Journal of Comparative International Management

An Examination of Business Applications and Implications of Emerging Technologies

Hamid Yeganeh

Volume 24, numéro 1, 2021

URI : https://id.erudit.org/iderudit/1081422ar
DOI : https://doi.org/10.7202/1081422ar

Aller au sommaire du numéro

Éditeur(s)

Management Futures

ISSN

1481-0468 (imprimé)
1718-0864 (numérique)

Découvrir la revue

Citer cet article

Yeganeh, H. (2021). An Examination of Business Applications and Implications of Emerging Technologies. *Journal of Comparative International Management*, *24*(1), 61–78. https://doi.org/10.7202/1081422ar

Résumé de l'article

This paper aims at offering a review and assessment of various emerging technologies and their business applications and implications. The study focuses on nineteen emerging technologies categorized under five major themes: (1) automation and robotics; (2) data and connectivity; (3) interfaces and visualization; (4) materials; (5) energy and resources. For each theme, the associated technologies are examined, their business applications and implications are assessed, and some examples are provided. In the end, an integrative table of nineteen emerging technologies is offered, and some avenues for future research are discussed.

Journal of Comparative International Management 2021, Vol. 24, No. 1, 61–78

An Examination of Business Applications and Implications of Emerging Technologies

by

Hamid Yeganeh
Winona State University, Minnesota, USA

This paper aims at offering a review and assessment of various emerging technologies and their business applications and implications. The study focuses on nineteen emerging technologies categorized under five major themes: (1) automation and robotics; (2) data and connectivity; (3) interfaces and visualization; (4) materials; (5) energy and resources. For each theme, the associated technologies are examined, their business applications and implications are assessed, and some examples are provided. In the end, an integrative table of nineteen emerging technologies is offered, and some avenues for future research are discussed.

1. Introduction

In the past three decades, the pace of innovation has substantially accelerated, and product lifecycles have shortened. Trade has become more global, and new products and technologies have reached many users in short periods. While it took the telephone almost 70 years to reach 80% penetration in U.S. households, it took only 12 to 15 years for smartphones to reach the same level of penetration (Dediu, 2012). Currently, businesses are under growing pressure from investors and consumers to innovate faster than ever. We are witnessing the emergence of technologies that are expected to drastically transform social or economic domains such as education, healthcare, transportation, and retail (Brey, 2017). Emerging technologies are still in their infancy and for the same reason, are supposed to involve huge influences across the world (Boon & Moors, 2008). According to Gunther and Day (2000) and Srinivasan (2008), emerging technologies are science-based innovations with the potential to create new industries or transform existing ones.

There is no agreement on the definition of the concept of emerging technologies as they represent a wide variety of technologies in different domains. Nevertheless, definitions proposed by previous studies point to several common characteristics. According to Rotolo et al. (2015), emerging technologies are marked by five key attributes, precisely: radical novelty, fast growth, coherence, noticeable impact, uncertainty, and ambiguity. In other words, emerging technologies are radically novel and relatively fast-growing technologies with the potential to exert a considerable impact on the socio-economic domains (Rotolo et al., 2015).

Conventional technologies are related to commercialized products, processes, procedures, and techniques that are widely used and have familiar applications. As a result, conventional technologies' innovation consists of incremental improvements to existing products (Brey, 2017). By contrast, emerging technologies rely on new concepts, methods, and techniques. Emerging technologies presage new and potentially superior solutions to problems. While they change rapidly, they display persistence over time and are detected by specific scientific discourse. More importantly, emerging technologies exert huge impacts on socio-economic systems by changing institutions' composition and structures. Emerging technologies involve high levels of uncertainty, and since they are research-based, they tend to be more expensive (Mitchel, 2007; Rotolo et al., 2014; Stanoevska-Slabeva, 2003; Stirling, 2007).

Given their rising significance, emerging technologies deserve more research and examination (Thomas et al., 2009; Veletsianos, 2010). Understanding emerging technologies, their characteristics, and more importantly, their business applications and implications could be of great importance to managers, policymakers, and entrepreneurs. Hence, the current paper aims at offering a review and assessment of various emerging technologies and their business applications and implications. To this end, the remainder of the text is structured around five major themes, including 1) automation and robotics, 2) data and connectivity, 3) interfaces and visualization, 4) materials, and 5) energy and resources. For each theme, the associated technologies are examined, their business applications and implications are assessed, and some examples are provided. In the end, an integrative table of nineteen emerging technologies is offered, and some avenues for future research are discussed.

2. Automation and Robotics

Augmented Intelligence

Augmented intelligence involves the use of intelligent tools by human beings in order to enhance their intellectual and cognitive capacities (Sabhikhi, 2018). Augmented intelligence systems rely on machine learning to extend human cognitive abilities such as the brain's capacity to calculate, assess, prioritize, and analyze information. Augmented Intelligence systems use natural language processing, spatial navigation, machine vision, logical reasoning, and pattern recognition (Sabhikhi, 2018). In other words, augmented intelligence systems help connect people and computers to jointly analyze, interpret, and process the fast-changing big data in real-time.

While most artificial intelligence methods focus on replacing humans, augmented intelligence aims at creating collaboration between machines and humans. The augmented intelligence systems are characterized by five major abilities:

1. Understanding: they derive meaning from all forms of multi-structured data and user interactions.
2. Interpreting: they represent the meaning in a deterministic and probabilistic knowledge graph based on declared, observed, and inferred entities, events, and relationships.
3. Reasoning: they reason over the domain-optimized interpretation in business and user context to develop personalized advice with supporting evidence.
4. Learning: they learn continuously based on real-time and historical data, user, and system interactions.
5. Assuring: they ensure ongoing compliance and governance for responsible and risk-managed use of cognitive services (Sabhikhi, 2018).

By using these capacities, augmented intelligence will assist users in making more informed and faster decisions in a wide range of areas, including finance, investment, healthcare, manufacturing, retail, travel and tourism, energy, and agriculture. Augmented intelligence systems can be used by businesses that are facing fast-changing customer behaviour, strict security, and regulatory requirements. For instance, augmented intelligence may help patients with chronic diseases get personalized care and avoid medical errors. Augmented intelligence systems can analyze an individual's environment and lifestyle patterns to deliver targeted health-related recommendations. Likewise, financial planners can use augmented intelligence systems to offer personalized financial services to their clients. Augmented intelligence systems can help shoppers in their shopping experience depending on the context, occasion, and location of their purchase.

Autonomous Vehicles

In the past two decades, advances in multiple technologies such as robotics, navigation, sensing, computer vision, and high-performance computing have revived interest in autonomous vehicles. Autonomous vehicles are being developed along two streams: 1) vehicle automation, which consists of technologies concerning automation of vehicle control functions without direct driver inputs, and 2) vehicle connectivity, which consists of different vehicular communication technologies such as vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-personal device communication (Kockelman, 2017). The National Highway Traffic Safety Administration (NHTSA) proposed a five-level conceptualization of automated vehicles as the following (Hedlund, 2017):

- Level 0: No automation; the human driver is in complete control of all functions of the car.
- Level 1: Driver assistance; the vehicle can assist the driver or take control of either the vehicle's speed or its lane position.
- Level 2: More than one function is automated at the same time, but the driver must remain constantly attentive.
- Level 3: Limited self-driving; the driving functions are sufficiently automated that the driver can safely engage in other activities.
- Level 4: Full self-driving under certain conditions.
- Level 5: Full self-driving under all conditions: the vehicle can operate without a human driver or occupants.

A future with autonomous motor vehicles is not very far away, as currently, various models of autonomous vehicles are being tested in research facilities and on public roads. A growing number of carmakers are showing interest in autonomous vehicles, including Audi, BMW, Ford, GM, Mercedes-Benz, Nissan, Toyota, Volkswagen, Volvo, Tesla, and Local Motors. Even technology companies such as Apple, Google, and Uber are investing in autonomous vehicle technology (Kockelman, 2017). There is extensive agreement that Levels 3–5 of automated vehicles will be commercially available to some buyers within five years. In 2016, Ford announced its plans to have a high-volume, fully autonomous SAE Level 4 vehicle in commercial operation in 2021 in a ride-hailing or ride-sharing service (Ford, 2016). Autonomous vehicles will probably be available for sale across the country in a few years, but not all vehicles on the road will be autonomous and conventional driving will continue to exist for a long time (Hedlund, 2017). Most experts believe that Level 4 or 5 autonomous vehicles will be widely commercialized sometime after 2025–2040 (Hedlund, 2017). According to a recent study, the Netherlands, Singapore, the United States, Sweden, and the United Kingdom are ranked as the most prepared countries for the commercialization and widespread use of autonomous vehicles on policy and legislation, technology, infrastructure, and consumer acceptance (Autonomous Vehicles Readiness Index, 2018).

The commercialization of autonomous vehicles will have substantial implications for many aspects of our lives, including transportation, jobs, urban planning and infrastructure, economic models, and more obviously for roadway rules and regulations. Autonomous vehicles are expected to reduce human error on roadways, improve capacity on the roadways, and increase the utilization of travel time (Angerholzer et al., 2017). The market for liability coverage may be impacted significantly by manufacturers, owners, and operators (Autonomous Vehicles Considerations, 2016). Autonomous cars are expected to significantly reduce the cost of congestion because drivers could engage in alternative activities. Autonomous vehicles could restructure transportation models that are based on car ownership.

Furthermore, autonomous vehicles can increase the mobility of young people, the elderly, the disabled, and other communities underserved by traditional personal and public transportation systems

(Angerholzer et al., 2017). The commercialization of autonomous cars could lead to more dispersed and low-density patterns of land use surrounding metropolitan regions (Anderson et al., 2014). Currently, a large portion of space in metropolitan regions is devoted to parking. Naturally, the use of autonomous vehicles and sharing programs necessitate fewer parking spaces and thus could revolutionize land use in metropolitan areas. The overall effect of autonomous vehicles on energy and pollution is indeterminate, but it is widely expected that autonomous vehicles will reduce energy use and pollution. Autonomous vehicles require adapted infrastructure, pavements, traffic signals, signs, and street markings.

Moreover, autonomous vehicles need to install various types of sensors and communications technology (Henaghan, 2018). Buildings will need to be located and designed to facilitate both pedestrians and autonomous deliveries. The commercialization of autonomous vehicle technology involves some critical impacts on the transportation industry and associated sectors. For instance, truck, bus, taxi, and delivery vehicles are expected to undergo major transformations. Cab and truck drivers and mechanics may lose their jobs, and the revenues derived from selling or renting parking spots may decline or disappear. Likewise, all those workers and institutions involved in car maintenance and insurance may be disrupted (Anderson et al., 2014).

Drones and Unmanned Aerial Vehicles

The U.S. Department of Transportation estimates that the number of drones and unmanned aerial vehicles operations will exceed that of regular or manned aircraft operations by 2035 (Kuzma et al., 2017). Drones can be used in many sectors, including agriculture, energy, public safety, security, military, e-commerce, delivery, and transport. In the military sector and defense, drones are already employed, and their application will continue to increase in the next several years. Drones can be used in precision agriculture to enhance farms' productivity. In the energy sector, drones may reduce various risks to personnel performing hazardous tasks, or the risks to the environment and assets.

Furthermore, they can be used in inspecting industrial infrastructure, oil refineries, pipelines, tanks, and power lines. In public safety and security, drones can play an essential role by facilitating the assessment and management of hazardous situations. In e-commerce and delivery, the drone may be used to deliver packages and supply materials more efficiently and more quickly. Most of all, drones can replace present aircraft, railways, buses, and taxis by providing safe, reliable, and fast mobility. Autonomous drones can be used as a mode of transport to carry individuals or small groups of passengers to a destination. Currently, different prototypes are in development for use, particularly in high-density urban environments. Passenger drone is a prototype that is slightly larger than a small car and can change the traditional means of commuter transportation by flying at a speed of 50 miles per hour (PassengerDrone.com). Public acceptance for flights with automated drones will require substantial improvements in other technologies such as connectivity and autonomy in ground vehicles, aerial transport, and the design of buildings, public spaces and power systems, and transport infrastructure. Dubai has already begun trials of a passenger drone service. The advent of partial and fully autonomous flying vehicles will be some time after 2025 (Undertaking, 2016). Drones will bring about new forms of air traffic, especially at very low levels of airspace with high demand in densely populated areas.

3. Data and Connectivity

5G Mobile Internet and the Internet of Things

As the volume of data is growing exponentially, the next generation of the mobile Internet or 5G is expected to handle vast amounts of data, connect more devices, reduce latency, and provide increased network reliability. 5G networks have a speed of 10 Gb/s per user, which is over 1,000 times that of 4G

(Starkloff, 2015). 5G is not an extension of 3G and 4G; instead, it is an innovative web that includes a heterogeneous network, including 4G, Wi-Fi, millimeter-wave, and other wireless access technologies (West, 2016). The 5G networks offer a fully connected and interactive world with various applications, including enhanced mobile broadband, machine-to-machine communications, artificial intelligence, and advanced digital services.

By 2020, the 5G network will support 50 billion connected devices and 212 billion connected sensors and will enable access to 44 zettabytes (ZB) of data (MacGillivray, 2013). The vast network of devices connected to the Internet or the Internet of Things (IoT) may incorporate sensors to measure different variables in real-time, including energy consumption, pressure, temperature, and many other economic, medical, or social indices. Thanks to 5G, digital networks will connect billions of devices and sensors, enabling advances in healthcare, education, resource management, transportation, agriculture, and many other areas (King, 2016). For example, medical devices can reliably transmit data about variables such as blood pressure, pulse, and breathing rate in near-real-time to a health service provider, who can rapidly intervene in case of need. Road transport, train travel, and flights can become safer and more efficient, as connected vehicles and planes share information in real-time with others.

Similarly, manufacturing can be revolutionized with connected robots and information-sharing about the different activities of the supply chain (Davies, 2016). Buildings, bridges, and roads can be monitored continuously. Similarly, governments may use air pollution monitoring data to control emissions.

The 5G systems include heterogeneous devices incorporating both low and high bandwidth. 5G is considered a transformative system because it moves us from a user-centric world to one based on machine-to-machine communications. This transformation and the ensuing IoT will connect these devices intelligently and lead to the commodification of information and intelligence (King, 2016). 5G will provide access to a wide range of services with increased resilience, continuity, and much higher resource efficiency, including a substantial decrease in energy consumption (5G Infrastructure Association, 2015).

Blockchain

Blockchain can be defined as a distributed digital ledger that records transactions in a peer-to-peer network. The blockchain technology is a register that notifies and time-and-date stamps each exchange between each node in a block (Peters & Panayi, 2016). These characteristics enable several parties to use blockchain to engage in multiple transactions or exchanges without the presence of a third party. In other words, blockchain liberates users and transactions from the company of a trusted third party and creates immense opportunities for a distributed, secured disintermediation, organized in a peer-to-peer mode. Blockchain technology has the potential for innovation and the disruption of dominant economic models by creating an Internet of transactions.

While the idea of blockchain appeared with the rise of bitcoin, it can be used to create transactional highways for any peer-to-peer economic mode (Peters & Panayi, 2016). The concept of blockchain is very revolutionary because it can create a system based on trust, but without trusted third parties like banks, financial institutions, Airbnb, and Uber. Indeed, the alternative models to Uber may use blockchain technologies to eliminate intermediaries. Blockchain technologies allow the traceability, security, and transparency of each transaction. For example, cryptocurrencies such as bitcoin incorporate into the source code access to the past transactions relating to the unit of value, and at the same time, they protect the identity of the individuals associated with the transaction. As a result, the theft of a person's identity during the execution of a transaction becomes impossible (Peters & Panayi, 2016).

Another advantage of blockchain technology is its high speed of execution. The world of finance is currently testing the use of blockchain to facilitate intermediation between banks, clearinghouses, and central banks. The blockchain technology can be applied in various areas such as financial systems, the sharing economy, smart contracts including self-executing and autonomous algorithms, the digital vote, and the management of the logistics chain. Blockchain technology can transform the organization of transport, supply chains, advertising, energy production, the distribution sector, real estate markets, the insurance industry, and many other sectors by uniting the digital and physical worlds. Blockchain may help give objects identity and full autonomy, thus creating opportunities for driverless cars and the IoT. In the field of Internet security, a startup called oneName is using blockchain technology to make a unique digital identity, so the user can use this identity in multiple Web-based platforms without memorizing different usernames and passwords. In the healthcare sector, the company BlockRX is using blockchain to digitize medical records and information about the patient that can be transferred more easily from one healthcare professional to another. Peer-to-peer insurance may create a revolution in the insurance industry by abolishing the current standards and the tripartite relationship between payers, insured parties, and insurers. Blockchain can be used in smart contracts where an agreement between two parties is digitalized, automated, and therefore self-executed. Ethereum, the second most popular cryptocurrency after bitcoin, is relying on smart contracts to give various parties the assurance that, once the conditions have been fulfilled, the contract will be honored, with no possibility for fraud or interference with a third party (Peters & Panayi, 2016).

Bluetooth 5.0

Bluetooth is a relatively old technology that was developed more than two decades ago and is used for data transmission through radio waves. Bluetooth is a flexible technology, as it does not have any constraints on the type of the transmitted data, including photos, documents, music, and videos. However, one major limitation with Bluetooth has been the short range of data transmission that generally did not exceed 100 meters. Bluetooth 5.0 is the latest version of the Bluetooth wireless communication standard that offers significant improvements regarding the range, speed, and broadcasting capacity of data (Collotta, Pau, Talty & Tonguz, 2017). Bluetooth 5.0 offers an 800% increase in data broadcasting capacity by doubling the speed and quadrupling the range of previous versions and maintains a very low power consumption. Therefore, the latest version of Bluetooth known as Bluetooth 5.0 can be used for wireless communication between various machine-to-machine communication and IoT devices (Chang, 2014). Bluetooth technology will support the consumer adoption of the IoT, industrial automation, and the proliferation of dense sensor networks. By 2022, more than 50 billion connected devices worldwide will rely on Bluetooth 5.0 to connect and communicate (Chang, 2014).

Li-Fi

Li-Fi or light fidelity is a form of visible light communication that uses the visible light portion of the electromagnetic spectrum to provide local wireless communications at very high speeds. In other words, Li-Fi is a visible light communication system capable of transmitting data at high speeds over the visible light spectrum. As the visible light spectrum is 10,000 times larger than radio waves, Li-Fi technology can achieve Internet speeds of up to 224 GB per second which are much faster than the current standard Wi-Fi. Li-Fi technology offers many advantages and peculiarities. For instance, while Wi-Fi works close to full capacity, Li-Fi has almost no limitations on capacity. As light cannot pass through walls, Li-Fi makes the transfer of data more secure than Wi-Fi and reduces the interference between multiple devices, and as a result, the data transmitted via Li-Fi cannot be hacked. Li-Fi offers many advantages, including working across higher bandwidth, and working in areas susceptible to electromagnetic interference such as aircraft cabins and nuclear power plants. Li-Fi technology may be applied in several areas such as the IoT, retail, construction, aviation, transportation, traffic management, and urban environments. Furthermore, future home and building automation are expected to be highly dependent on Li-Fi technology for being secure and fast.

Quantum Computing

Quantum computing uses subatomic particles and quantum-mechanical phenomena such as superposition and entanglement to store data (Gershenfeld & Chuang, 1998). Current digital computing encodes data into binary digits (bits) that are always in one of two definite states (0 or 1), but quantum computation uses quantum bits that can hold much more complex information or even negative values (Accenture, 2018). In a conventional computer, bits are processed sequentially, but in quantum computation, qubits are entangled together, so changing the state of one qubit influences the state of others (Accenture, 2018). Unlike classical computing, quantum answers are probabilistic, and because of superposition and entanglement, multiple possible answers are considered in a given computation (Accenture, 2018). Therefore, quantum computers have superior processing power over current computers which are based on binary logic. Quantum computers are able to compute complex problems and offer novel possibilities. While classical or binary computers take more time for each variable added, quantum computers can rely on quantum bits to solve complex problems. Currently, quantum computing is more suitable for solving problems using three types of algorithms: optimization, sampling, and machine learning (Accenture, 2018). Full-scale quantum computers have not been developed yet, but the first basic systems threading together tens of quantum bits have been made available.

Several national governments and military agencies are funding research to develop quantum computers for civilian, business, trade, environmental, and national security purposes. Many companies, including D-Wave, Google, Microsoft, MIT Lincoln Laboratory, and Intelligence Advanced Research Projects Activity, are working on developing quantum hardware (Accenture, 2018). The applications of quantum computers are gaining acceptance in healthcare, manufacturing, supply chain management, purchasing and procurement, production, and distribution. In investment and financial services, quantum computing could help determine attractive portfolios, given thousands of correlated assets (Accenture, 2018). Furthermore, quantum computing could be used to effectively identify fraud indicators. In healthcare, quantum computing can be used to predict the effects of potential therapeutic approaches and to optimize non-adverse effects. Lockheed Martin, one of the largest defense companies in the world, is using quantum computing to verify and validate aeronautics systems, design lifesaving drugs, and debug millions of lines of code (Srivastava et al., 2016). In manufacturing, quantum computing could improve supply chain optimization problems in procurement, production, and distribution. Quantum computing can be useful in product optimization, advertising scheduling, and revenue maximization systems where hundreds of attributes about a consumer's preferences are collected. Quantum computing may strengthen the next generation of transport or logistics automation and remote sensor management.

Smart Dust

Smart dust is networks of micro-electro-mechanical devices, which include a processing unit, some memory, and a radio chip, allowing them to communicate wirelessly with other smart dust devices within range (Arief et al., 2013). Smart dust incorporates sensing, computing, wireless communication capabilities, and autonomous power supplies at a low cost. Furthermore, these smart dust devices are expected to be so small and light that they can remain suspended in the environment like ordinary dust particles (Azodolmolky et al., 2013). Because of these features, smart dust can be used to scrutinize the environment without affecting the natural processes. By collecting data in real-time via miniaturized low-power sensors and wireless networks, smart dust will transform our understanding of the environment.

Currently, the size of smart dust particles is about five cubic millimeters, but the size will continue to become smaller. The University of California at Berkeley's Smart Dust research team estimates that they can fit in the necessary sensing, communication, and computing hardware, with a power supply, in a volume no more than a few cubic millimeters (Azodolmolky et al., 2013). Therefore, the future models of smart dust are expected to be small enough to remain suspended in the air and communicate for an extended period, sometimes for many years.

Smart dust technology is in its infancy, but it has the potential to be applied to different areas, including security, military, traffic management, construction, mining, agriculture, and urban planning. The smart dust technology can allow continuous real-time monitoring of industrial and urban projects and structures. The data gathered on environmental, biological, and structural variables may help to improve the efficiency of global resource use. The experiments in California showed that smart dust technology could be used by military and law enforcement personnel to monitor movement in the region (Azodolmolky et al., 2013). Some examples of the smart dust technology include arranging defense networks by unmanned aerial vehicles, tracking the movements of birds, small animals, and insects, monitoring environmental conditions, managing inventory, and monitoring product quality (Chen, 2012). The development of smart dust technology increases some concerns about privacy and security issues. The minuscule smart dust sensors could be used for mischievous, illegal, or unethical purposes. For example, smart dust technology can be used for industrial espionage or for monitoring people without their knowledge. As smart dust technology becomes smaller, cheaper, and more powerful, the risks and concerns associated with the misuse of this technology will grow exponentially. One major concern is that once the smart dust networks are scattered, they are not easily retrieved, and they may involve serious environmental polluting effects.

4. Interfaces and Visualization

Deep Mapping

Deep mapping is an emerging technology that refers to a map incorporating various types of data within a geographic information system (GIS) environment (Bodenhamer et al., 2015). Thus, deep mapping investigates the spatial location and systematizes different levels of information into conceptions using three-dimensional scenes. Deep mapping collects data from many sources, including remote sensor networks, aerial and satellite imagery, crowdsourcing, smartphones, and on-site mapping vehicles. The deep maps may contain rich and valuable information about a location regarding health, education, demographics, physical variables, air pollution, driving conditions, commercial and business issues, and many other factors. Deep mapping can be combined with surveillance devices to provide a richer visualization of a location. By offering historical and real-time information about each particular location in one single interface, deep mapping can facilitate planning and decision-making in many areas such as construction, traffic control, agriculture, and business activities. For instance, Google's Ground Truth is an ongoing project that combines data from governments and other organizations with the data it gathers itself through satellite imagery.

Mixed Reality

The concept of mixed reality is an emerging trend in information technology and refers to integrating the physical and digital worlds. Unlike virtual reality and augmented reality, mixed reality does not immerse any content onto the real world; instead, it uses transparent lenses to make virtual objects both appear and interact with real ones. The mixed reality technological features provide virtual objects with a realistic sense of touch, and change how people access information, share experiences, and provide feedback. Therefore, mixed reality is expected to drastically change the relationships between humans, computers, and the physical environment. The combination of computer processing, human input, and environmental input creates mixed reality experiences. For instance, movement in the physical space can be translated into movement in the digital world and vice versa. Indeed, mixed reality can be positioned between augmented reality and virtual reality.

The current augmented reality and virtual reality offerings represent a very small part of this spectrum and do not allow blending digital representations of people, places, and things with the real world. The windows mixed reality devices are either holographic or immersive. The holographic devices can place digital content in the real world as if it were there, whereas the immersive devices can hide or change the physical world and replace it with a digital experience. Fragments and RoboRaid are immersive devices that use the user's physical environment like walls, floors, and furniture to place digital content in the world.

Mixed reality can unleash unbelievable possibilities beyond our imagination. Due to its spatial technology, mixed reality will have major applications and implications in areas such as design, architecture, and construction. For example, Microsoft's HoloLens enables users to view and interact with scalable, photorealistic, and responsive 3D holograms overlaid on the user's visual field. Some businesses are using mixed reality technology to inspect three-dimensional renderings of site plans before construction.

Multi-Sensory Interfaces

Multi-sensory interfaces are emerging technologies that allow communication between humans and machines through a wide range of senses, eye or body movements, speech, and gestures. Due to their ease of use, multi-sensory interfaces are expected to replace conventional computer control systems such as the keyboard and mouse. The integration of speech and other forms of conversational interfaces may allow real-time cross-language communications in the near future. Developments in mixed reality and virtual reality will require a new generation of user interfaces and experiences. Multi-sensory interfaces process multiple inputs across multiple devices to deliver contextual, connected, and viral experiences; they use all senses to capture information, and they do not ask for any information they should already know. They can rely on the previous data, and they continue to learn from their user’s behaviours (Coenraets & Ward, 2015). For instance, Samsung Inc. is developing a blink-detecting contact lens equipped with a display, camera, antenna, and movement sensors that can project an image directly onto the eye’s retina.

5. Materials

Nanomaterials

Nanotechnology is a fast-growing area that is concerned with the production of tiny particles or nanomaterials. A nanometer is one-billionth of a meter, and nanomaterials are less than 100 nanometers. Nanotechnology relies on microscopic processing techniques to produce various materials and components. Generally, there are two methods to produce nanomaterials. In the top-down method, small components are produced using larger parts of the material. In the bottom-up method, nanomaterials are produced from molecules or atoms. In nanotechnology, standard rules of physics and chemistry no longer apply, and many materials may show unique properties. For instance, they may become very much more robust, more conductive, or reactive (Roco et al., 2011).

One substantial property of nanoparticles is the massive surface area that makes them different from other materials (Shaffer & Windle, 1999). Because of their essential characteristics, such as strength, lightweight, and insulating properties, nanomaterials have widespread applications in many industries, including agriculture and food, energy production and efficiency, the automotive industry, cosmetics, medical appliances and drugs, household appliances, computers, and weapons (Varma, 1997). There are many possible applications of nanomaterials in building corrosion-free steel, low-energy LEDs, and ultra-thin PV cells. Nanomaterials such as graphene could be used in water purification technology to improve access to clean drinking water. Nanotechnology has various applications in the field of electronics. For instance, nanotechnology is used in miniaturized products to make high-purity materials with better thermal conductivity. Furthermore, nanomaterials are used to produce long-lasting and durable interconnections. Because of their physical characteristics, nanomaterials are used in developing super capacitors that have a large capacity compared with normal capacitors.

Nanotechnology can be used to produce effective insulation materials for homes and offices. High-energy density batteries, heating and cooling bills, and cutting tools are other areas of nanomaterial applications. Nanoparticles can be used in medicine to selectively deliver drugs to specific cells. This method reduces overall drug consumption and side-effects by placing the active agent in the morbid region (Knaian, 2008). Nanotechnology may be applied in all stages of food preparation, including production, processing, safety, and packaging. Currently, nanoparticles are used to create new food products. By adding nanoparticles to a polymer, a nanocomposite is formed that is much more transparent than a polymer containing micron particles, which is opaque. In energy production, nanotechnology offers a practical alternative to non-renewable fossil-fuel consumption by producing cheaper, cleaner, and more efficient and renewable energies. Nanotechnology is still in its infancy, and many of its applications are under development.

Programmable Materials

Programmable materials can change their physical properties such as shape, density, conductivity, and optical properties in a programmable way depending on user input or self-sufficient sensing (Knaian, 2008). In other words, programmable materials refer to a form of controlled and shape-shifting matter that can transition from their current shape into the desired shape with complete reversibility (Amend & Lipson, 2009). There are two primary approaches to programmable matter: bottom-up attempts to change the behavior of materials at the atomic or molecular level and top-down approaches to creating miniature robotic systems to form a larger item (Kirby et al., 2007).

Programmable materials could drastically change our understanding of matter, and naturally, could have major implications for all aspects of our lives. The idea of programmable materials implies that matter can be reused infinitely for different purposes. Programmed materials could bring a new generation of structures that respond dynamically and automatically to their environment. Applications of programmable materials could include architecture, infrastructure, production lines, construction, and operation. Programmable materials can be used in paintable displays, shape-changing robots and tools, rapid prototyping, and sculpture-based haptic interfaces. For instance, researchers at MIT are working on a project to build shape-shifting carbon fiber in a race car spoiler. The spoiler reacts to environmental change, morphing into its most efficient shape, and improving the car's performance. The MIT Media Lab recently showed the latest version of Transform, which is a form of dynamic furniture that can turn digital information into three-dimensional shapes. The Transform dynamic furniture responds to hand movements to change its shape.

Bio-Based Materials

The term bio-based material refers to a wide range of substances such as chemicals, natural fibers, plastics, concrete, wood, composites, and final products. Bio-based materials are substances derived from living organisms. The production of bio-based materials does not rely on the extraction and emission of fossil carbon; instead, it uses feedstock that contains biogenic carbon. The feedstock may include agricultural crops, residues, and organic waste streams, wood, microorganisms, and animal products (Broeren, 2018). Bio-based materials offer sustainable alternatives to fossil-based materials, as they are often biodegradable and use low-energy production routes. The production of bio-based materials smartly uses biomass and contributes positively to savings in greenhouse gas emissions, toxicity, and waste reduction (Schmidt, 2012). Therefore, the bio-based materials industry is attractive to policymakers, as it is associated with sustainable development, environmental protection, and the circular economy (Broeren, 2018).

Furthermore, the bio-based materials industry offers exciting opportunities to rural areas in terms of economic development and job creation (Van der Meer, 2017). Due to their environmental benefits, bio-based materials have various applications. The bio-based materials industry may grow by 300% in the next four years. Construction, furniture, packaging, and manufacturing industries are likely to adopt bio-based materials. The attractiveness of bio-based materials will encourage researchers and engineers to accelerate innovation. For instance, researchers at the Wageningen Institute in the Netherlands have developed bioplastics for packaging, casings for consumer electronics, textiles, and parts for the automotive industry. Furthermore, they develop inks, coatings, paper, cardboard, and construction materials from biomasses (wur.nl).

6. Energy and Resources

Foam Batteries

Batteries are big business, as they are used in various devices from computers and tablets to cars and wearables. Conventional batteries are made up of two-dimensional surfaces that limit the direction and speed at which energy can flow. As a result, the existing batteries take a long time to charge, lose energy rapidly, and require frequent replacement. Prieto, an innovative startup, is introducing new batteries produced with a copper foam substrate that is approximately 98% air or void space (Chen et al., 2012). Due to an increase in the surface area of approximately 60 times, the foam battery is expected to have much higher power densities. The foam battery will be customizable and can be optimized for either power density or energy density (prietobattery.com).

Furthermore, foam battery technology promises to be cost-effective to manufacture and fast to charge. In addition, foam batteries are smaller, lighter, safer, and less toxic than traditional 2D batteries. Some large companies in the consumer electronics sector such as Apple, LG, and Nokia, have shown a growing interest in the new battery technology (Chen et al., 2012). Foam batteries can be shaped to fit spaces that are inaccessible to traditional batteries in a safer and less expensive way. Because of its unique design, the foam battery can be used in wearables and tablets without compromising energy and power (prietobattery.com).

Furthermore, the foam battery technology can be used to build novel devices with military and industrial applications. In the transport sector, foam battery technology is expected to be a viable option by offering improved efficiency, higher safety, and lower cost. Over time, foam technology could provide energy storage solutions for grid-scale applications (Chen et al., 2012).

Fusion Reactors

In a fusion process, power is generated by using nuclear fusion reactions. During the process, two lighter atomic nuclei combine to form a heavier nucleus, and at the same time, they release large amounts of energy that can be harnessed to produce electricity. The fusion process in reactors is similar to what happens in stars like the sun. Fusion releases massive amounts of energy about one million times more powerful than a chemical reaction and 3–4 times more powerful than a conventional fission nuclear reaction. Fusion seems more advantageous than fission because it is safer and produces more energy and less waste and radioactivity. Fusion reactors could provide clean energy with no long-lasting radioactive waste. The vast amount of energy produced by fusion reactors can change the transport and other energy-intensive industries and replace fossil fuels. The major barriers to fusion power are fuel and a highly confined environment with a high temperature and pressure. Lockheed Martin, a giant defense firm, uses magnetic field pressure to make a fusion reactor that is ten times smaller than other prototypes. The use of magnetic field pressure may effectively manage extremely high temperatures during the fusion process (Azodolmolky et al., 2013).

Transparent Solar Panels

Researchers at Michigan State University invented a transparent luminescent solar panel in 2014. Transparent solar panels use organic materials to absorb light wavelengths that are invisible to the human eye. The main obstacle to the widespread use of conventional photovoltaic panels is their appearance (Michigan State University, 2014). Therefore, the transparency of solar panels is a significant game-changer because transparent panels could replace conventional window glasses. Urban areas that do not have enough rooftop space will transform their glass windows into energy-producing panels. Commercial buildings have many windows and vast energy generation with solar panels (Michigan State University, 2014). Also, the new solar panels can come in colourful semi-transparent devices, which designers and architects can use to design or decorate buildings (Chen et al., 2012). Transparent materials can also be used on car windows, cell phones, or other devices with a clear surface and can transform any surface into an energy-producing system. It is estimated that by using invisible solar panels, a skyscraper could provide more than a quarter of the building's energy needs (Chang et al., 2018). The widespread adoption of such panels can meet U.S. electricity demand and significantly reduce the use of other energy resources like fossil fuels. Transparent solar technologies could supply some 40% of energy demand in the United States in the next decade. Although the cost of developing transparent panels remains high, and their energy output is still limited, their extensive prospective application appeals to scientists and investors.

Pollution Digesters

With increasing levels of environmental pollution, the reduction of pollutants is becoming a serious challenge for many countries across the world. Pollution digestion technologies have been considered solutions to deteriorating air quality and environmental pollution, particularly in urban areas. Pollution digesters could include a wide range of methods, including anaerobic, large-scale air ionizers, and photocatalytically active substances. In anaerobic digestion, organic matter is broken down into smaller particles by reactions in the absence of oxygen (Adekunle & Okolie, 2015). An anaerobic digester can be designed to treat different waste flows, for example, municipal solid waste, municipal organic waste, industrial waste, or sludge from a wastewater treatment plant (Arivalagan et al., 2011). Pollution digestion technologies can be used to remove, filter, and transform airborne pollutants, and thus improve air quality. Pollution digesters may be installed in building facades or across urban areas to improve air pollution. As the quality of air, particularly in Asia and South America, continues to deteriorate, there is a growing interest from business and scientific communities in developing more efficient pollution digesters. For instance, Photoment is a powder-like substance that is photocatalytically active and reacts with sunlight to transform toxic airborne nitrous oxide into non-toxic nitrates that are not harmful to the environment or human health and are washed away by rain. Photoment can be added to concrete paving surfaces in urban areas to reduce the number of airborne pollutants.

7. Conclusion

Emerging technologies are rapidly growing technologies that are expected to significantly affect the social and economic spheres of our lives in the future. This paper aimed at offering an examination of key emerging technologies and their business/social applications and implications. Table 1 presents five major groups and nineteen associated emerging technologies ranging from automation, connectivity, and visualization, to materials and resources. While these categories are not comprehensive, they offer a classification of emerging technologies, their origins, their applications, and their relationships.

According to Table 1, the list of emerging technologies is dominated by information technologies associated with knowledge-based and service-oriented economic production. Customers are the focus of the new technologies as they will enable businesses to collect, accumulate, and process their private information to create economic value. These technologies are progressing fast and are expected to cause major economic, industrial, and social transformations and disruptions. As shown in Table 1, some of these emerging technologies including drones, robots, blockchain, deep mapping, mixed reality, and nanotechnology, are already used in certain industries, whereas others like quantum computing, programmable materials, bio-based materials, and pollution digesters are in the early stages of development.

The nineteen emerging technologies are categorized under five major themes and are presented in nineteen separate groups, but indeed, many of these technologies have significant overlap, and some may represent a combination of several techniques. For instance, vehicle automation is part of a much larger revolution in automation and connectivity and many other technologies (Smith & Svensson, 2015). Likewise, the popularity of drones and unmanned aerial vehicles is the result of recent developments in a wide range of technologies, including microprocessors, GPS, sensors, batteries, motors, lightweight structural materials, and advanced manufacturing techniques. Deep mapping incorporates various types of data within a geographic information system (GIS) environment (Bodenhamer, 2015). Mixed reality is the result of recent progress in computer vision, graphical processing power, sensors, display technology, mobile network capacity, and input systems.

Similarly, multi-sensory, smart dust, programmable materials, nanomaterials, bio-based materials, and pollution digesters rely on several technological advances. The rising interdependency of emerging technologies leads to a confluence of technological innovations that rely mainly on cyber-physical systems, intelligent data gathering, and data storage and distribution systems (Schwab, 2017). It seems that technological innovations are moving toward a point where everything will be linked to everything else. The ensued confluence may disrupt many industries and change many aspects of our lives, including the perceptions of communication, socialization, consumption, ownership, emotion, leisure, space, and time. The imminent technological confluence could have nefarious effects on our privacy and freedom as individuals. While this paper was devoted to applications and implications of emerging technologies, future studies may investigate the interdependencies of new technologies and their conjunction over time. Under the current rapidly changing circumstances, it is essential to understand not only the nature of emerging technologies but also their interdependencies.

Table 1: Emerging Technologies, their Categories, Descriptions, Applications, and Implications

Themes	Emerging Technology	Description	Applications & Implications
Automation and Robotics	1) Augmented Intelligence	Use of intelligent tools in conjunction with human intelligence	- Extend human cognitive abilities - Collaboration between machines and humans - Informed and faster decisions in finance, investment, healthcare, manufacturing, retail, travel and tourism, energy, and agriculture
	2) Autonomous Vehicles	Vehicle automation and connectivity	- Increase the utilization of travel time - Restructure transportation models, roads, urban centers - Transportation, jobs, urban planning and infrastructure, economic models
	3) Drones and Unmanned Aerial Vehicles	Unmanned aerial vehicles	- Replace the present aircraft, railways, buses, and taxis - Perform tasks in the energy sector, public safety, security, military, e-commerce, transport, precision agriculture
Data and Connectivity	4) 5G Mobile	A heterogeneous network	- Increased resilience, continuity, and much higher resource efficiency - The fully connected and interactive world, Internet of Things (IoT)
	5) Blockchain	A distributed digital ledger	- Create a system based on trust - Eliminate trusted third parties like banks, financial institutions - Abolishing the tripartite relationship liberates users and transactions
	6) Bluetooth 5.0	Data transmission through radio waves	- Doubling the speed and quadrupling the range - 800% increase in data broadcasting capacity - Industrial automation, Internet of Things (IoT)
	7) Li-Fi	Visible light communication	- Local wireless communications at very high speeds - No limitations on capacity, high security - IoT, retail, construction, aviation, transportation, traffic management
	8) Quantum Computing	Using subatomic particles to store data	- Superior processing power, suitable for solving sophisticated problems - Applications in civilian, business, trade, environmental, and national security - Applications in product optimization, advertising scheduling, and revenue maximization systems
	9) Smart Dust	Networks of micro-electro-mechanical devices	- Continuous real-time monitoring of industrial and urban projects - Tracking the movements of birds, small animals, and insects, monitoring environmental conditions, managing inventory, and monitoring production - Can be used for illegal or unethical purposes and cause environmental pollution

Interfaces and Visualization	10) Deep Mapping	A map incorporating various types of data	- Facilitates planning and decision-making - Applications in construction, traffic control, agriculture, and business
	11) Mixed Reality	Integration of the physical and digital worlds	- Changes the relationships between humans, computers, and the physical environment - Applications in design, architecture, and construction
	12) Multi-Sensory Interfaces	Communication between humans and machines through senses	- Replacing conventional computer control systems such as keyboard and mouse
Materials	13) Nanomaterials	Manipulation of small particles (Nano-particles)	- Creating new materials with special properties - Applications in agriculture and food, energy production and efficiency, automotive industry, cosmetics, medical appliances and drugs, household appliances, computers
	14) Programmable Materials	Materials with changeable physical properties	- Applications in architecture, infrastructure, production lines, construction, and operation - Shape-changing robots and tools, rapid prototyping, and sculpture-based haptic interfaces
	15) Bio-Based Materials	Substances made from living organisms	- Reduction of greenhouse gas emissions, toxicity, and waste reduction - Applications in construction, furniture, packaging, and manufacturing industries are likely to adopt bio-based materials - Sustainable development, environmental protection, the circular economy
Energy and Resources	16) Foam Batteries	Batteries with higher power densities	- Energy storage solutions for grid-scale applications - Applications in wearables and tablets, military and industrial, and transport
	17) Fusion Reactors	Energy production through a combination of lighter atomic nuclei	- Provides clean energy with no long-lasting radioactive waste - Changes the transport and energy-intensive industries and replace fossil fuels
	18) Transparent Solar Panels	Transparent solar panels to absorb light wavelengths	- Increases solar energy production - Application in car windows, cell phones, or other devices - Transforms any surface into an energy-producing one
	19) Pollution Digesters	Removing the filter, and transforming pollutants	- Solutions to deteriorating air and water quality and environmental pollution

References

Accenture. (2018). Innovating with Quantum Computing Enterprise Experimentation Provides View into Future of Computing. https://accenture.com/t00010101T000000__w__/br-pt/_acnmedia/PDF-45/Accenture-Innovating-Quantum-Computing-Novo.pdf

Adekunle, K.F., & Okolie, J.A. (2015). A Review of Biochemical Process of Anaerobic Digestion. *Advances in Bioscience and Biotechnology Advances in Bioscience and Biotechnology*, *6,* 205–12.

Amend, J.R., & Lipson, H. (2009). *Shape-Shifting Materials for Programmable Structures*. International Conference on Ubiquitous Computing: Workshop on Architectural Robotics.

Anderson, J.M., Nidhi, K. Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). Autonomous Vehicle Technology: A Guide for Policymakers. Retrieved from: https://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-2/RAND_RR443-2.pdf

Angerholzer III, M. Mahaffee, M. D., Vale, M., Kitfield, J., & Renner, H. (2017). *The Autonomous Vehicle Revolution: Fostering Innovation with Smart Regulation.* Retrieved from: https://www.ftc.gov/system/files/documents/public_comments/2017/03/00002-140353.pdf

Arief, B., Blythe, P., & Tully, A. (2013). *Using Smart Dust in Transport Domain*. Retrieved from: https://www.cs.kent.ac.uk/people/staff/ba284/Papers/SmartDustUbicomp.pdf

Arivalagan, K., Ravichandran, S., Rangasamy, K., & Karthikeyan, E. (2011). Nanomaterials and Its Potential Applications. *International Journal of ChemTech Research, 3*(2), 534–38.

Autonomous Vehicles Considerations. (2016). https://munichre.com/site/mram-mobile/get/documents_E706434935/mram/assetpool.mr_america/PDFs/3_Publications/Autonomous_Vehicles.pdf

Autonomous Vehicles Readiness Index. (2018). Assessing countries' openness and preparedness for autonomous vehicles. https://assets.kpmg.com/content/dam/kpmg/nl/pdf/2018/sector/automotive/autonomous-vehicles-readiness-index.pdf

Azodolmolky, S., Wieder, P., & Yahyapour, R. (2013). Cloud Computing Networking: Challenges and Opportunities for Innovations. *IEEE Communications Magazine, 51*(7), 54–62.

Bodenhamer, D. J., Corrigan, J., & Harris, T. M. (2015). Deep Maps and Spatial Narratives. Bloomington: Indiana University Press.

Boon, W., & Moors, E. (2008). Exploring emerging technologies using metaphors: a study of orphan drugs and pharmacogenomics. *Social Science and Medicine, 66*(9), 1915–1927.

Brey, P. (2017). Ethics of Emerging Technologies. In S. O. Hansson (Ed.), *Methods for the Ethics of Technology*. Maryland: Rowman and Littlefield International.

Broeren, M. L. M. (2018). *Sustainable Bio-Based Materials-Application and Evaluation of Environmental Impact Assessment Methods*. [Dissertation, Utrecht University.]

Chang, K. H. (2014). Bluetooth: A Viable Solution for IoT, Industry Perspectives. *IEEE Wireless Communications, 21*(6), 6–7.

Chang, S. Y., Cheng, P., Li, G., & Yang, Y. (2018). Transparent Polymer Photovoltaics for Solar Energy Harvesting and Beyond. *Joule, 2*(6), 1039–54.

Chen, C. C., Dou, L., Zhu, R., Chung, C. H., Song, T. B., Zheng, Y. B., & Yang, Y. (2012). Visibly Transparent Polymer Solar Cells Produced by Solution Processing. *ACS Nano, 6*(8), 7185–90.

Collotta, M., Pau, G., Talty, T., & Tonguz, O. K. (2017). Bluetooth 5: A Concrete Step Forward Towards the IoT. *IEEE Communications Magazine, 56*(7), 1–17.

Coenraets, C. & Ward, J. (2015). Principles of Multi-Sensory Applications, available at https://multisensory.github.io/

Davies, R. (2016). 5G Network Technology: Putting Europe at the Leading Edge. *EPRS, European Parliamentary Research Service, Members' Research Service*.

Dediu, H., (2012). When Will Smartphones Reach Saturation in the US? Retrieved from http://www.asymco.com/2012/04/11/when-will-smartphones-reach-saturation-in-the-us/

Ford (2016, August 16). *Ford Targets Fully Autonomous Vehicle for Ride Sharing in 2021; Invests in New Tech Companies, Doubles Silicon Valley Team* [Press release]. Retrieved from https://media.ford.com/content/fordmedia/fna/us/en/news/2016/08/16/ford-targets-fullyautonomous-vehicle-for-ride-sharing-in-2021.html

Gershenfeld, N., & Chuang., I. L. (1998). Quantum Computing with Molecules. *Scientific American*. Retrieved from: http://www.fisica.unipg.it/~luca.gammaitoni/fisen/Document/Scientific-American-Quantum-Computing-with-Molecules-June-1998.pdf

Gunther, R. E., & Day, G. S. (Eds.). (2000). *Wharton on Managing Emerging Technologies*. New Jersey: Wiley.

Hedlund, J. (2017). *Autonomous Vehicles Meet Human Drivers: Traffic Safety Issues for States. Spotlight on Highway Safety*. Governors Highway Safety Association. Retrieved from: https://www.ghsa.org/sites/default/files/2017-01/AV%202017%20-%20FINAL.pdf

Henaghan, J. (2018). *Preparing Communities for Autonomous Vehicles.* American Planning Association. Retrieved from: https://planning-org-uploaded-media.s3.amazonaws.com/document/Autonomous-Vehicles-Symposium-Report.pdf

King, I. (2016, May 2). 5G Networks Will Do Much More Than Stream Better Cat Videos. *Bloomberg News*.

Knaian, A. N. (2008). *Design of Programmable Matter*. [Doctoral dissertation, Massachusetts Institute of Technology.]

Kockelman, K. (2017). *An Assessment of Autonomous Vehicles: Traffic Impacts and Infrastructure Needs--Final Report*. Center for Transportation Research. The University of Texas at Austin.

Kirby, B. T., Aksak, B., Campbell, J. F., Hoburg, T.C., Mowry, P. P., & Goldstein, S. C. (2007). *A Modular Robotic System Using Magnetic Force Effectors*. Proceedings of the IEEE International Conference on Intelligent Robots and Systems (IROS '07).

Kuzma, J., O'Sullivan, S., Philippe, T. W., Koehler, J. W., & Coronel, R. S. (2017). Commercialization Strategy in Managing Online Presence in the Unmanned Aerial Vehicle Industry. *International Journal of Business Strategy, 17*(1), 59–68.

MacGillivray, C. (2013, Oct 3). The Internet of Things Is Poised to Change Everything, Says IDC. *Business Wire*.

Michigan State University. (2014, August 19). Solar Energy That Doesn't Block the View. Michigan State University. *MSUTODAY*.

Mitchel, S. (2007). The import of uncertainty. *Pluralist, 2*(1), 58–71.

Peters, G.W., & Panayi, E., (2016). Understanding Modern Banking Ledgers through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money. In Tasca, P., Pelizzon, L., Perony, N., & Aste, T. (Eds.) *Banking Beyond Banks and Money*, 239–78. Cham: Springer.

https://prietobattery.com

Roco, M. C., Mirkin, C. A., & Hersam, M. C. (2011). Nanotechnology Research Directions for Societal Needs in 2020: Summary of International Study. *Journal of Nanoparticle Research, 13,* 897–919.

Rotolo, D., Hicks, D., &Martin, B. (2015). What is an emerging technology? *Research Policy, 44*(10), 1827–1843.

Rotolo, D., Rafols, I., Hopkins, M., & Leydesdorff, L., (2014). Scientometric mappings strategic intelligence for tentative governance of emerging science and technologies, *SPRU Working Paper Series*, 2014-10, SPRU - Science Policy Research Unit, University of Sussex Business School.

Sabhikhi, A. (2018). 10 Questions about Augmented Intelligence. *Cognitive Scale*. Retrieved from: https://cognitivescale.com/augmented-intelligence-you-can-trust/

Schwab, K., (2017). *The Fourth Industrial Revolution*. New York: Crown Business.

Shaffer, M. S., & Windle, A. H. (1999). Advanced Materials 11, p. 937.

Schmidt, O., Padel, S., & Levidow, L. (2012). The Bio-Economy Concept and Knowledge Base in Public Goods and Farmer Perspective. *Bio-Based and Applied Economics, 1*(1), 47–63.

Smith, B.W., & Svensson, J. (2015). *Automated and Autonomous Driving: Regulation under Uncertainty*. International Transport Forum.

Srinivasan, R. (2008). Sources, Characteristics, and Effects of Emerging Technologies: Research Opportunities in Innovation. *Industrial Marketing Management*, *37*, 633–640.

Srivastava, R., Choi, I., Cook, T., & N.U.E. Team. (2016). *The Commercial Prospects for Quantum Computing*. Networked Quantum Information Technologies.

Stanoevska-Slabeva, K. (2003). Towards a Reference Model for M-Commerce Applications. Proceedings of the European Conference on Information Systems, 2002: http://aisel.aisnet.org/ecis2002/159

Starkloff, E. (2015, August 21). The Future of 5G: The Internet for Everyone and Everything. *Business 2 Community Magazine.*

Stirling, A. (2007). Risk, precaution and science: towards a more constructive policy debate. Talking point on the precautionary principle. *EMBO Rep., 8*(4),309–315.

The 5G Infrastructure Association. (2015). *The 5G Infrastructure Public Private Partnership: The Next Generation of Communication Networks and Services*. Retrieved from: https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/5G-Vision-Brochure-v1.pdf

Thomas, J. P., Andreas, S., Frédéric, T., Elgar, F. (2009). NFC Based Service Innovation in Retail: An Explorative Study. 17th European Conference on Information Systems, Verona, Italy, June 8–10, 2009.

Sesar Joint Undertaking. (2016). European Drones Outlook Study-Unlocking the Value for Europe.

Van der Meer, Y. (2017). Sustainable Bio-Based Materials: Opportunities and Challenges. Biotech France 2017 International Conference, October 2017.

Varma, R. S., Saini, R. K., & Dahiya, R. (1997). Active manganese dioxide on silica: Oxidation of alcohols under solvent-free conditions using microwaves. *Tetrahedron Letters, 38*(45), 7823–7824.

Veletsianos, G. (2010). *Emerging Technologies in Distance Education*. Edmonton: Athabasca University Press.

West, D. M. (2016). How 5G Technology Enables the Health Internet of Things. *Brookings Center for Technology Innovation, 3*, 1–20.

https://wur.nl/en/About-Wageningen.htm