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Disruptive technology and the board: the tip of the iceberg[1]

Gary L. Evans[2]

Abstract: This paper reviews the disruptive technologies literature and the potential impact disruptive technologies will have in the boardroom. Changes in industries and the growth of technology are creating a new paradigm shift in industries and strategic planning within the corporate world. Disruptive technologies are changing the very fabric of our decision making and how we deliver products and services.

The last ten years have seen exponential growth in research on disruptive technologies and their impact on industries, supply chains, resources, training, education and employment markets. Current research predicts changes in how we will conduct our daily lives and, ultimately, in the workforce of the future. Predictions are seldom totally correct as the technologies often move in directions we failed to anticipate. The debate is still open on who will be the winners and losers of future industries, but what is certain is that change has picked up pace and we are now in a new technology revolution whose impact is potentially greater than the industrial revolution. This paper gathers past research on disruptive technologies in order to better understand the pace and direction of change and how it will influence the role of boards in helping directors to adapt to manage the changing business world.

Keywords: corporate governance, disruptive technologies, artificial intelligence, board culture, disruptive innovation.

JEL codes: L21, M14, M15, O30.

Introduction

The methodology of the literature review breaks it into three segments: academic peer reviewed journals; professional practitioners, including both major consulting and accounting firms; and lastly, publications from governance institutions who take responsibility for keeping their members (directors) informed of the latest fiduciary and strategic issues faced by boards. The review

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looks at these three areas of literature to see what, if any, convergence exists between them.

The concept of disruptive innovation and its links to technology go back to Schumpeter's 1942 paper, 'Creative Destruction', in *Capitalism, Socialism and Democracy*. This was followed with the first work on artificial intelligence as a scientific discussion with Turing's1950 paper on intelligent machines. At this stage technology was in its infancy and, with its popularity in science fiction novels and the beginning of television, it was more fantasy than reality. In the mid-eighties more scientific publications on the impact of technologies and innovation came to the forefront (Foster, 1986). In the 1990s, Christensen starting publishing a series of articles on the influence of technology and markets leading to the evolution of Christensen's 1997 disruptive innovation theory (Bower & Christensen, 1995; Christensen & Bower, 1996; Christensen, 1997). While a substantial debate followed Christensen's 1997 disruptive innovation theory, the focus of this paper is on the role of technology in disruption. A number of scholars have taken exception to different parts of Christensen's innovation theory over the years and that debate continues to this day. While scholars may differ from Christensen on the structure, categories or dimensions of the theory, they accept that technology is the major disruptor of existing market places (Markides, 2006; Tellis, 2006; Vriens & Soilen, 2014; Yu & Hang, 2010). This paper does not give an opinion on Christensen's innovation theory but rather considers it as part of the literature demonstrating the need for boards to become more enlightened on the impact that technological change has on every industry and consumer. The paper looks at the progression of technological change and how it changes the core elements of decision making within the boardroom. The board has two primary duties: its fiduciary duty and its strategic duty. Both are influenced by changes in technology and boards will need to address these shortcomings sooner rather than later if their organizations are to survive the wave of change that is inevitable (Bravard, 2015; Gottenberg, 2016; Lauterbach & Bonime-Blanc, 2016; Nueno, 2016; Valentine, 2014; Whalen, 2016). The board may want to consider the wave of change like a tsunami: by the time you see the wave, it may be too late.

The aim of this paper is to assess disruptive technology within the academic, industry and governance literature and determine if there is convergence in the signalling of the disruptive challenges and opportunities that will be faced by corporations and their boards. The first section provides an overview of disruptive innovation and disruptive technology and its application within this paper. Section two looks specifically at artificial intelligence (AI) as a disruptive technology and provides a brief history, current development status and estimated future development. Section three reviews the role of robotics within the office environment and its direct interface with AI for deployment, while section four reviews the impact of the internet on the disruptive technologies and introduces some of the most current areas of development and

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research that are forecasted to have far reaching impact on all existing corporate systems. Section five looks at the current state of advanced manufacturing and how the disruptive technology developments are changing the scope and nature of the supply chain. The paper concludes with a brief summary of the findings and suggested areas for future research.

1. Christensen's disruptive innovation theory

Christensen's theory is based on innovation and not just technology change. He proposes that disruptive innovation theory has two basic categories. The first is when incumbent companies ignore the low-end part of the market, allowing new entrants to come into the market and take over the low-end market, building a trajectory to the upper level markets. An example cited is the high-end camera industry targeting the professional market and ignoring the low-end market, allowing for disruptive entry into the lower market and subsequent movement to the upper market with improvement in technologies (Sandström, Magnusson, & Jörnmark, 2009). The second category of innovation acknowledged in Christensen's theory is the creation of a new market where none existed before. The use of wearable technology to measure physical fitness or activities could be seen as a new market where none previously existed. It is important to note that while Christensen closely ties technology to many of the disruptive innovations, the theory does not need technology as its only platform to exist (Christensen, 1997, 2006; Christensen & Bower, 1996; Christensen, Raynor, & McDonald, 2015; Sandström et al., 2009).

The term "disruptive technology" as defined by Christensen (1997) highlights the important role of technology in understanding disruption. The application of innovation theory expands beyond the realms of technology and speaks of a wide range of innovations that can occur, but for Christensen, as with many other scholars, the root of much of the change and innovation we see today is through technology (Christensen, 1997, 2006; Cortez, 2014; Denning, 2016; Drnevic & Croson, 2013). Christensen points out that the theory has had 20 years of development and not all innovations that shake up an industry fit into his criteria of disruptive innovation (Christensen, 2006; Christensen et al., 2015; Christensen, Johnson, & Rigby, 2002; Christensen & Raynor, 2003; Christensen, Suarez, & Utterback, 1998). Some technologies such as Uber do not fit into either category and the definition of disruption as it has entered an existing market not at the low end but at the same level as the incumbents; nor is Uber creating a new market as it is going after the same customers that existed and has not created a new market. Christensen refers to Uber and companies that have improved service models and payment models as "sustaining innovations" rather than disruptive innovations, as what they have done is improve the service and they are therefore themselves open to counterattack

(Christensen et al., 2015). The fact that a company or product may not fit directly into the Christensen model does not make it any less dangerous to incumbent organizations as history has a long list of where technologies have changed industries from the pen to laptop computers (Kaplan, 2012; Utterback & Acee, 2005). Disruption does not occur suddenly and the incumbents frequently overlook the disrupters until the market has already moved away from them (Christensen et al., 2002). Key factors that allow incumbents to respond to digital disruption include resources, processes and values/culture (Karimi & Walter, 2015). The culture of the organization will play a key role in determining if an organization has the capability to handle the amount of change it is faced with in light of the disruptive technologies. Culture surfaces frequently as a criterion that either enables or disables boards' and organizations' ability to manage change (Denning, 2016; Evans, 2013; LeBlanc & Schwartz, 2007).

This paper takes an expanded view of disruptive technologies to include other discontinuous technology innovations, including attack from above as well as from below (Utterback & Acee, 2005). This includes technologies that, due to high cost, cannot initially approach the market from below. Many of the next wave of technologies may appear cost prohibitive at first, but as technology advances these costs quickly change allowing entry into new markets or, for some vendors, the ability to attack from above and move downward. Others easily create new markets which displace or eliminate existing markets. Some incumbents may become the innovators themselves, but for entrepreneurs like Elon Musk (co-founder of Tesla Motors), "new entrants are what drives innovation" (Stringham, Miller, & Clark, 2015, p. 86). Disruptive innovation and disruptive technology are now part of the business vocabulary and we have only witnessed the start of the disruptive wave that is quickly moving towards the business world. The timelines for technology change have moved from linear to exponential, and experts are forecasting that what happens during the next decade will eclipse what has occurred over the last century in its level of profound change (Diamandis & Kotler, 2016; Fenwick & Vermeulen, 2016; Müller & Bostrom, 2016). Yu & Hang (2010) highlighted that more research was needed to address disruptive technologies as these were likely to be the main drivers for disruptive innovation.

Accepting that change is all around us, what are the technologies that will cause the most disruptive change within industries and how good are we at forecasting their impact? What are the questions we should be asking and how do we prepare for this wave of disruptive change? Recent history has shown us that forecasting political events is less than certain and industry may find predicting technology change equally challenging. While the scope of technology change is daunting this paper will look at four specific categories and the literature as applied to these areas of research. While we look at technology categories independent of one another, in reality we must accept that each category crosses over and supports new developments in other categories: nothing today

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can be isolated totally. Some research companies such as InterSearch (2015) and the Future Today Institute (Webb, 2017), break the technologies down into dozens of categories. This paper summarizes the technology research into four disruptive technology categories, these being artificial intelligence, robotics, networking and advanced manufacturing. The ability of a board to incorporate these technologies into both the fiduciary and strategic planning processes may prove critical for their corporate survival (Bravard, 2015; Gottenberg, 2016; Kaplan, 2012; Nueno, 2016; Olson, Remick, & Tapia, 2016; Valentine, 2014).

2. Artificial intelligence

To appreciate where we are today in artificial intelligence (AI), we need to go back to the beginning and understand the definition of what artificial intelligence is. The concept of AI crystallized with Turing's paper in 1950 in the philosophy journal *Mind* where he laid out a process for determining a structure to ascertain the level of AI. The Turing test has become a standard protocol for testing how effectively AI can pretend to be human. In 2014 an AI system convinced over 30 per cent of judges it was human and it is forecast that in the near future computers will routinely pass the Turing test (Yampolskiy & Spellchecker, 2016). AI as a science was restricted until recently by the very formats and structures we used to program computers and therefore historically was restricted to 'narrow AI' (narrow AI is defined as a very specific task with limited decision making by the software) and, while some progress was possible, the very method of coding was restricted to specific applications (Lauterbach & Bonime-Blanc, 2016; Simon, 1995). With the improvement in technology and a totally different approach, we moved from traditional technology development to a disruptive technology that was no longer reliant on humans writing code or specific commands for a specific reaction. In John McCarthy's 2001 paper 'What is Artificial Intelligence?' he addresses a number of questions including the difficulty of coding intelligence using old methodologies. McCarthy (2001) contended that the only way forward was to consider a totally new method to get around this inherent weakness of past coding methods. His position was that it was not the technology or speed of computing that was the critical element but rather the method by which we attempt to provide intelligence to the machines. He explained the difference between coding for chess and coding for Go, a Chinese game believed to be a "scandalous weakness" (McCarthy, 2001, p. 6) of our programing ability and our ability to reach the next level of AI. In 2016, the Go World Champion was beaten by a deep neural network (Yampolskiy & Spellchecker, 2016). AI scientists taking a different path to AI by incorporating the latest in probabilistic machine learning and using fuzzy logic and maths have adapted the whole process and methodology on how to create AI far beyond the concepts first used. More recently

IBM's Big Blue's Watson won *Jeopardy!* in 2011 against top human champions (Ghahramani, 2015; Liu, You, Li and Tian, 2017). Watson is currently mastering medical science and it is believed that the system is capable of mastering any area of knowledge. One method of measuring the advance of AI in the field of image recognition has been to track the errors year on year and they have halved each year since 2011, moving from over 25 per cent errors to less than three per cent (Tyagi, 2016). Recognition software is a good example where, in its initial development, it had very high error rates due to simple changes of someone wearing glasses or cutting their hair or a multitude of other variations. Using less structured programing techniques, the software is allowed to make more of its own decisions and therefore learn from its mistakes (Ghahramani, 2015; Liu et al., 2017; Tyagi, 2016). Using the probabilistic or fuzzy logic systems analysis teaches the AI maths and allows it to develop learning patterns based on the input it has received so that it becomes self-learning and is not dependent on a set outcome. In the past, to teach a computer to play chess at a champion level would require millions of lines of code created by a human, whereas, using new methodologies the system will create its own outcomes based on what it receives as input. Much of the software used in defending cybercrime – a major concern of many boards – will depend on the development of AI technology. Systems will need to understand when they are being attacked and the potential remedies that can be applied. Boards will need to understand the difference between effective and ineffective AI and learn new concepts in risk management, historically left to the technologist. Boards need to start recruiting and training existing board members on the importance of technology (Olson et al., 2016; Vasarhelyi, 2013).

For the board member who is still not convinced of the importance of having a better understanding of AI consider the artificial intelligence measurement of disclosure (AIMD), the system without human intervention using a sample of 127,895 observations of companies regulated by the Security Exchange Commission (SEC). The system in test mode demonstrated perfect reliability and a superior ability to provide consistent analysis (Grüning, 2011).

Faced with the increase in new technologies and techniques for AI development the question on where AI is going and how fast continues to be a question for both scientists and business leaders. The impact of AI goes far beyond the software and computers to its application in industries, governments and companies. What was seen as science fiction only a few years ago is now considered by the scientist in charge of developing the technology as merely a matter of time. A survey of a number of conferences including the top 100 authors on AI looked at different levels of AI development and asked the participants to select the year they anticipated high level machine intelligence (HLMI), which was defined as a machine capable of doing the same job as a qualified human, including professional positions and using a scale of 5,000 years, predict both HLMI and superintelligence, or where machines greatly surpass human in-

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telligence. The results of the study showed a convergence of opinion around 2040 with dates as early as 2020 for HLMI and superintelligence likely to follow between two and thirty years after (Müller & Bostrom, 2016). While the media often portrays a scary image of AI it is important not to fan the flames of hysteria of science fiction but rather to take a pragmatic view that we can accomplish great steps forward with technology and while we may face disruption of industries and markets as we develop the new world with basic standard operating environment, many of the concerns can be eliminated (Kaplan, 2017). KPMG (2016a) released an insight report on AI which identified that the bulk of corporate finance positions in both tier one (clerical) and tier two (analytical) would be taken over by AI between 2018 and 2020. At the same time new skills would be required but the difference at first glance appears to be ten jobs lost for each new one gained. What the report does not identify is the potential job creation that may come about through new markets. The 2015 Global Information Security Workforce Study estimates that there is currently a global shortfall of approximately 400,000 positions and this is forecast to grow to 1.5 million by 2019. Retraining and education will be key factors in filling the gaps that will be created by new demands and new markets. Training and educating board members on the latest in virtual reality and AI will be necessary if we are to get the board to understand the impact of AI on corporations (Lancefield & Gagliardi, 2016).

AI development will likely be the backbone of all disruptive technologies in that it is this intelligence capability that allows new services and products to be offered. The future director needs to understand how the technologies interrelate and how an advancement in one area can lead to changes or disruptions within their industries (Lauterbach & Bonime-Blanc, 2016). The King IV report put out in November 2016 separates technology and information as major assets of organizations and "technology is now part of the corporate DNA". Thus, the security of information systems has become critical. Technology governance and security should become another recurring item on the governing body's agenda" (King IV Report, 2016, p. 6). Directors need to embrace AI as a strategic business and governance imperative.

The wealth of opportunities presented by AI cannot be fulfilled without progression in other areas of technological growth including robotics, networking and manufacturing automation.

3. Robotics

The world has become accustomed to the use of robotics in manufacturing and the large welding arms often used in pictures of robotics in automotive manufacturing come immediately to everyone's mind. While robots will continue and expand the levels of service that they provide in manufacturing facilities they

have now expanded to the office and, using the Oxford Canadian Dictionary definition of "functioning like a human" (Barber, Fitzgerald, Howell, & Pontisso, 2006, p. 880), the use of AI has become intermixed with robotics. Many of the functions once completed by humans are now functions of office automation or robotic process automation (RPA). This new term is applied to the office robotics designed to replace outsourcing 'swivel chair' processes where a human worker sits at a workstation taking inputs from a range of electronic information, whether email, spreadsheets, databases or other sources of information, in order to set up a process or complete a series of necessary tasks such as preparing complex management reports or providing many of the HR tasks required within an organization (Lacity & Willcocks, 2016). RPA is more than just automation: it is a combination of clerical to middle management back office tasks that were often targets of potential outsourcing. Seasongood (2016) adds a new level with robotic desktop automation (RDA), which differs from RPA as it automates a wide range of front office functions including "determining credit decisions, loan underwriting, insurance underwriting, insurance claim adjudication, payment processing, customer service delivery, accounting data entry and procurement, to name a few activities" (p. 32). Kaplan (2015) argues that with the large volume of information required for processing today, there is no alternative but to seek greater levels of robotic integration. Every industry is being impacted by RPA and RDA applications replacing scores of workers (Kaplan, 2015; Lacity & Willcocks, 2016; Seasongood, 2016).

Few industries are immune, if any, from the next wave of robotics and AI. Wealth management – once the field of the elite in financial planning – is being impacted by the latest in RPA and RDA specialists aiming to disrupt the existing market by offering complex financial plans, taking into account aspects of client information and better risk management at lower rates (Bhatnagar, 2016). Disruptive technologies are not just replacing humans: they are improving services, products and productivity and, in many cases, changing how markets operate, removing the barriers of entry for new companies to take on the giants (Fenwick, Hisatake, & Vermeulen, 2016; Stringham et al., 2015).

If there is disagreement it is on the timeframe whereby the intelligent car will dominate the market. In North America states and provinces are quickly changing laws to ensure a smooth transition from people-controlled vehicles to the autonomous car. The level of change that is occurring within this industry is far beyond the car as a mode of transportation. To understand how it will impact the industry it is necessary to look at the impact across the whole supply chain and multiple industries, including logistics, public transit and individuals. Ultimately it is a question of whether it is a mode of transportation or much more, with links to communication, other networks and maybe an experience yet to be defined, with both robotic and AI advancements yet to be determined. Early indications show disruption at all levels of the current market (Dirican, 2015; Fenwick et al., 2016; Stringham et al., 2015; Walker, 2014).

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While mass unemployment may not be imminent, Sohn (2016) suggests that leaders need to understand the risk factors and that current indicators suggest that both governments and corporations have underestimated the impact that the next wave of robotics and AI will have on employment levels to the extent that unemployment issues are quickly replacing concerns about climate change. Two hundred years ago, as Kaplan (2017) states, 90 per cent of the population worked on farms; since the Industrial Revolution less than two per cent of the population has worked on farms and that may decease to one per cent during the next revolution, despite producing more food than ever before. Like our predecessors we will reap the rewards of the technology revolutions, allowing for a different view of the areas of work in the future (Kaplan 2015, 2017).

4. Networks

Lyytinen and Rose (2003) wrote about the disruptive nature of information technology and the role of the internet in system development organizations. The fast advancement of the internet has had a major impact across industries, including systems developers who have had to navigate the difficulties of integrating past standalone systems into the world of the internet. The changes in IT architectural innovation have had "pervasive and radical impacts on development processes and their outcomes" (Lyytinen & Rose, 2003; p. 557). This was identified prior to the development of the cloud and the concept of blockchain technology which, combined, have had a profound impact on developmental systems. The benefits that have arisen from network technology have been instrumental in breaking down the traditional economical boundaries necessary to build a global economy. In 2015, 3.2 billion of the seven billion people on the planet were connected to the internet and a correlation has been established between exports and internet population use. Companies with limited resources now have a global reach for both business and consumer customers (Meltzer, 2016). With the growth of the internet came the transformational issue of big data and analytics that did not exist prior to the internet. Not only was the internet disruptive to old business methods but it brought with it the need to develop new skills sets and new disruptive technologies that would further change industries and market places (Baesens, Bapna, Marsden, Vanthienen, & Zhao, 2016; Drnevich & Croson, 2013; Lyytinen & Rose, 2003). Knowledge sharing has become part of the disruptive web that has been woven. Knowledge sharing has provided companies with increased research capabilities and productiveness in both new and existing industries (Arazy, Gellatly, Ester, & Nov, 2015; Baesens et al., 2016). Boardroom directors have accepted that no corporate strategy is complete without the inclusion of a network technology strategy but a company's MIS strategy cannot be separated from the rest of the organization: it is part of the core business of the corporation (King IV Report, 2016).

Brandon (2016) proposed that blockchain would become the future of business information systems. Historically data were stored on relational database structures but while they were considered best practice in their day they are now, in light of the next generation of system architects, considered old and in need of retirement. Walker (2014) highlights the convergence of disruptive technologies and, without speaking directly of blockchain technology, highlighted the potential impact the convergence would have on the banking sector. While blockchain technology was initially for the bitcoin or internet currency the technology behind it is far-reaching, allowing companies to create transactions using the tools of the internet to ensure protection yet transparency of the transaction (Brandon, 2016; Caytas, 2016; Xie, Chen, & Hu, 2017). For the non-technologist, according to Davidson, De Filippi, and Potts (2016):

> The actual technology of blockchain combines mathematical cryptography, open source software, computer networks and incentive mechanisms. However that list of ingredients is perhaps no more enlightening than to say it is the 'magic' behind 'magic internet money'. A better starting point is what blockchains do, what they compete with and will potentially replace, namely ledgers. A ledger is a way of producing consensus about the facts that are necessary for commerce to function. Ledgers are the basic transactional recording technology at the heart of all modern economies (p. 4).

In 2016 a survey by KPMG UK found that technology companies and their boards who were the leaders of technology disruption are being disrupted themselves by the small nimble start-ups and a third of the boards admit they are not ready for the disruption (KPMG, 2016b).

Not all disruptive technologies are devoid of risk and cases of technology gone wrong can damage markets and industries with unforeseen consequences. Kaplan (2015) outlines the nine per cent drop in the stock market on May 6 2010, which plunged the market into disbelief as it watched over a trillion dollars disappear and, with it, savings from many pension funds. Six months after the drop the securities exchange commission SEC was able to conclude that the reasons behind the drop: "Competing computer programs, buying and selling stocks on behalf of their owners, had gotten out of control. In the murky, secretive world known as high-frequency trading, these systems not only reap small profit opportunities that appear and disappear in an instant but also detect and exploit each other's trading strategies" (Kaplan, 2015, p. 8). What Kaplan (2015) exposes in his book is the need for both governments and companies to consider new levels of risk management and the governance and remedies that can be applied when issues occur. The role of ethics has become a concern as AI is assuming a greater level of independence in decision making. Developers and board members need to consider ethical issues when developing new technologies. (Johnson, 2015; Piper, 2016).

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The internet has many subcomponents. One mentioned earlier under AI is cyber security and, as stated, the cyber security sector is substantially understaffed on a global level. Cyber security has direct links to AI, robotics and the network. While cyber security is often listed as a concern of boards the specific issue of disruptive technologies is only starting to penetrate the boardroom. The various associations providing information to directors – including the National Association of Corporate Directors (NACD), the Institute of Directors (IOD) and the Institute of Corporate Directors (ICD) – all have dedicated material for directors to help them be better informed on technology issues. The NACD in 2016 provided all members with a cyber risk oversight handbook to help instil the need for greater board involvement. In the NACD survey less than 30 per cent of the boards interviewed were confident that their organization was adequately prepared for a cyber-attack. The IOD (2017) reported that it takes on average 120 days for a company to know it has been compromised and 43 per cent of directors do not know where their company's data is physically stored. The big four accounting firms – KPMG, PWC, Ernest & Young and Deloittes – are all providing research papers and consulting services on disruptive technologies. The 2017 USA PWC report on data science and the analytics job market indicates great opportunities and, as with cyber security, large gaps in the existing job market. The PWC report outlines the close connection between big data, the internet and the requirement for analysts, data engineers and scientists to work closely with the convergence of AI, robotics and networking. The data analytics market is expected to grow from 2.3 million in 2015 to 2.9 million in 2018. As the technology improves this growth rate is expected to accelerate faster. Ernst & Young (2017) highlighted that the economics of disruptive technology will impose direct fiduciary responsibility on the board members. Both practitioners and academics have identified the need to improve governance at the government and corporate levels for all forms of technology. In 2014, Cortez highlighted the shortcomings of existing regulatory structures and within the corporate structure of organizations: he proposed caution in making hard rules or regulations for a technology that is constantly shifting and adapting to new and existing technologies. Other researchers and scholars take a more structured approach suggesting that board directors need to consider new structures for corporate governance and a re-examination of the role of the board of directors for investor relations and listed companies (McCahery, Vermeulen, & Hisatake, 2013; Zukis, 2016). While McCahery et al. (2013) were focused on structural and board changes other researchers saw the need for more formalization of standards in regard to automation, robots and IT governance. Vasarhelyi (2013) believes the audit ecosystem and many of the operational systems will be either fully or partially automated, making it necessary to formalize the collaboration between humans, AI and other aspects of technological disruption. The crossover between the technologies needs to be fully appreciated by the board: not having technol-

ogy expertise is no longer an accepted format for any organization (Bravard, 2015; Cunha & Frogeri, 2016; Gottenberg, 2016; Lauterbach & Bonime-Blanc, 2016; Nueno, 2016; Spitsberg, Verti, Brahmandam, & Coulston, 2015; Valentine, 2014; Valentine, Dehaes & Timbrell, 2016; Valentine & Stewart, 2013; Weill & Woerner, 2016). Some companies are seeing the change and taking action at the highest levels. General Electric CEO Jeffrey R. Immelt in 2013 moved the head office of the company from Fairfield, Connecticut, to Boston in the hope of attracting world class software engineers.

5. Advanced manufacturing

The manufacturing sector will continue to expand its reliance on technology and, with the lowering cost of technology and robotics and the potential of 3D printing, the whole logistic chain can be reset. The same technology of analytics, big data, cloud, internet, robotics and AI will be the drivers of future manufacturing. Drone technology will impact everything from agriculture to construction, while the combination of AI, networking and robotics will drive up production and drive down cost. Manufacturing, on the positive side, will be safer than any time in history, providing workers with new opportunities to learn and adapt to new technologies. The continued expansion of technology in the manufacturing environment will bring with it positive factors within the work environment (Yu, Zhang, Shen, & Lewark, 2017). The new manufacturing world has moved away from mass production to one that uses the latest advanced manufacturing technologies (AMT) linked to enterprise management systems through internet technology, improving both productivity and customer service. Jonsson (2012), in comparing those organizations with high levels of AMT, emphasized worker improvement programmes and greater empowerment. The use of AMT also provides better maintenance integration and these companies have a better position with complementary capabilities just as in the office environment, big data technologies used in manufacturing lead to an increase in productivity and a reduction of supply chain risk (Dubey, Gunasekaran, Childe, Wamba, & Papadopoulos, 2016). Both AI and blockchain technology are identified as revolutionary with the ability to transform existing systems with greater security and empowerment of users. Combined with big data, cloud and other internet technologies will impact the decision makers at the highest levels. More research is required to understand clearly the scope of the improvements that the technologies will deliver (Abeyratne & Monfared, 2016; Li, Hou, Yu, Lu, & Yang, 2017). The same technologies that are transforming today's offices are having a similar impact on the manufacturing industry. Everything from the size of the plant to where to locate is being changed with the leading disruptive technologies.

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Conclusions

The literature clearly indicates that the world is changing and the rate of change is accelerating. Academics, practitioners and governance institutions are all sounding the warning bells for boards to become more engaged in technology and to prepare for the technological revolution that is upon us. Many companies are adjusting to the new world and the evidence is clear in their actions. General Electric sees the transformation of its core business and other companies such as Tesla, Apple, Google, IBM and Microsoft are all participants in preparing for the new world of technology that is developing. The benefits and advancements in new products and services will drive forward the need for change. The world is now connected and it is impossible to put the genie back in the bottle. Companies need to incorporate into their fiduciary and strategic planning processes a level of understanding and oversight beyond the concept of passing it on to external advisors. Each company will need to implement effective oversight of the technology to even stay competitive, requiring a much deeper understanding from existing board members than appears within current literature. Each corporation at the board level needs to consider which of the technologies will have the biggest impact on their markets and make informed decisions on the range of fiduciary and strategic options that may be open to them. Webb (2017) of the Future Institute provides a detailed report on the potential impact of a range of technologies on existing and future organizations by industry and by technology. Very few organizations are aware of such reports and few have taken any of the necessary steps to properly understand the impact disruptive technology will have on their industry let alone their company.

The literature displays convergence between the professional practitioners and the academic scholars. The academic and professional firm surveys display similar business and job opportunities and industry trends. The surveys of boards continue to indicate that, in general, boards are not prepared for the level of change that is predicted. An awareness is growing of the importance of cyber security that is only now being acknowledged by board surveys. The same surveys indicate that the majority of corporations see themselves as unprepared.

The literature demonstrates a need for solutions to be more inclusive of academic institutions to ensure the alignment of future skills sets. Certain levels of technology, such as the autonomous car, are certain to occur: what is unclear is how this will impact the whole ground transportation industry. Big data will continue to drive analytics and this is a space that it appears will be shared between AI and humans for some time to come. Blockchain technology is more difficult to predict but indications from both the professional and research worlds are that it will have far-reaching ramifications, bringing a new level of verification to e-commerce. Cyber security will continue to be a growth market and, even with improved AI, a shortage of qualified technologies will

continue for the foreseeable future. Companies and boards will need to continue to ask questions about how technology will invade their space and what they will do to stay competitive.

Indications show that jobs are more likely to disappear at a faster rate than they appear in new industries or markets but the massive shortcomings predicted in certain fields will make skills training a growth industry (Schatsky & Schwartz, 2016).

The full impact of the wave of disruptive technologies is only touched upon in this review. To gain a deeper appreciation future research needs to look into the details of each of the technologies outlined and expand to other areas of new technology that are being developed daily and creating new markets. Directors need to gain a better grasp of the disruptive technologies or they will risk their organization not surviving the transition to the new world and markets.

Governments and businesses will make major investments in new technology. Some will prove insightful and others will be leapfrogged by yet newer technology and represent a loss in terms of costs. Jobs will be more meaningful and new markets will develop making it unlikely that anyone will yearn for the good old days. We are truly seeing only the tip of the iceberg.

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