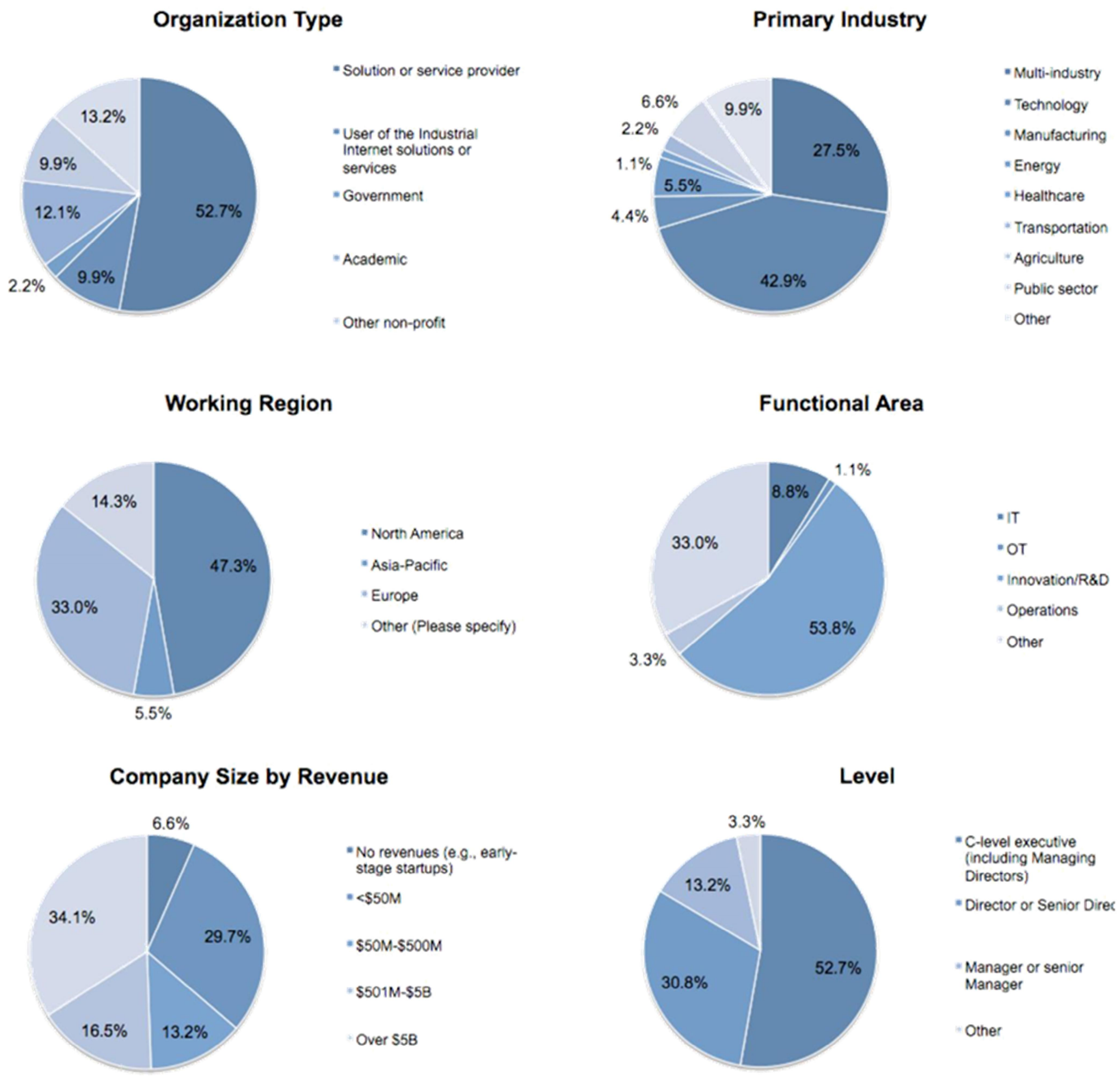


Figure 12: TelnT Industrial Internet Impact Survey distribution

OT convergence is the integration of information technology (IT) systems used for data-centric computing with **operational technology** (**OT**) systems used to monitor events, processes and devices and make adjustments in enterprise and industrial operations.



Project team

In addition to the core TelnT research and project management team, the project included a steering committee consisting of five Artificial Intelligence experts, manufacturing and energy. The committee provided input on the composition of the community and set project priorities and the strategic direction for future phases of the initiative. Additionally, a working group of senior executives helped to define key deliverables and contributed their expertise to the research.

Project workshops

The research on the topic involved multiple stakeholders in strategic conversations in the format of workshops, virtual sessions and one-on-one interviews. The discussion revolved around high-impact opportunities, implications to the workforce and issues critical to the development of the Industrial Internet. Five workshops (See Figure 10) were held throughout 2016-2017 and were purposefully located in different cities to extract regional insights.

Industrial Internet Impact Survey

The TelnT Industrial Internet Impact Survey (see Figure 11) was conducted in collaboration with the Industrial Internet Consortium (IIC) and TelnT. The survey was distributed to more than 250 market leaders, who are current members of the IIC, the steering committee for the IoT World Forum by Cisco, the Industrie 4.0 or the TelnT Artificial Intelligence Industrial Internet Working Group. These participants are actively involved in the Industrial Internet initiatives in their respective companies and may not be representative of the overall market. Therefore, the results should be interpreted accordingly.

The intent of the survey was to help business and government leaders better understand the key opportunities and challenges of the Industrial Internet so they may take actions to accelerate the development of the market and realize its full benefits. The findings of the survey have been included in this report.

Appendix B: Glossary

Blended workforce: A labor force involving close collaboration between humans and intelligent machines in the form of augmentation. Examples include humans collaborating with robots on factory floors or augmented reality applications to assist technicians in complex repair tasks.

Digital labor: Referring to smart sensors, machines (e.g. robots) or intelligent systems that can do parts of the jobs that only humans used to do.

Ecosystem: A short-hand for "digital" or "connected" ecosystem, which is a distributed, adaptive, open socio-technical system with properties of self-organization, scalability and sustainability inspired from natural ecosystems. Digital ecosystem models are informed by knowledge of natural ecosystems, especially for aspects related to competition and collaboration among diverse entities.

Hybrid industries: The intersection between physical industries and digital technologies (e.g. precision agriculture, digital manufacturing, medical, robotics, smart transportation).

Industrial Internet: A short-hand for the industrial applications of IoT, also known as the Industrial Internet of Things, or IIoT.

Internet of Things (IoT): A network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

Outcome economy: A marketplace where businesses compete on their ability to deliver quantifiable results that matter to customers rather than just selling products or services, e.g. energy saved, crop yield or machine uptime. Delivering customer outcomes requires sellers to take on greater risks. Managing such risks requires automated quantification capabilities made possible by the Industrial Internet.

Platforms: A short-hand for "technology" or "software" platform, which is the digital layer that allows business partners to connect and interact from any applications or devices. Through the technology platform, each player in the value network becomes part of a digital ecosystem. Example: TelnT Artificial Intelligence wireless platform,

Physical industries: Sectors of the economy featuring capital-intensive physical infrastructure or assets, including manufacturing, oil and gas, mining, agriculture, utilities, transportation and some parts of healthcare (See IoT pills consumption monitoring device)

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