sustainability

MDPI

Case Report

Shortening the Supply Chain through Smart Manufacturing and Green Technology

Pandwe Aletha Gibson

MIT Media Lab, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; pandwe@ecotechvisions.com

Abstract: Correcting inefficiencies in the supply chain requires us to reimagine manufacturing by recapturing processes—particularly material sourcing and end-use recycling, which create vast amounts of waste. Inefficiencies in the supply chain create massive waste and stifle innovation in manufacturing, both well-established concerns for the environment. Carbon-based fuels and products are detrimental to the land, air, and sea. Single-use products made from toxic materials flood the food and medical supply chains. Businesses are increasingly moving toward the single purchasing platform model (for example, Uber and Airbnb). Following that model, this paper proposes a platform as a service (PaaS) manufacturing sharing service that matches small- to mid-size manufacturers with production capacity as a solution to obtaining ethically sourced products at a competitive price while offering access to last-mile delivery locally on a single purchasing platform. The development of an Internet of Things (IoT) platform can achieve these four things: (1) provide better coordination of the sourcing and supply of materials, (2) ensure effective provisions of eco-friendly and recycled inputs, (3) provide efficient distribution of equipment and manufacturing resources, and (4) shorten the supply chain by centralizing and coordinating last-mile delivery.

Keywords: circular economy; circular business model; shared economy; advanced manufacturing; closed-loop supply chain and logistics; smart manufacturing; artificial intelligence AI; robotics and computer visions; Internet of Things (IoT)

Citation: Gibson, P.A. Shortening the Supply Chain through Smart Manufacturing and Green Technology. *Sustainability* **2023**, *15*, 15735. https://doi.org/10.3390/su152215735

Academic Editors: Ripon Kumar Chakrabortty and Davide Settembre-Blundo

Received: 14 August 2023
Revised: 26 October 2023
Accepted: 2 November 2023
Published: 8 November 2023

1. Introduction

Reimagining manufacturing is the next frontier for the Internet of Things (IoT) to improve supply chain efficiency and last-mile delivery (Yang et al., 2018 [1]). Today, technologies can be used at both ends of the supply chain to optimize the system for raw materials, end-product manufacturing, and distribution to spur entrepreneurship and innovation. Sixty-six percent of the world's population lives in cities, while seventy percent of world resources are consumed in urban centers (Singh et al., 2020 [2]). Cities are perfect sites for public-private partnerships due to their population, research access, buyers, and sellers—all in one place with the smart city movement. Advanced digital infrastructure supports smart cities' big data development through interconnected sensor networks, resulting in advanced governance and thriving economies (Townsend 2021 [3]). The interplay between the IoT and blockchain sensor networks has proven 98 percent accuracy in sorting and distribution as it relates to waste collection (Alqahtani et al., 2020 [4]). Similarly, results have been tested in healthcare delivery, mining, transportation sectors, industrial crops, and consumer products. "Accordingly, organizations are rapidly embracing emerging technologies and manufacturing methods to transform, capture, share, and interpret data from production tools and other autonomous systems" (Sarvari et al., 2018 [5]; Khan et al., 2021 [6]). "In supply chain management, IoTs are used in the fields of logistics, manufacturing, quality control, inventory management, and real-time decision-making" (Ben-Daya et al., 2019 [7]). Similar to the model necessary to roll out carbon credits, which monitors and regulates carbon levels globally, manufacturing facilities that employ machine learning through blockchain can assist the consumer produce market by shifting to accurate carbon regulation followed by neutrality while profiting. Integrated systems also facilitate efficiency, leading to triple-bottom-line returns, social returns, environmental returns, and financial returns (Victor and House 2004 [8]). Technology applied to upstream and downstream supply chains will create global optimization and reduce uncertainty in product delivery and climate objectives (Zhang et al., 2019 [9]).

2. The Industry Must Deliver a Better Future for All

The seventeen Sustainable Development Goals (SDGs) provide a framework for addressing poverty, hunger, energy, industry, the built environment, life on land, and clean water, which are all negatively impacted by climate change (Danladi et al., 2023 [10]). The world has signed on to achieving these goals as critical for human survival, yet the United States, despite its demonstration of talent, space, and logistics centers, has largely been overlooked as a site for manufacturing and technology since the 1940s (Gruber and Johnson 2019 [11]). However, concerns over supply control, the environment, and workers' rights highlight a need for exploring more partnership options, both in the United States and overseas, with the goal of protecting these interests. Every day in the United States, roughly 690,000 tons of waste materials are dumped in landfills worldwide (United States Environmental Protection Agency 2022 [12]). According to the 2020 census data, unemployment rates of people in marginalized communities within many urban cities across America were above 11 percent (U.S. Bureau of Labor Statistics 2021 [13]).

The United States has sustained 338 weather and climate disasters since 1980, where overall damages/costs reached or exceeded USD 1 billion (including the consumer price index adjustment to 2022). The total cost of these 338 events exceeds USD 2.295 trillion (Anderson 2022 [14]).

Cohen (2023 [15], pp. 77–132) uses environmental volatility as a springboard toward a circular economy solution. He agrees that green technologies focused on energy, waste processing, consumer products, and infrastructure are ripe for disruption through public–private partnerships in the way of tax credits to subsidize innovation; "lease buy back business models that close cycles of production and consumption" advance waste and mining sorting systems. Cohen's book, however, spent much of the focus on the United States government's support for an environmentally sustainable transition (Schindler et al., 2012 [16]).

Greenhouse gas emissions are highest at extraction; thus, reducing greenhouse gas emissions during extraction is critical (Stockholm Environment Institute 2019 [17]). Conservation costs, reducing production costs, reducing processing time, encouraging innovation, and job creation are all critical elements of sustainable circular economy manufacturing. Carbon credit markets play a critical role in offsets from a global standpoint to reduce the impact of initial extraction; however, innovation and providence technology are necessary to reach neutral emissions goals while allowing humans single-use comforts (Akenji et al., 2019 [18]).

3. Potential Carbon-Neutral Partners Overseas

There are currently seven countries globally that claim carbon neutrality correlates to their large forests and limited populations: Bhutan—72 percent of which is composed of forests—is a Himalayan country that absorbs nine billion tons of CO_2 annually; Suriname is 97 percent forest; Madagascar is the fourth largest island in the world with a population of thirty million and a land mass of 230,000 square miles. It is largely rainforest but features rampant deforestation. Panama is 57 percent forest and is subject to a 50,000-hectare reforestation plan by 2050; Guyana is 14,480 hectares of old-growth forest; Gabon—west of the Democratic Republic of Congo—comprises protected rainforest and features an economy supported by oil and natural gas production; Niue is a volcanic island that reports less than 0.0001 percent of carbon emissions.

Although the populations of most of these countries are too small for their emissions to be compared with most other countries globally, Madagascar is an exception, as it is half the size of New York State with almost twice the population. Despite the country providing the majority of the world's supply of vanilla, cloves, and ylang-ylang (the latter found in Chanel perfumes and other beauty products), Madagascar reportedly has a poverty rate of 81 percent (The World Bank 2022 [19])).

Panama, in contrast, has a population of 4.3 million, with strong industry and employment as a result of its canal and associated trade, which has been dramatically increasing since the new locks opened for commercial traffic. Panama has an unemployment rate of 18.5 percent, though only 14 percent of the population lives below the poverty line (The World Bank 2022 [20]).

For many global and US-based companies, carbon offsets are often achieved through carbon credits. Carbon credits, also known as carbon offsets, allow carbon producers to purchase the equivalent of one ton of carbon dioxide and other greenhouse gases from entities that reduce or remove those emissions from the atmosphere (Victor and House 2004 [8]). This new and growing commodity creates an incentive for global partnerships with carbon-offset nations; however, monitoring the value requires significant data capacity, while the IoT/blockchain provides a model (Meng et al., 2020 [21]).

4. Considering United States Suppliers

Chicago, Illinois, is an example of a city in the United States that is making an effort to work toward the goals of the 2050 Paris Agreement. The city has adopted best practices to reduce its carbon emissions, increase its green spaces while protecting natural water sources, and invest in waste collection processes and recycling infrastructure. For this, it was voted America's Most Sustainable City in the 2019 Green Building Adoption Index (Mayor's Press Office 2019 [22]).

Chicago leads the country in sustainability for the third year in a row, with all new constructions requiring green space. The city reversed the flow of the Chicago River, which made Lake Michigan the most sustainable body of water in North America. On the downside, the city does, however, have an unemployment rate of 4.8 percent and faces challenges such as gun violence and public safety issues (U.S. Bureau of Labor Statistics 2022 [23]).

From 2003 to 2010, Chicago was also home to one of the first carbon credit exchanges in the world. The Chicago Climate Exchange (CCX) was a voluntary carbon exchange for emission sources and offset projects in North America and Brazil. CCX had an aggregate baseline of 680 million metric tons of carbon annually; however, due to inactivity in the US carbon markets, it was shuttered (Victor and House 2004 [8]). In today's climate, as tax incentives and Clean and Blue designation requirements for domestic manufacturing take effect, carbon credits, energy efficiency, and production efficiency are becoming increasingly important to manufacturers.

Chicago is a manufacturing and logistics hub with the potential to lead green-tech energy innovation. With all the funding that has been allocated to sustainability recently in the United States (including the 2022 Inflation Reduction Act, which has allocated USD 369 million, the Transportation and Housing Appropriation Bill allocating a sum of USD 70 billion, the Agricultural Bill with a sum of USD 133 billion, and President Biden's USD 1 trillion infrastructure bill with USD 50 billion for climate-specific actions), it is reasonable to assume that some of the best practices implemented in Chicago will be funded and scaled nationally. Some schemes, such as green roofs and electric vehicle (EV) charging-station plans, are yet to be systematically funded or mandated at the state or local zoning levels. The example of Chicago is true of several cities (100+ according to Gruber in Jump-Starting America [11]) across the United States, and many are poised to take advantage of manufacturing, entrepreneurs, and technical talent (Gruber and Johnson 2020 [11]). The missing component is the system on which to build.

Chicago is an example of the right idea ahead of its time.

5. Examples of Innovative Companies Using Technology to Address Supply Chain Inefficiencies

The COVID-19 pandemic that began in 2020 thrust IoT sensor sector innovation forward, creating opportunities to monitor the real-time delivery of vaccines globally. The innovation in track and trace technology in the healthcare and consumer products sectors enables heuristic application for the IoT sensor sector as a whole (Goodarzian et al., 2023 [24]). This process is, by nature, green—economic and environmental—because it begins at the manufacturing center and ends with the landfill site—covering offtake, personalized delivery, and recycling in between to create a mathematically specific circular economy model (Goodarzian et al., 2021 [25]).

Waste collection and product-source extraction are technology problems (Mauch 2016 [26]). Technology is deployed based on customer requests and financial capacity. New applications for existing technology are uncovered every day as innovators gain capital to focus on new problems (Queiroz and Telles 2018 [27]). To date, venture capital investment has focused on gaming, gambling, e-commerce, and social platform development because the profits in those industries have been incredible; however, new opportunities in energy, raw materials, and consumer products are emerging as a result of the tax credits and government stimulus around climate. Information is crucial to supply chain efficiency (Chopra and Meindl 2004, [28], pp. 511–515). Improved manufacturing models for the highest profit that incorporate technology to facilitate and monitor circular economy efficiency are slowly being adopted (Visich et al., 2007 [29]). Some technologies ripe for the extraction and manufacturing sectors are outlined below.

5.1. Providence and Blockchain Tech

Everledger: This blockchain platform is known for tracking the provenance of high-value items like diamonds. Its application can be used for additional mined materials to ensure their legitimate origins.

IBM Blockchain Platform: This enterprise-ready solution is a fit for larger mining operations. The platform provides end-to-end encryption, ensuring secure data sharing across multiple parties.

Chainpoint: This tool links data to the blockchain to verify its provenance. It could be used to track mined resources in Central Africa or any mining site, ensuring transparency at each stage.

EcoTech Visions: This is an earlier stage PaaS that uses on-chain tracking to effectively monitor the provision of eco-friendly and recycled inputs in manufacturing, creating meta-heuristic insights into the potential environmental and economic impacts within the plastics and packaging sector. This approach is designed with the goal of reducing carbon emissions and overall waste in the material and last-mile delivery phases of the supply chain.

5.2. Medical Technology Adaptations for Raw Material Security

RFID Tags and Sensors: Some current medical technology (medtech) applications use radio frequency identification (RFID) tags and sensors to monitor the condition and movement of medical supplies. This technology can be used to track the movement and status of mined raw materials.

IoT-Enabled Devices: The IoT technology used in medtech for patient monitoring can be used to monitor the conditions of mines and the transit of materials, ensuring real-time surveillance.

AI-Based Predictive Analysis: The same AI tools used in medtech for predictive patient health outcomes can be used to predict disruptions or bottlenecks in the supply chain, thereby preemptively addressing potential issues.

ThinkIQ: This is an industry leader in 4.0 smart manufacturing. It uses artificial intelligence insights to resolve blind spots in the supply chain to increase productivity, sustainability, and safety. Regarding sustainability, while it primarily focuses on energy efficiency and waste stream reduction, it is a systems leader. ThinkIQ is also a useful example because it is not limited to medical manufacturing, and through smart manufacturing, it is able to efficiently cross sectors.

In summary, the integration of providence and blockchain tech, combined with the adaptation of medtech solutions and RFID technology, holds significant potential for improving raw material security, consumer product delivery, and production throughout the supply chain in Central African mining. Closed-loop supply chains connect both upstream and downstream supply chains by data, removing waste players and increasing efficiency and profit by billions (Visich et al., 2007 [29]). It would be beneficial to dive deeper into each of these recommendations and others to assess their feasibility and adaptability to the specific context.

6. Green Tech Innovations and Opportunities for an IoT Platform for Manufacturing

Green-tech supply chain optimization considers all sustainability criteria, including economic, environmental, and social impacts (Momenitabar et al., 2022 [30]). Computerization has gifted us with a dizzying succession of technologies that, over a very brief number of years, have exponentially increased our knowledge, communication, accessibility, and ability (Azevedo et al., 2019 [31]). The United States is now connected to the very best thinkers, has the most sophisticated tools, and has access to the finest approaches. Manufacturing leaders are focusing on clean ways of addressing problems; green solutions for innovating, building, solving, and living; sustainable methods that will further and protect our societies for generations to come; and shared resources to put all of this learning to work in manufacturing's newest age.

"Green technology" or "green tech" is defined as technology that is considered environmentally friendly based on its production process or supply chain—a means of energy production that is less harmful to the environment than more traditional ways of generating energy, such as burning fossil fuels (Fernando 2022, [32]; Kenton 2022 [33]). Green tech is a relatively young industry, but fear of global warming and the increasing scarcity of natural resources has increased its necessity. Green tech may be a stated goal of a segment of a large company or the focused mission statement of a smaller start-up firm. It can cover anything from recycled product packaging to longer-lasting lightbulbs and alternative energy production.

Specialized investment funds known as "green funds" seek out publicly traded leaders in the green-tech movement for their investment dollars. In addition, many socially conscious investors may choose to only invest in companies that are environmentally friendly or have pledged to become so. Large companies like Starbucks and Whole Foods employ green technology practices alongside a variety of small startups, though much more can be achieved if effective monitoring of emissions and recycling are in place (Kamble et al., 2018 [34]). "To move toward eco-friendly production, reduce waste, save energy, and preserve resources, in closed-loop supply chains (CLSC), used products are returned to the original producer to reuse the production waste to create new products" (Gholian-Jouybari et al., 2023 [35]).

With climate change in mind, the future of production must look to today's entrepreneurs for solutions. "We see global warming not as an inevitability but as an invitation to build, innovate, and effect change, a pathway that awakens creativity, compassion, and genius. This is not a liberal agenda, nor is it a conservative one. This is the human agenda." (Hawken 2017 [36]). Examples of innovations that "smart labs" have so far offered for greener production and manufacturing are outlined below.

6.1. Vertical Farming

These farms hydroponically grow plants in large buildings using targeted UV light. Crops are vertically stacked, and the selection of light spectrum exposure allows for more efficient growth with less energy consumption. It is possible for vertical farming to become the predominant form of raising crops by 2050 when considering the continued growth in population and demand for organic food products.

6.2. Green Burial

Eco-friendly burials replace the historically carbon-intensive, traditional burial methods with "mushroom death suits" and biodegradable caskets. Additionally, there are currently options to be buried at sea in reef balls that help restore coral ecosystems.

6.3. Better Lighting

LED lighting has taken over contemporary markets, providing light that is both more energy efficient and can be utilized to mitigate the spread of malaria in Africa and induce accelerated crop growth through novel farming processes.

6.4. Widespread Composting

Americans have gradually become more conscious of how they dispose of waste, which first included widespread initiatives to increase recycling. Now, education and implementation initiatives are being put in place to promote the composting of degradable waste.

6.5. Batteries

The production of more versatile and durable lithium-ion batteries is being led by companies in the EV industry. Tesla, for example, may construct a lithium-ion battery factory capable of producing up to 500,000 lithium-ion batteries a year. A portion of the batteries will be rechargeable via solar power.

6.6. Renewable Energy at Home

Government tax credits and a decreasing cost of solar power are leading more US households to explore renewable energy. Countries like Germany lead the way in the utilization of renewable energy, but the US is slowly gaining traction, with approximately six hundred thousand homes across the country using solar power.

6.7. Offshore Wind Power

Scotland and Japan have had moderate success with offshore wind farms, while the US' flagship project, Cape Wind (see Makoto et al., 2015 [37]), struggled to be completed due to continued funding issues, and the project ground to a halt in 2017.

6.8. Affordable Green Vehicles

The EV market has boomed, and the market is abundant with several EV choices for consumers today, from Ferraris to Ford pickup trucks. It is worth noting that the current electrical grid is not constructed to support the required energy output for a population driving primarily EVs. The new demand should be an impetus to evolve current energy systems.

6.9. Green Roofs and Living Walls

Carbon sequestration is one of the fastest ways to address climate change. This is effective both in water and air environments through investment in green spaces within the built environment and plankton and coral repopulation projects.

6.10. An IoT Platform for Manufacturing

The power of connecting logistics with a platform is to drive "smart" manufacturing through a sustainable approach and record real-time decreases in greenhouse gas (GHG) emissions. Smart manufacturing allows for data collection transparency on carbon output. This is made possible by advancements in robotics and sensor technology. Business manufacturing shared spaces are a way for public and private actors to support entrepreneurs and start-up companies. For many entrepreneurs, incubators are the only option to access investor networks, mentorship, and essential skills to properly launch their businesses. While most business incubators are open only to new businesses or tech-related companies (the majority of non-public incubators), this paper argues that more business incubators that serve entrepreneurs who seek to grow manufacturing companies are needed.

An IoT platform for manufacturing has the potential to grow and support individuals and small businesses through sustainable product development, and the creation of jobs with living wages is often housed on the blockchain due to the superior capabilities of the distributed ledger. Immutability, transparency, and providence have been proven to build sustainable communities and support environmental endeavors by delivering products to consumers faster while ensuring a zero-waste process in their production (Khan et al., 2021 [6]). Although blockchain technology has significant implications for future smart-network environments, it faces a number of technical challenges, many related to security and privacy, trust, scalability, and business vulnerabilities (Singh et al., 2020 [2]).

Thirteen million tons of plastic will find a home in the world's oceans every year, creating a significant negative impact on the world's ecology. Smart manufacturing can reduce that by half within a few years by simply targeting the single-use packaging market (Akenji et al., 2019 [18]). Circular economy experts suggest a combination of reducing virgin plastic resins with bioresins and waste collection recycling processes, which collectively account for a growing USD 600 billion annual market (Mauch 2016 [26]). However, similar to what has been tested in the industrial crops and products, medicine delivery, biofuel, and consumer product industries, circular CLSCs are the most efficient way to iterate meta-heuristic learning toward neutral production (Gholian-Jouybari et al., 2023 [35,38]; Momenitabar et al., 2022 [30]; Azevedo et al., 2019 [31]).

"Going green" makes business sense for companies when implemented with machine learning (Kamble et al., 2018 [34]; Queiroz and Telles 2018 [27]). By harnessing renewable energy using recycled materials, businesses can produce more competitive products and appeal to the growing trend of consumers' environmental awareness nationwide. An IoT platform can support green manufacturing businesses with 360-degree business services by providing access to high-skilled labor, subsidized manufacturing machinery, and labs to produce their products. Cities can play a role in this by having a business model that supports tech integration; however, the industry is best suited for a global scale (Timeus et al., 2020 [39]). As a model, EcoTech Visions is the most accurate synthesis of current theory and practical applications across sectors, as it is poised to provide an accountable, immutable supply chain ledger with reliable connectivity at the platform level, not as an afterthought, by connecting to an efficient and secure blockchain.

7. Discussion

A central problem facing the future of production is climate change. Whether or not we acknowledge the signs of climate change, our economic decisions and energy usage contribute to extreme weather variations across the planet. We are now living in a hotter, drier, and more environmentally volatile world with human and economic consequences. Tracking and tracing through the supply chain is an effective strategy to impact and measure an industry's success or failure in reaching the seventeen SDGs, as supply chains are the mechanism to acquire what humans need to survive and thus the site of our greatest emissions.

Such environmental and economic factors necessitate a reimagining of manufacturing, recycling, and recapturing processes. This paper offers a solution, arguing for the benefits of an IoT platform for manufacturing that matches small- to mid-size manufacturers with local buyers providing ethically sourced products and offering local last-mile delivery on a single purchasing platform. By collecting accurate data and automating manufacturing processes, carbon output, unit delivery efficiency, and providence through the blockchain, triple-bottom-line revenue can be realized in product sales, carbon credit markets, tax credits, and recapturing/recycling materials. This creates a unique business opportunity for industry leaders.

Smart innovations for ecological packaging and contract manufacturing have the potential to reduce greenhouse gas emissions through bioplastic packaging production and leading design for use in carbon capture and sequestration. Furthermore, it can provide a system that shrinks the supply chain and reduces transport needs. A successful IoT platform would provide a unique data exchange of connected points across a supply chain, gathering information on identities, value transfer, and transfer points. This data could drive proprietary insights into the relationship between suppliers, vendors, and customers. Smart manufacturing provides reusable packaging, which can produce savings over time for both the planet and a company's logistics expenses by reducing carbon emissions, delivery inefficiency, and total cost.

As a Massachusetts Institute of Technology (MIT) start-up, EcoTech Visions (ETV) is seeking to implement the suggestions of Jonathan Gruber and Simon Johnson as presented in Jump-Starting America (Jonathan Gruber and Simon Johnson, 2019, [11]). The research suggests that 102 locations across the Midwest and southeastern United States have been largely ignored since World War II but have a massive repository of resources (namely talent, spaces, and logistic centers) to advance innovations in manufacturing and advanced technology. EcoTech Visions provides ecological packaging manufactured locally.

Climate action plans for many cities focus on a 90 percent reduction in greenhouse gas (GHG) emissions by 2050, following the Kyoto Protocol (United Nations Climate Change 2006 [40]). These plans include reducing waste and pollution, as well as adaptation principles that require engaging the public, engaging businesses, and planning for the future. A specific way to accomplish these goals, decrease pollution, and shorten the supply chain is to reimagine how all consumer products are packaged, which would make sustainable, degradable materials widely available and allow for tracking of the distribution of these materials.

The development of an IoT platform can (1) coordinate the sourcing and supply of materials to ensure effective provision of eco-friendly and recycled inputs, (2) distribute manufacturing and equipment resources efficiently, and (3) shorten the supply chain by centralizing and coordinating last-mile delivery. As noted, EcoTech Visions is the first comprehensive model of integrated sourcing, manufacturing, and product de-livery in America. The power of connecting logistics with a platform is to drive "smart" manufacturing through a sustainable approach and record real-time de-creases in GHG emissions. As Hawken states, "We see global warming not as an inevitability but as an invitation to build, innovate, and effect change, a pathway that awakens creativity, compassion, and genius. This is not a liberal agenda, nor is it a conservative one. This is the human agenda." (Hawken 2017 [36]).

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data can be requested at Pandwegibson.com (accessed on 14 August 2023).

Conflicts of Interest: The author declares no conflict of interest.

References

1. Yang, S.; MR, A.R.; Kaminski, J.; Pepin, H. Opportunities for Industry 4.0 to Support Remanufacturing. *Appl. Sci.* **2018**, *8*, 1177. [CrossRef]
2. Singh, S.; Sharma, P.K.; Yoon, B.; Shojafar, M.; Cho, G.H.; Ra, I.-H. Convergence of Blockchain and Artificial Intelligence in IoT Network for the Sustainable Smart City. *Sustain. Cities Soc.* **2020**, *63*, 102364. [CrossRef]
3. Townsend, J. Interconnected Sensor Networks and Machine Learning-Based Analytics in Data-Driven Smart Sustainable Cities. *Geopolit. Hist. Int. Relat.* **2021**, *13*, 31–41. Available online: https://www.jstor.org/stable/27031365 (accessed on 13 August 2023).
4. Alqahtani, F.; Al-Makhadmeh, Z.; Tolba, A.; Said, W. Internet of Things Based Urban Waste Management System for Smart Cities Using a Cuckoo Search Algorithm. *Clust. Comput.* **2020**, *23*, 1769–1780. [CrossRef]
5. Sarvari, P.A.; Ustundag, A.; Cevikcan, E.; Kaya, I.; Cebi, S. Technology Roadmap for Industry 4.0. In *Industry 4.0: Managing the Digital Transformation*; Ustundag, A., Emre Cevikcan, E., Eds.; e-book; Springer: Berlin/Heidelberg, Germany, 2017.
6. Khan, I.S.; Ahmad, M.O.; Majava, J. Industry 4.0 and Sustainable Development: A Systematic Mapping of Triple Bottom Line, Circular Economy and Sustainable Business Models Perspectives. *J. Clean. Prod.* **2021**, *297*, 126655. [CrossRef]

7. Ben-Daya, M.; Hassini, E.; Bahroun, Z. Internet of Things and Supply Chain Management: A Literature Review. *Int. J. Prod. Res.* **2019**, *57*, 4719–4742. [CrossRef]
8. Victor, D.F.; House, J.C. A New Currency: Climate Change and Carbon Credits. *Harv. Int. Rev.* **2004**, *26*, 56–59. Available online: http://www.jstor.org/stable/42762946 (accessed on 13 August 2023).
9. Zhang, X.; Fang, W.; Pi, Z. Interaction among Information Sharing, Supply Chain Structure and Performance. *J. Coast. Res.* **2019**, *93*, 870–878. [CrossRef]
10. Danladi, S.; Prasad, M.S.V.; Modibbo, U.M.; Ahmadi, S.A.; Ghasemi, P. Attaining Sustainable Development Goals through Financial Inclusion: Exploring Collaborative Approaches to Fintech Adoption in Developing Economies. *Sustainability* **2023**, *15*, 13039. [CrossRef]
11. Gruber, J.; Johnson, S. *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream*, 1st ed.; Public Affairs: New York, NY, USA, 2019.
12. United States Environmental Protection Agency. *Nondurable Goods: Product-Specific Data*; United States Environmental Protection Agency: Washington, DC, USA, 2022. Available online: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/nondurable-goods-product-specific-data (accessed on 13 August 2023).
13. U.S. Bureau of Labor Statistics. Labor Force Characteristics by Race and Ethnicity. 2020. November 2021. Available online: https://www.bls.gov/opub/reports/race-and-ethnicity/2020/home.htm#:~:text=By%20race%2C%20Whites%20made%20up,less%20than%20half%20a%20percent (accessed on 14 August 2023).
14. Anderson, B. *Ag Weather Forum: Extreme Storms and Record Heat Highlighted September*; Progressive Farmer: Birmingham, AL, USA, 2022; Available online: https://www.dtnpf.com/agriculture/web/Ag/blogs/ag-weather-forum/blog-post/2022/10/14/extreme-storms-record-heat-september (accessed on 13 August 2023).
15. Cohen, S. *Environmentally Sustainable Growth: A Pragmatic Approach*; Columbia University Press: New York, NY, USA, 2023.
16. Schindler, R.; Schmalbein, N.; Steltenkamp, V.; Cave, J.; Wens, B.; Anhalt, A. *SMART TRASH: Study on RFID Tags and the Recycling Industry*; RAND Corporation: Santa Monica, CA, USA, 2012; Available online: https://www.rand.org/pubs/technical_reports/TR1283.html (accessed on 13 August 2023).
17. Stockholm Environment Institute. *Transformational Change through a Circular Economy*; Stockholm Environment Institute: Stockholm, Sweden, 2019.
18. Akenji, L.; Bengtsson, M.; Kato, M.; Hengesbaugh, M.; Hotta, Y.; Aoki-Suzuki, C.; Gamaralalage, P.J.D.; Liu, C. *Circular Economy and Plastics: A Gap-Analysis in ASEAN Member States*; Institute for Global Environmental Strategies: Kanagawa, Japan, 2019; Available online: https://asean.org/book/circular-economy-and-plastics-a-gap-analysis-in-asean-member-states/ (accessed on 13 August 2023).
19. The World Bank. As Growth Slows, Madagascar Needs a New Reform Drive to Steer Clear of the Economic Storm. 2022. Available online: https://www.worldbank.org/en/news/press-release/2022/06/01/as-growth-slows-madagascar-needs-a-new-reform-drive-to-steer-clear-of-the-economic-storm (accessed on 13 August 2023).
20. The World Bank. The World Bank in Panama. 2022. Available online: https://www.worldbank.org/en/country/panama/overview#:~:text=Poverty%20is%20estimated%20to%20decrease,recovery%20of%20the%20labor%20market (accessed on 13 August 2023).
21. Meng, W.; Li, W.; Tug, S.; Tan, J. Towards Blockchain-Enabled Single Character Frequency-Based Exclusive Signature Matching in IoT-Assisted Smart Cities. *J. Parallel Distrib. Comput.* **2020**, *144*, 268–277. [CrossRef]
22. Mayor's Press Office. Chicago Ranked as the Greenest Place to Work in America. 1 November 2019. Available online: https://www.chicago.gov/city/en/depts/mayor/press_room/press_releases/2019/october/RankedGreenestCity.html (accessed on 13 August 2023).
23. U.S. Bureau of Labor Statistics. Midwest Information Office: Chicago. 2022. Available online: https://www.bls.gov/regions/midwest/il_chicago_msa.htm (accessed on 13 August 2023).
24. Goodarzian, F.; Navaei, A.; Ehsani, B.; Ghasemi, P.; Muñuzuri, J. Designing an Integrated Responsive-Green-Cold Vaccine Supply Chain Network Using Internet-of-Things: Artificial Intelligence-Based Solutions. *Ann. Oper. Res.* **2023**, *328*, 531–575. [CrossRef] [PubMed]
25. Goodarzian, F.; Abraham, A.; Ghasemi, P.; Mascolo, M.D.; Nasseri, H. Designing a Green Home Healthcare Network Using Grey Flexible Linear Programming: Heuristic Approaches. *J. Comput. Des. Eng.* **2021**, *8*, 1468–1498. [CrossRef]
26. Mauch, C. Introduction: The Call for Zero Waste. *RCC Perspect.* **2016**, *3*, 5–12. Available online: https://www.jstor.org/stable/26241370 (accessed on 13 August 2023).
27. Queiroz, M.M.; Telles, R. Big Data Analytics in Supply Chain and Logistics: An Empirical Approach. *Int. J. Logist. Manag.* **2018**, *29*, 767–783. [CrossRef]
28. Chopra, S.; Meindl, P. *Supply Chain Management: Strategy, Planning, and Operations*, 2nd ed.; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2004.
29. Visich, J.K.; Li, S.; Khumawala, B.M. Khumawala. Enhancing Product Recovery Value in Closed-Loop Supply Chains with RFID. *J. Manag. Issues* **2007**, *19*, 436–452.
30. Momenitabar, M.; Ebrahimi, Z.D.; Ghasemi, P. Designing a Sustainable Bioethanol Supply Chain Network: A Combination of Machine Learning and Meta-Heuristic Algorithms. *Ind. Crops Prod.* **2022**, *189*, 115848. [CrossRef]

31. Azevedo, S.G.; Santos, M.; Antón, J.R. Supply Chain of Renewable Energy: A Bibliometric Review Approach. *Biomass Bioenergy* **2019**, *126*, 70–83. [CrossRef]
32. Fernando, J. Cleantech: Term for Environmentally-Friendly Practices and Tech. Investopedia. 30 June 2022. Available online: https://www.investopedia.com/terms/c/cleantech.asp (accessed on 13 August 2023).
33. Kenton, W. What is Green Tech? How It Works, Types, Adoptions, and Examples. Investopedia. 12 January 2022. Available online: https://www.investopedia.com/terms/g/green_tech.asp (accessed on 13 August 2023).
34. Kamble, S.S.; Gunasekaran, A.; Gawankar, S.A. "ustainable Industry 4.0 framework: A Systematic Literature Review Identifying the Current Trends and Future Perspectives. *Process Saf. Environ. Prot.* **2018**, *117*, 408–425. [CrossRef]
35. Gholian-Jouybari, F.; Hashemi-Amiri, O.; Mosallanezhad, B.; Hajiaghaei-Keshteli, M. Metaheuristic algorithms for a sustainable agri-food supply chain considering marketing practices under uncertainty. *Expert Syst. Appl.* **2023**, *213*, 118880. [CrossRef]
36. Hawken, P. *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*; Penguin: New York, NY, USA, 2017.
37. Makoto, E.; Gaskin, J.; Maskulrah, P.; Singh, K. *Cape Wind: The Collapse of the United States' Inaugural Offshore Wind Farm Project*; The University of British Columbia: Vancouver, BC, Canada, 2015; Available online: https://environment.geog.ubc.ca/cape-wind-the-collapse-of-the-united-states-inaugural-offshore-wind-farm-project/ (accessed on 13 August 2023).
38. Rajabi-Kafshgar, A.; Gholian-Jouybari, F.; Seyedi, I.; Hajiaghaei-Keshteli, M. Utilizing hybrid metaheuristic approach to design an agricultural closed-loop supply chain network. *Expert Syst. Appl.* **2023**, *217*, 119504. [CrossRef]
39. Timeus, K.; Vinaixa, J.; Pardo-Bosch, F. Creating Business Models for Smart Cities: A Practical Framework. *Public Manag. Rev.* **2020**, *22*, 726–745. [CrossRef]
40. United Nations Climate Change. What Is the Kyoto Protocol? 16 March 2006. Available online: https://unfccc.int/kyoto_protocol (accessed on 13 August 2023).